Departamento de Departamento de Historia, Geografía y Filosofía

Facultad de Ciencias del Mar y Ambientales

Integrated coastal and ocean management of areas hosting marine mammals: a case study in the Strait of Gibraltar

Gestión integrada de las áreas costeras y oceánicas que albergan mamíferos marinos: el caso de estudio del Estrecho de Gibraltar

Ph. D. Thesis

TESIS DOCTORAL

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Esta Tesis Doctoral ha sido realizada dentro del Grupo de Investigación Gestión Integrada de Áreas Litorales del Departamento de Historia, Geografía y Filosofía, en la Facultad de Ciencias del Mar y Ambientales de la Universidad de Cádiz.

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Education and Culture

Erasmus Mundus

Memoria presentada para optar al título de Doctorado Erasmus Mundus en Gestión Marina y Costera

MaCoMa

Alessia Scuderi

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HACEN CONSTAR:

Que esta Memoria, titulada "Gestión integrada de las áreas costeras y oceánicas que albergan mamíferos marinos: el caso de estudio del Estrecho de Gibraltar" presentada por Dª. Alessia Scuderi, resume su trabajo de Tesis Doctoral y, considerando que reúne todos los requisitos legales, autorizan su presentación y defensa para optar al grado de Doctor en Gestión Marina y Costera/Marine and Coastal Management.

Cádiz, Enero de 2023

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Chiara Mancin

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KO AHAU TE TOHORĀ, TE TOHORĀ KO AHAU.

TE AO MĀORI

I am the whale, and the whale is me.

Māori World

You are not Atlas carrying the world on your shoulder. It is good to remember that the planet is carrying you.

Vandana Shiva

Per le mie balene Carminella, Marta e Tina.

INDEX

EXTENDED ABSTRACT - English

The Strait of Gibraltar is a cross-border coastal and marine area in which overlapping intense maritime traffic and highly protected species of cetaceans could generate conservational or economic conflict. The current publication applies an integrated management approach in order to improve knowledge of cetaceans, maritime activities, and Whale Watching (WW), as well as to involve key stakeholders in WW and to provide insights for a sustainable public policy in the Strait.

A comparative study on WW activity in the Strait of Gibraltar and in the Hauraki Gulf, New Zealand, was interrupted due to the COVID-19 pandemic. This abrupt change allowed us to investigate the effects of the human lockdowns, such as the reduction in maritime traffic, on the marine animals of the Gulf, contributing to the study of the global effects on nature.

This thesis is organized into the following sections: i) Whale watching activities, ii) monitoring maritime traffic and cetaceans using ferries as platforms and iii) effects of COVID-19 lockdowns on nature.

In order to achieve social, economic, and ecological sustainability, **WW** in the Strait of Gibraltar needs adequate management. In Tarifa (Spain) and Gibraltar (UK), between 2017 and 2019, key stakeholders (e.g., WW customers and operators, researchers, NGOs, and policymakers) were invited to fill out 637 questionnaires and a direct assessment of the WW trips was conducted. Results suggest that: (1) local WW operators only partially follow WW legislation, (2) whale watchers had high levels of education and purchasing power, and the majority of them were national tourists who showed signs of loyalty to WW and support for conservation, (3) 51% of the expenses made by WW customers directly benefited the local economy of Tarifa, (4) customers scored WW operators more highly when cetaceans were indifferent to, or approached vessels, and their satisfaction improved depending on the education provided before and during the WW trip, and (5) interviewed stakeholders recognize the scientific, recreational and educational values of WW. As a result of this study we recommend implementing educational programmes, launching national publicity campaigns targeting whale watchers, establishing administrative facilities for WW companies, monitoring WW activities, and enforcing WW legislation to promote sustainable management of WW. Furthermore, the designation of Marine Protected Areas, a regional shipping plan, and an integrated management approach could benefit the WW industry and improve its sustainability.

Cetaceans and their threats were monitored using **ferries** as a platform of opportunity along the routes Algeciras–Ceuta and Algeciras-Tanger Med in the Strait during 2018 and 2019, following the standardized protocol of the international cooperative project Fix Line Transect Mediterranean Monitoring Network (FLT Med Net). During 59 visual surveys 264 sightings of cetaceans were reported, including seven species and four near-miss collisions (pilot, sperm, and fin whales). Data were used to i) investigate cetaceans' seasonal presence and distribution and, for the bottlenose dolphin, habitat suitability in the Strait, ii) consider cetaceans' relationships with different maritime activities identifying risk areas and the consistency of the spatial conservation spatial management measures in force, and iii) compare data with the other partner of the FLT Med Net across two Habitat Directive 6-year periods (2013-2019/2008-2012), testing four potential indicators to assess short-term range and habitat trends of the Risso's dolphin, and of the pilot and Cuvier's whale (low-density species). The

FLT Med Net sampling design proved adequate for trend assessment in the Western Mediterranean and Adriatic. In conclusion, together with international surveillance, the designation of a micro-sanctuary in the Bay between Algeciras and Gibraltar, and a mandatory speed reduction to 13 knots in an extended Cetacean Critical Navigation Zone can positively optimize conservation efforts in the Strait of Gibraltar.

The lockdown due to the **COVID-19 pandemic** banned all non-essential services and travel both on land and sea in several parts of the world. In response to this sudden drop in traffic, the bigeyes fish and the bottlenose dolphin experienced an immediate increase in their communication ranges by up to 65% in the Hauraki Gulf Marine Park, demonstrating how small vessels can impact underwater soundscapes. These results were shared with the global scientific community to monitor the immediate impacts of lockdowns, demonstrating how humans are both threatening and protecting ecosystems and species. It is possible to favourably tilt this delicate balance by reducing impacts and increasing conservation effectiveness.

Keywords: Mediterranean Sea, Atlantic Ocean, tourism, whale watcher, economic impact, conservation, vessels, acoustics, COVID- 19 lockdown, pandemic.

RESUMEN AMPLIADO – Español

El Estrecho de Gibraltar es una zona costera y marina transfronteriza en la que el solapamiento entre el intenso tráfico marítimo con especies de cetáceos altamente protegidas podría generar un conflicto entre conservación y economía. En este trabajo se aplica un enfoque de gestión integrada para mejorar el conocimiento sobre los cetáceos y sobre las actividades marítimas y, en detalle, sobre la observación de cetáceos (WW), para involucrar los actores claves de este espacio y, finalmente, para proporcionar ideas para una política pública sostenible en el Estrecho.

Un estudio comparativo sobre la actividad de WW en el Estrecho de Gibraltar y en el Golfo de Hauraki (Nueva Zelanda) fue interrumpido debido a la pandemia de COVID-19. Este cambio abrupto permitió investigar los efectos del confinamiento humano (como la reducción del tráfico marítimo) sobre los animales marinos del Golfo y, contribuir a estudiar los efectos a nivel global del confinamiento humano sobre la naturaleza.

La tesis se desarrolla en bloques i) actividad de avistamiento de cetáceos, ii) seguimiento del tráfico marítimo y de los cetáceos utilizando los ferris como plataforma y iii) efectos del confinamiento por COVID-19 en la naturaleza.

Para lograr la sostenibilidad social, económica y ecológica, el **WW** del Estrecho de Gibraltar necesita una gestión adecuada. En Tarifa (España) y Gibraltar (Reino Unido) entre 2017 y 2019, se invitó a las principales partes interesadas (por ejemplo, clientes y operadores de WW, investigadores, ONG y responsables políticos) a rellenar 637 cuestionarios y se realizó una evaluación directa de los viajes de WW. Los resultados indican que (1) los operadores locales de WW siguen parcialmente la legislación sobre WW; (2) las clientas tenían un alto nivel educativo y poder adquisitivo, la mayoría eran turistas nacionales que mostraron signos de fidelidad a la actividad de WW y actitud positiva hacia la conservación; (3) el 51% de los gastos realizados por las clientas de WW beneficiaron directamente a la economía local de Tarifa; (4) las clientas valoran mejor a los operadores de WW cuando los cetáceos son indiferentes a las embarcaciones o se acercan a ellas, y sus satisfacciones mejoran en función de la educación proporcionada antes y durante el viaje de WW; (5) las partes interesadas entrevistadas reconocen los valores científicos, recreativos y educativos de WW. Recomendamos poner en marcha programas educativos, lanzar campañas publicitarias nacionales dirigidas a los observadores de cetáceos, establecer instalaciones administrativas para las empresas de WW, supervisar las actividades de WW y hacer cumplir la legislación sobre WW para promover su gestión sostenible. Además, la designación de áreas marinas protegidas, un plan regional de navegación y un enfoque de gestión integrada podrían beneficiar a la industria del WW y mejorar su sostenibilidad.

Los cetáceos y algunas de las amenazas que lo afectan fueron monitorizados utilizando **ferries** como plataforma de oportunidad a lo largo de las rutas Algeciras-Ceuta y Algeciras-Tanger Med en el Estrecho durante 2018 y 2019, siguiendo el protocolo estandarizado desarrollado por la cooperación internacional Fix Line Transect Mediterranean Monitoring Network (FLT Med Net). Durante 59 muestreos visuales se reportaron 264 avistamientos de cetáceos, incluyendo siete especies y cuatro casi colisiones (calderones, cachalotes y rorcuales comunes). Los datos se utilizaron para i) investigar la presencia y distribución estacional de los cetáceos y, para el delfín mular, la idoneidad del hábitat en el Estrecho; ii) considerar las relaciones de los

cetáceos con diferentes actividades marítimas identificando áreas de riesgo y la coherencia de las medidas de gestión espacial de conservación en vigor, y iii) comparar datos con los otros participantes de la FLT Med Net a lo largo de dos periodos de 6 años de la Directiva Hábitat (2013-2019/2008-2012), probando cuatro indicadores potenciales para evaluar las tendencias a corto plazo del área de distribución y el hábitat del delfín mular, el calderón común y el zifio de Cuvier (especies de baja densidad). El diseño de muestreo de la red FLT Med demostró ser adecuado para la evaluación de tendencias en el Mediterráneo Occidental y en el Adriático. En conclusión, junto con la vigilancia internacional, la designación de un micro santuario en la Bahía entre Algeciras y Gibraltar y una reducción obligatoria de la velocidad a 13 nudos en una Zona Crítica de Navegación para Cetáceos ampliada pueden optimizar los esfuerzos de conservación en el Estrecho de Gibraltar.

El confinamiento debido a la **pandemia de COVID-19** prohibió todos los servicios no esenciales y los viajes tanto por tierra como por mar en varias partes del mundo. En respuesta a este cierre repentino, los peces *Pempheris adspersa* y los delfines *Tursiops truncatus* experimentaron un aumento inmediato de sus rangos de comunicación de hasta un 65% en el Parque Marino del Golfo de Hauraki, lo que demuestra cómo las pequeñas embarcaciones pueden repercutir en los paisajes sonoros submarinos. Estos resultados se compartieron con la comunidad científica mundial para supervisar los efectos inmediatos de los confinamientos, demostrando cómo los seres humanos amenazan y protegen a la vez los ecosistemas y las especies. Es posible inclinar favorablemente este delicado equilibrio reduciendo los impactos y aumentando la eficacia de la conservación.

Palabras clave: Mar Mediterráneo, Océano Atlántico, turismo, observador de cetáceos, impacto económico, conservación, embarcaciones, acústica, confinamiento COVID- 19, pandemia.

RIASSUNTO ESTESO - Italiano

Lo Stretto di Gibilterra è un'area costiera e marina transfrontaliera ove l'intenso traffico marittimo si sovrappone alla presenza di specie di cetacei altamente protette, e tale evenienza potrebbe generare un conflitto tra esigenze di pari importanza, una economica e l'altra conservativa. A tal fine per dirimere eventuali conflitti, si applica qui un approccio di gestione integrata per migliorare le conoscenze sui cetacei e sulle attività marittime e, in dettaglio, sull'attività commerciale di avvistamento di cetacei, denominata Whale Watching (WW), per coinvolgere le principali parti interessate e, infine, per contribuire ad attuare una programmazione politica mirata alla sostenibilità nel rispetto delle esigenze delle parti.

Uno studio comparativo sulle attività di WW nello Stretto di Gibilterra e nel Golfo di Hauraki, in Nuova Zelanda, è stato interrotto a causa della pandemia COVID-19. Questo imprevisto ha determinato, come conseguenza, la possibilità di studiare gli effetti del confinamento umano (specificamente gli effetti della riduzione del traffico marittimo) sugli animali marini del Golfo e di contribuire ad un monitoraggio globale degli effetti sulla natura.

La tesi è organizzata in blocchi: i) attività di whale watching, ii) monitoraggio del traffico marittimo e dei cetacei utilizzando i traghetti come piattaforma e iii) gli effetti del confinamento umano per COVID-19 sulla natura.

Per raggiungere la sostenibilità sociale, economica ed ecologica, il **WW** nello Stretto di Gibilterra necessita di una gestione adeguata. Tra il 2017 e il 2019, a Tarifa (Spagna) e Gibilterra (Regno Unito), i principali attori (ad esempio clienti e operatori di WW, ricercatori, ONG e responsabili politici) sono stati invitati a compilare 637 questionari, ed è stata condotta una valutazione diretta dei viaggi di WW. I risultati suggeriscono che: (1) gli operatori WW locali seguono in parte la legislazione sul WW; (2) i clienti di WW, in maggioranza, hanno un livello di istruzione universitario e alto potere d'acquisto, la maggior parte sono turisti nazionali che si sono fidelizzati al WW e che sono a sostegno della conservazione dei cetacei; (3) il 51% delle spese effettuate dai clienti del WW va direttamente a beneficio dell'economia locale di Tarifa; (4) i clienti apprezzano maggiormente gli operatori di WW quando i cetacei sono indifferenti o si avvicinano alle imbarcazioni, e la loro soddisfazione migliora a seconda del servizio di educazione ambientale ricevuto prima e durante il viaggio di WW; (5) gli attori intervistati riconoscono i valori scientifici, ricreativi ed educativi del WW. Raccomandiamo di attuare programmi educativi, di lanciare campagne pubblicitarie nazionali rivolte agli osservatori di balene, di istituire strutture amministrative per le aziende che si occupano di WW, di monitorare le attività di WW e di far rispettare la legislazione in materia per promuovere una gestione sostenibile del WW. Inoltre la designazione di aree marine protette, di un piano di navigazione regionale e l'uso di un approccio di gestione integrata, potrebbero giovare all'industria del WW e migliorarne la sostenibilità.

I cetacei, e le minacce nei loro confronti, sono stati monitorati utilizzando i **traghetti** come piattaforma di opportunità lungo le rotte Algeciras-Ceuta e Algeciras-Tanger Med nello Stretto di Gibilterra durante il 2018 e il 2019, seguendo il protocollo standardizzato della cooperazione internazionale Fix Line Transect Mediterranean Monitoring Network (FLT Med Net). Durante i 59 censi visivi sono stati segnalati 264 avvistamenti di cetacei, che includono sette specie, e quattro possibili eventi di collisioni con globicefali, capodogli e balenottere comuni. I dati sono stati utilizzati i) per studiare la presenza e la distribuzione stagionale dei cetacei e, per il tursiope, l'idoneità dell'habitat nello Stretto; ii) per considerare le relazioni dei cetacei con le diverse attività marittime, identificando le aree a rischio e la coerenza delle misure di gestione spaziale di conservazione in vigore, iii) per confrontare i dati con gli altri partner della FLT Med Net nei due periodi di 6 anni della Direttiva Habitat (2013-2019/2008-2012), testando quattro potenziali indicatori per valutare le tendenze a breve termine dell'areale e dell'habitat del grampo, del globicefalo e dello zifio (specie a bassa densità). Il lavoro del FLT Med Net si è dimostrato adeguato per la valutazione delle tendenze di queste specie protette nel Mediterraneo occidentale e nell'Adriatico. In conclusione, insieme alla sorveglianza internazionale, la designazione di un micro santuario nella Baia tra Algeciras e Gibilterra, e la riduzione obbligatoria della velocità a 13 nodi in una zona di navigazione critica per i cetacei, possono ottimizzare gli sforzi di conservazione nello Stretto di Gibilterra.

Il confinamento umano dovuto alla **pandemia COVID-19** ha limitato tutti i servizi e i viaggi non essenziali sia via terra che via mare in diverse parti del mondo. Conseguentemente a questo cambio nell'ambito del traffico marittimo, particolarmente delle piccole imbarcazioni nel Parco Marino del Golfo di Hauraki, i pesci *Pempheris adspersa* e i delfini *Tursiops truncatus* hanno immediatamente ampliato il loro raggio di comunicazione (fino al 65%). Questo dimostra che le piccole imbarcazioni possano avere un impatto sui paesaggi sonori sottomarini. Questi risultati sono stati condivisi con la comunità scientifica per monitorare gli impatti immediati del confinamento a livello mondiale, ed é stato dimostrato come gli esseri umani stiano sia minacciando che proteggendo gli ecosistemi e le specie. È possibile inclinare favorevolmente questo delicato equilibrio riducendo gli impatti e aumentando l'efficacia della conservazione.

Parole chiave: Mar Mediterraneo, Oceano Atlantico, turismo, whale watcher, impatto economico, conservazione, imbarcazioni, acustica, confinamento COVID- 19, pandemia.

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CHAPTER 1 – GENERAL INTRODUCTION

1.1 Integrated management

Marine and coastal areas are complex systems to manage (de Andrés et al., 2018, 2020). These zones are often considered to be conflictual due to the general concurrence of high productivity, species richness (Harris et al., 2022; Purwanto et al., 2021) as well as extremely high volumes of human activities and pressures (Adyasari et al., 2021; Korpinen et al., 2021). Currently, integrated management, ecosystem-based approaches and marine spatial planning tools are regarded as relevant to achieve a harmonic coexistence within those areas and to attain their sustainable use (García Sanabria, 2014, 2015).

Ecosystem Services (ESs) are the benefits obtained by human beings from a healthy ecosystem (Millennium Ecosystem Assessment, 2005), with whales being recognised as providers of food and other products (i.e. meat, oil-based products deriving from blubber, bones, teeth and baleen), contributors to ecosystem regulation and maintenance by enhancing biodiversity and regulating the climate through carbon sequestration, and as supporters of various cultural services including the WW industry (Cook et al., 2020). ESs make a significant contribution to human well-being (Costanza et al., 2017), thus the services provided by WW must be managed using an integrated approach that takes ecological, social and economic perspectives into account.

Integrated Coastal and Ocean Management (hereafter integrated management or IM) (Chircop & O'Leary, 2012; UNESCO, 2006) is applied in multi-jurisdictional coastal areas (Bellanger et al., 2020) and recognizes the importance of stakeholders participation (Dinkel & Sánchez-Lizaso, 2020; Elliott et al., 2020; Páez et al., 2020). It was identified as a practical approach in the obtention of a sustainable ocean economy (Winther et al., 2020) and could also help to achieve cetacean conservation objectives (Abate, 2009). The integrated management of coastal-marine areas is a process that is legitimised through public policy and that has a technical-scientific basis, whilst also taking traditional knowledge into account (Barragán, 2014). Its aim is the administration of common goods and public interests (Barragán, 2014). IM is oriented towards decision-making to obtain the best and most equitable benefits from coastal-marine ecosystem services, taking special care to conserve natural capital, cultural heritage and landscapes whilst simultaneously addressing the risks and threats to people, goods and resources (Barragán, 2014). In **several areas**, integrated management was used to manage issues related to marine mammal conservation, including proposals to reduce accidents between artisanal fisheries and cetaceans on the Brazilian coast and central Amazon (Seminara et al., 2019; Zappes et al., 2013), to outline a strategy for monitoring cetaceans in data-poor regions (Liu et al., 2022), to create a Marine Protected Areas Network in South America (Augustowski & Palazzo, 2003), and to improve the robustness of management strategies that confront direct and human-mediated threats due to climate change (Elizabeth Alter et al., 2010). Thanks to an integrated management approach, the conflictive co-presence of maritime traffic and highly protected species of cetaceans has successfully been dealt with in other areas. For instance, **seasonal and dynamic regional shipping plans** have been adopted in parts of the Salish Sea (Pacific Ocean) and the North Atlantic to protect southern resident killer whales[1] and North Atlantic Right Whales (NARW)[2]. Using this

[1] https://www.pac.dfo-mpo.gc.ca/fm-gp/mammals-mammiferes/whales-baleines/srkw-measures-mesures-ers-eng.html#maps

approach to reduce ship strike mortality was proven effective in the case of NARW (Laist et al., 2014). The current conservation status of many species of marine mammals, including those occurring in the Gibraltar strait, requires a regulatory response that must be sensitive to the multidimensional nature of the issues (Abate, 2009). Specifically for **whale watching (WW) activities**, it has been suggested that a comprehensive management approach, that integrates multiple stakeholder perspectives in a research-informed and adaptive process, could lead to the long-term sustainability of the sector (Higham et al., 2009). Management of the WW industry, both in Gibraltar and elsewhere, needs to move towards an integrated and adaptive site and species-specific approach, and must consider both social and ecological contexts by establishing genuine relationships with the local community (Fumagalli et al., 2021).

1.2 The Strait of Gibraltar

The **Strait of Gibraltar** (figure 1.1) is the only passage between the Mediterranean Sea and the Atlantic Ocean and encompasses Spanish, British, and Moroccan territorial waters.

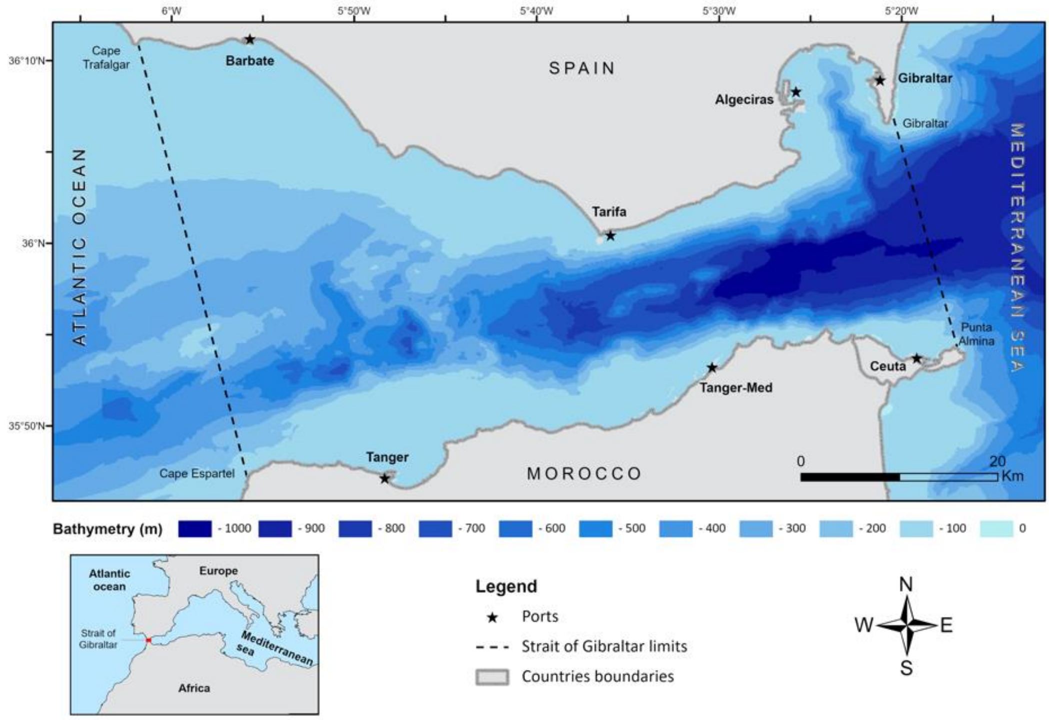

Figure 1.1 The area of study in the Strait of Gibraltar with main ports represented as stars and borders as dotted lines (in the west from Cape Trafalgar to Cape Espartel and in the east from Gibraltar to Punta Almina). The Atlantic Ocean and the Mediterranean Sea, together with the two continents Africa and Europe, are also marked. Map courtesy of André Pedrosa, University of Aveiro.

[2] https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales

The Strait of Gibraltar hosts seven protected species of **cetaceans** (table 1.1). Among these are the Endangered short-beaked common dolphin, *Delphinus delphis,* (Bearzi et al., 2021) (hereafter common dolphin), and the Critically Endangered populations of long-finned pilot whales, *Globicephala melas,* (Verborgh & Gauffier, 2021) (henceforward pilot whale), and killer whales, *Orcinus orca,* (R. Esteban & Foote, 2019) (also called orcas). The Strait also hosts the Endangered Mediterranean subpopulations of fin whale, *Balaenoptera physalus,* (Panigada et al., 2021) and sperm whale, *Physeter macrocephalus,* (E Pirotta et al., 2021). These classifications are according to the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species. Striped and bottlenose dolphins (*Stenella coeruleoalba* and *Tursiops truncatus*) also inhabit the waters of the Strait (Espada Ruíz et al., 2018; Tenan et al., 2020), and bottlenose dolphin being a priority species listed in Annex II of the Habitats Directive (92/43/CEE, HD) for which Special Areas of Conservation are required. Species such as the common dolphin (Espada Ruíz et al., 2018; Olaya-Ponzone et al., 2020, 2022), the pilot whales (Cañadas et al., 2005; Cañadas, 2008; de Stephanis, García-Tíscar, et al., 2008; de Stephanis, Verborgh, et al., 2008; de Stephanis et al., 2014; Giménez, Cañadas, et al., 2018; Giménez, Louis, et al., 2018) and the orcas (de Stephanis et al., 2014; R. Esteban et al., 2013, 2016; R Esteban et al., 2014) are among the most studied in the Strait and a specific Conservation Plan for Critically Endangered orcas was designed in 2017 (Boletín Oficial del Estado, 2017). However, there are still knowledge gaps on the seasonal distribution and habitat use of all the cetaceans inhabiting the Strait, probably due to the difficulties associated with year-round monitoring. These gaps could affect the effectiveness of management measures for the conservation of protected species. Additionally, an update on species' use of habitats in the Strait could be useful in order to verify potential changes that require further mitigation or conservation measures.

Table 1.1 – The conservation status of the seven species that inhabit the waters of the Strait of Gibraltar, according to the IUCN Red List of Threatened Species at international level, and according to the 'Catálogo Nacional de Especies Amenazadas' (Ministerio de Medio Ambiente y Medio Rural y Marino, 2011) on the national level.

Common name	**Scientific name**	**Conservation Status - IUCN**	**Reference**	**Conservation Status – Spanish Assessment**
Short-beaked common dolphin	*Delphinus delphis*	Endangered Inner Mediterranean subpopulation (MED. SP)	(Bearzi et al., 2021)	Vulnerable
Striped dolphin	*Stenella coeruleoalba*	Least concern MED. SP	(Lauriano, 2021)	Data Deficient
Long-finned pilot whale	*Globicephala melas*	Critically Endangered Strait of Gib. SP	(Verborgh & Gauffier, 2021)	Vulnerable

Common bottlenose dolphin	*Tursiops truncatus*	Vulnerable MED. SP	(Natoli et al., 2021)	Vulnerable
Fin whale	*Balaenoptera physalus*	Endangered MED. SP	(Panigada et al., 2021)	Vulnerable
Sperm whale	*Physeter macrocephalus*	Endangered MED. SP	(E Pirotta et al., 2021)	Vulnerable
Killer whale	*Orcinus orca*	Critically Endangered (CE) Strait of Gib. SP	(R. Esteban & Foote, 2019)	Vulnerable

Legislative framework and marine spatial management tools

The Strait of Gibraltar (figure 1.1) is a transborder marine area connecting the Mediterranean Sea and the Atlantic Ocean and includes three national waters with a complex legislative framework. The coastal countries and territories of the Strait: Spain, Morocco, and Gibraltar, have ratified **international conventions** that aim to protect cetaceans directly or indirectly, among which figure the International Convention for the Regulation of Whaling (ICRW), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Bern Convention (BCCEW) and the Bonn Convention (CMS). Other legal instruments are in force in the Strait, but none are ratified by all three countries (table 1.2).

Table 1.2 International legal framework concerning cetaceans in the transboundary area of the Strait of Gibraltar. Name of the legal instrument and year of its entry in force, a brief description, the territorial dominion, and date of ratification by each country.

Type and year entry in force	Name	Short description	Territorial dominion	Morocco	UK	Spain
Convention 1948	ICRW - International Convention for the Regulation of Whaling	Provides for the proper conservation of whale stocks and thus facilities the orderly development of the whaling industry.	International with 88 parties all over the world	2001	1948	1979
Convention 1975	CITES - Convention on International Trade in	Aims to ensure that the international trade in specimens of wild animals and plants does not	International with 183 parties all over the	1976	1976	1986

	Endangered Species of Wild Fauna and Flora	threaten their survival.	world			
Convention 1978	Barcelona Convention - for the Protection of the Marine Environment and the Coastal Region of the Mediterranean	Aims to protect the marine and coastal environment in the Mediterranean, whilst promoting regional and national plans for sustainable development.	Mediterranean Sea	2012	No	1976
Convention 1982	BCCEW - Bern Convention - Convention on the Conservation of European Wildlife and Natural Habitats	A measure for nature conservation and particularly for protecting natural habitats and endangered species.	European continent and some States of Africa	1982	1982	1986
Convention 1983	CMS – Bonn Convention – Convention on the Conservation of Migratory Species of Wild Animals	A global platform for the conservation and sustainable use of migratory animals and their habitats.	Brings together 124 parties and States through which migratory animals pass	1993	1985	1985
European Directive 1992	EU Habitats Directive - Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Flora and Fauna	Ensures the conservation of a wide range of rare, threatened or endemic animal and plant species, and establishes the EU wide Natura 2000 ecological network of protected areas.	Europe	Relative common agreement with Portugal	2017	2007
European Directive 2008	Directive 2008/56/EC - MSFD - Marine Strategy Framework Directive	Aims to achieve Good Environmental Status of marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend.	Europe	-	-	2010

European Directive 2014	Directive 2014/89/EU - MSPD - Maritime Spatial Planning Framework Directive	Concerns the planning of when and where human activities should take place at sea, to ensure these are as efficient and sustainable as possible.	Europe			
Agreement 2001	ACCOBAMS - Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area	ACCOBAMS is a cooperative tool for the conservation of marine biodiversity, the reduction of threats and the improvement of knowledge of cetaceans.	Mediterranean and Black Seas	2018	-	1996
Real Decree 2007	Real Decree 1727/2007 of the 21st of December	Cetaceans Protection Measures	Spanish waters	-	-	2007
Marine Protection Regulation 2014	Marine Protection Regulation 2014/180	Protection of the marine environment, including cetaceans	Gibraltarian waters	-	2014	-

Other tools in force include **spatial management measures**. The Strait of Gibraltar is part of the **Intercontinental Biosphere Reserve of the Mediterranean**, established by the United Nations Educational Scientific and Cultural Organization (UNESCO). The biosphere includes both Spanish and Moroccan marine and terrestrial habitats, specifically the southern Iberian Peninsula of Andalucía and the region of Djbala (Tingitane Peninsula) in Morocco (figure 1.2). It was established in 2006 by 'The Man and Biosphere Programme' of UNESCO, in collaboration with the government agencies 'Consejería de Medio Ambiente' and the 'Ministerio de Medio Ambiente' of Spain, and the 'Direction Régionale des Eaux et Forêts du Rif' of Morocco. The Strait of Gibraltar dominates the maritime area of the Intercontinental Biosphere.

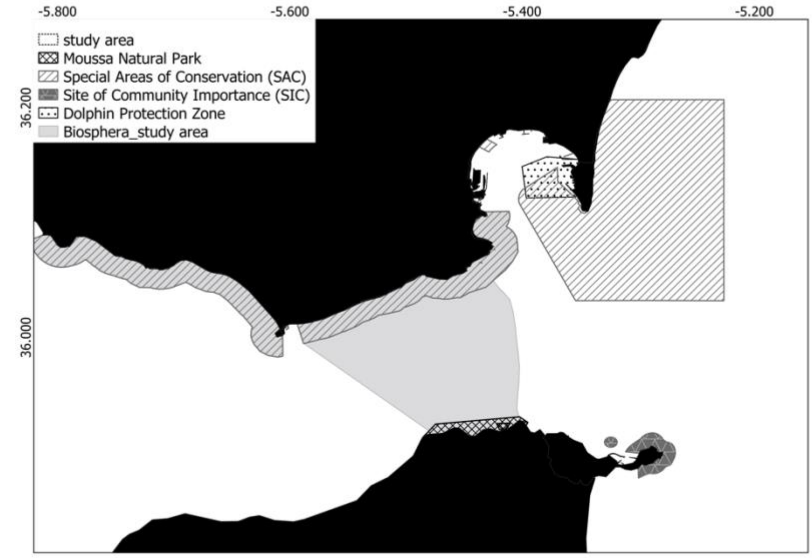

Figure 1.2 Figure indicating spatial management measures in force in the study area of the Strait of Gibraltar. National parks, the SACs, the SICs, the Dolphin Protection Zone and the Intercontinental Biosphere Reserve of the Mediterranean are highlighted.

Other spatial protection measures are in place under the **Birds and Habitats Directives**, the Ramsar Convention, and under local governments (Gibraltar, Spain, Morocco) (figure 1.2, tables 1.2 and 1.3 for further details). Three Special Areas of Conservation (SAC) cover the northern part of the Strait from west to east. The ES0000337 'Estrecho', the ES6120033 'Fondos Marinos Marismas del Rio Palmones', the ES6120032 'Estrecho oriental', and the Site of Community Importance (SIC) ES6310002 'Zona marítimo-terrestre del Monte Hacho' in the south-east; are protected under the Birds and Habitats Directives (respectively the Directives 92/43/EEC and the 2009/147/EC of the Council of the European Communities) (table 3 and figure 2). The ES0000337 is also protected at the national level as the **Strait Natural Park** 'Parque Natural del Estrecho' (table 3). This National Park was created by the legislative decree 57/2003, is located in the northern sector of the Strait, and includes both the maritime and terrestrial areas between the Bay of Getares (Algeciras) and Gracia Cape (Tarifa). The management of this area is taken care of by the 'Consejería de Medio Ambiente' with the support of the 'Junta Rectora del Parque'. The southern coast of the Strait is protected as part of the **Jbel Moussa Natural Park** and as the Ramsar Site Littoral de Jbel Moussa (Wetland of International Importance). Based on scientific literature, a marine protected area of Jbel Moussa is to be created (Derdabi & Aksissou, 2021).

Table 1.3 List of the different management spatial tools in force in the Strait of Gibraltar and of the related management plans. A mapping of the spatial management tools is available in figure 1.2.

Strait of Gibraltar areas and national jurisdiction	Spatial tools in force	Management plan	Practical measures to protect cetaceans
Northwest and central areas **SPAIN**	Special Area of Conservation (SAC) ES0000337 Estrecho	*Plan de Ordenación de los Recursos Naturales (PORN) Frente Litoral Algeciras-Tarifa,* that includes *Paraje Natural Playa de Los Lances, and Planes Rectores de Uso y Gestión (PRUG) Parque Natural del Estrecho*	PORN – no specific measures PRUG - Requires authorization from the council for any cetacean observation activities and the respect of the Royal Decree 1727/2007 during the sightings.
Northwest and central areas **SPAIN**	Estrecho Natural Park (in ES0000337 Estrecho)	PORN *Frente Litoral Algeciras-Tarifa* and PRUG *Parque Natural del Estrecho*	Same of the above
Northeast area **SPAIN and GIBRALTAR**	SAC-ES6120033 Fondos Marinos Marismas del Rio Palmones	PORN *Fondos Marinos Marismas del Río Palmones* Management Plan (MP) of the SAC ES6120033	PORN - no specific measures MP – To follow a selection of more specific measures: Promotion of the inclusion of SAC limits in nautical charts (Measure code: A.1.3.1) Environmental education actions directed at those active in nautical charts (C.1.3.2) The urging of a participative process among authorities, fisherman's guilds and shell-fishers for a sustainable use of resources (C.1.4.1)
Northeast **SPAIN and GIBRALTAR**	SAC-ES6120032 Estrecho oriental	*Real Decreto 1620/2012, de 30 de noviembre, por el que se declara Zona Especial de Conservación el Lugar de Importancia Comunitaria ES6120032 Estrecho Oriental de la región biogeográfica mediterránea de la Red Natura 2000 y se aprueban sus correspondientes medidas de conservación.*	Recommends navigating with extreme vigilance. Recommendation proposed to International Maritime Organization In case of collision mandatory call to the Emergency number 112 Whale watching activity has to follow the Royal Decree

			1727/2007 Marine Mammal Observers on board are mandatory for survey with high acoustic contamination For species *T.truncatus*, *D.delphis* and *S.Coeruleoalba* the development of scientific studies and of monitoring programs
Northeast **GIBRALTAR**	Dolphin Protection Zone Regulation 2018	Gibraltar Marine Reserve Management Plan	Under the Marine Protection Regulations 2014: -Cetacean Protocol to apply during an encounter with cetaceans -No anchoring zones -Designation of Marine Conservation Zones including Micro-Marine Reserves -Designation of no-fishing Zones Under the Dolphin Protection Zone Regulations 2018: -Strict conditions on recreational and sports fishing by creating an exclusion zone -Enforcement to respect the Cetacean Protocol -Studies and monitoring programs and educational activities on cetaceans. Prohibition of some activities.
Eastern **SPAIN**	SIC-ES6310002 Zona marítimo-terrestre del Monte Hacho	Preliminary plan included analysis	None
Central area **MOROCCO and SPAIN**	Intercontinental Mediterranean Biosphere Reserve. Andalusia (SP) – Morocco	No plan on our knowledge.	None

The north-western and southern marine area around Gibraltar rock have been regulated as a **Dolphin Protection Zone** since 2018 (Government of Gibraltar, 2018). Recently, the scientific community has also proposed a micro-sanctuary to protect the short-beaked common dolphins that inhabit the waters of the Bay (Olaya-Ponzone et al., 2022).

Important Marine Mammal Areas (IMMAs), defined as 'discrete portions of habitat, important to marine mammal species, that have the potential to be delineated and managed for conservation (https://www.marinemammalhabitat.org/immas/), were designed by the IUCN IMMA task force in the area of study. The Strait's waters are included in the Alborán Sea IMMA as well as those of the Strait of Gibraltar and the Gulf of Cádiz (figure 1.3).

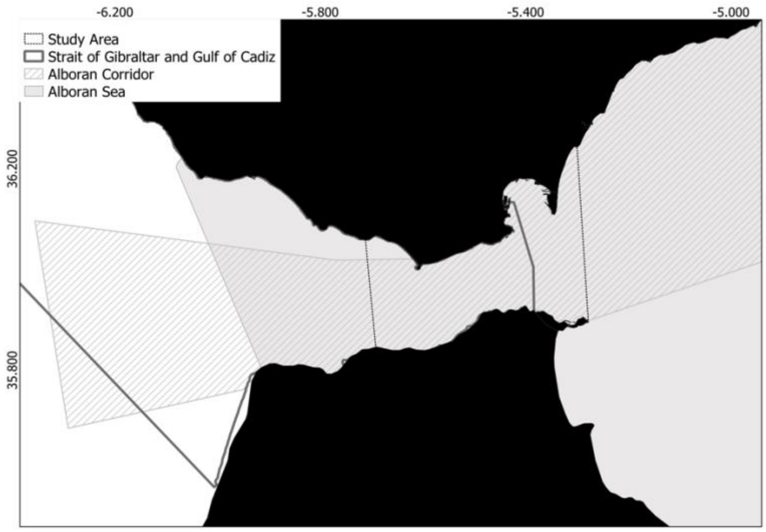

Figure 1.3 Figure indicating the Important Marine Mammals Areas (IMMAs) designed by the International Union for Conservation of Nature IMMA task force in the study area in the Strait of Gibrlatar.

The Strait, together with the Alborán Sea, was also defined as Cetacean Critical Habitat - **CCH**[3] **by ACCOBAMS** using a threat management approach that combines human activities and cetacean distribution (ACCOBAMS, 2017).

Furthermore, the Spanish State Secretary for Environmental Affairs has expressed an interest in designing a new Marine Protected Area (MPA) in the Strait's waters (Our Ocean, 2019; Presidencia del Gobierno de España, 2019). Additionally, the promotion and improvement of international cooperation for monitoring the highly mobile cetaceans are objectives of the Spanish Marine Strategy for the area "Strait and Alborán".

[3] https://accobams.org/conservations-action/protected-areas/

1.3 Whale and dolphin watching activities and the Strait of Gibraltar

Whale and dolphin watching (henceforth WW) is globally the most relevant economic activity based on cetaceans (Cisneros-Montemayor et al., 2010, 2020; Guidino et al., 2020; Hoyt, 2001; O'Connor et al., 2009). O'Connor et al. estimated that, in 2009, up to 13 million people in 119 countries participated in WW activities, generating a total expenditure of $2.1 billion (O'Connor et al., 2009). Indeed, Cisneros-Montemayor and co-authors estimated in 2010 that the potential development of WW activities in maritime countries could generate an additional yearly revenue of $413 million, and support 5,700 jobs, leading to an overall 19,000 positions and potential revenue of over $2.5 billion globally (Cisneros-Montemayor et al., 2010). In Peru, WW involving humpback whales has grown in the last ten years, reaching an annual input of $3 million (Guidino et al., 2020), whilst in the Gulf of California and Baja California Peninsula (Mexico), whale and shark watching, and recreational fishing attract 896,000 visitors a year, generating $518 millions and directly supporting 3,575 jobs (Cisneros-Montemayor et al., 2020). Even though in Scotland the number of WW passengers declined by 17.3% from 2000-2018, possibly due to shorter operational seasons with fewer tours due to adverse weather, WW remains an important source of employment and revenue in isolated coastal communities (Ryan et al., 2018).

Mainland Spain witnessed a year-on-year increase in the number of whale watchers and related expenditures between 1998 (Hoyt, 2001; O'Connor et al., 2009; Tenan et al., 2020) and the beginning of the COVID-19 pandemic in 2020[4]. Indeed, the number of whale watchers grew from 38,000 in 1998 to 74,629 in 2008, leading to an increase in total expenditures, from $1,925,000 to $8,155,446 respectively (Hoyt, 2001; O'Connor et al., 2009). In the Strait of Gibraltar**,** WW is a well-established industry with a strong socioeconomic role (Andreu Cazalla et al., 2016; Cabaleiro Mora et al., 2007; Elejabeitia et al., 2012; Sequeira et al., 2009), and is recognised as one of the fastest growing economic sectors in the area (Tenan et al., 2020). The town of Tarifa (Cádiz, Andalusia), located on the northern coast of the Strait of Gibraltar (figure 1.1), was identified in 2009 by O'Connor and colleagues as the main WW departure port on the Spanish mainland, hosting around 75% of the country's total whale watchers (O'Connor et al., 2009).

WW is linked to social, educational, environmental and scientific benefits (Cisneros-Montemayor et al., 2010; Cisneros-Montemayor & Sumaila, 2010; Hoyt, 2001; O'Connor et al., 2009), as well as an increased community sense of identity and pride (Hoyt, 2001). However, WW operations can also have adverse effects on cetaceans (Argüelles et al., 2016; Marega-Imamura et al., 2018; Sprogis et al., 2020) by inducing avoidance (Arias et al., 2018), disrupting behaviour patterns (Barra et al., 2020; Fumagalli et al., 2018) and influencing female reproductive success and calf survival (Senigaglia et al., 2019). WW can be therefore considered as **a sub-lethal stressor** (Fumagalli et al., 2021) and a form of capitalist exploitation (Higham et al., 2016; Higham & Neves, 2015) that requires management.

[4] https://www.firmm.org/es/news/article/items/recordando-la-corta-temporada-del-2020

Despite the existence of **regulations, legislations and guidelines** to mitigate the detrimental effects of boat-based WW, such as the reduction in approach speed and in the time spent with cetaceans, (Carlson, 2008, 2012a; International Whaling Commission, 2020b, 2020a), they are often disregarded by WW operators (Avila et al., 2015; Fraser et al., 2020; Kessler & Harcourt, 2013; Parsons & Brown, 2017; Seely et al., 2017), including those in the **Strait of Gibraltar** (hereafter also referred to as the Strait) (Andreu Cazalla et al., 2016; Cabaleiro Mora et al., 2007; Espada Ruíz et al., 2018). Within the scientific community, the development of the WW industry raises concerns about the potential negative effects of WW on cetacean communities (Espada Ruíz et al., 2018; Herr et al., 2020; Olaya-Ponzone et al., 2020; Tenan et al., 2020).

Considering the rapid growth of WW activities in the Strait (Elejabeitia et al., 2012; Tenan et al., 2020) and that WW is a sub-lethal stressor (Fumagalli et al., 2021), there is the need to develop management measures that support the protection of cetacean populations and that encourage sustainability (Andreu Cazalla et al., 2016; Espada Ruíz et al., 2018; Higham et al., 2009, 2016; Higham & Neves, 2015; Enrico Pirotta & Lusseau, 2015).

Eight WW operators dedicated to observing cetaceans are currently active in the Strait (table 1.4). The number of active companies varied between 7 to 12 (Hoyt, 2001, 2003; O'Connor et al., 2009) before stabilizing at 7-8 companies (Andreu Cazalla et al., 2016; Sequeira et al., 2009) in the past decade, with the total fleet increasing from 5 (Hoyt, 2003) to 12 vessels in summer 2022.

Table 1.4 Summary details of WW operators in the Strait of Gibraltar. 'Seasonally' indicates companies operating from March/April to September/October. Information is updated to summer 2022.

Companies	Port-based	Web pages	No. and type of boats	Duration of trip	Price adults	Pax carry capacity	Operations
Aventura Tarifa	Tarifa	http://www.aventuratarifa.com/contactar/	1 rigid-hulled inflatable boat	2 h 3 h	60 euros 75 euros	10	Seasonally
Firmm	Main in Tarifa, rarely Algeciras	https://www.firmm.org/es/	2 covered motor boats	2 h 3 h	45 euros 65 euros	100 60	Seasonally
Marine Blue	Tarifa and Algeciras	https://marinablue.es	1 yacht	2 h 3 h	100 euros 150 euros	na	All year round
Turmares Tarifa	Mainly in Tarifa, rarely Algeciras	https://www.turmares.com	2 covered motor boats 1 motor boat	2 h 3 h	45 euros 65 euros	150 60 6	Seasonally
Dolphin Adventure	Gibraltar	http://www.dolphin.gi	2 catamarans	1 h 15 min/30 min	25 pounds (≃ 27 euros)	70 49	All year round
Dolphin	Gibraltar	https://www.	1 motor boat	1 h 15	25 pounds	25	All year

Safari		dolphinsafarigibraltar.site		min/30 min	(≃ 27 euros)		round
Ecolocaliza	La Línea de la Concepción	https://ecolocaliza.com	1 sailing boat	2 h 4 h	60 euros 95 euros	6	All year round
Estrecho Natura	Algeciras	www.estrechonatura.es	1 motor boat	2 h 5 h	65 euros 150 euros	6	Seasonally, potentially all year round

All eight companies are based in the central-northern and central-eastern parts of the Strait, and operate in its central-western and central-eastern sectors (figure 1.4). More specifically, four vessels operate from Tarifa, one from Algeciras (both locations in Spain), two from Gibraltar (UK) and one is based in La Línea de la Concepción (Spain). These companies offer between two and six daily trips, which are between one hour and 15 minutes to five hours long, with the cost for each trip ranging from 27 to 150 euros (table 1.4). Whilst **Error! Bookmark not defined.**Spanish and Gibraltarian WW companies operate in Moroccan waters on a regular basis, we are not aware of any Moroccan WW boats operating in Spanish waters or close to Gibraltar.

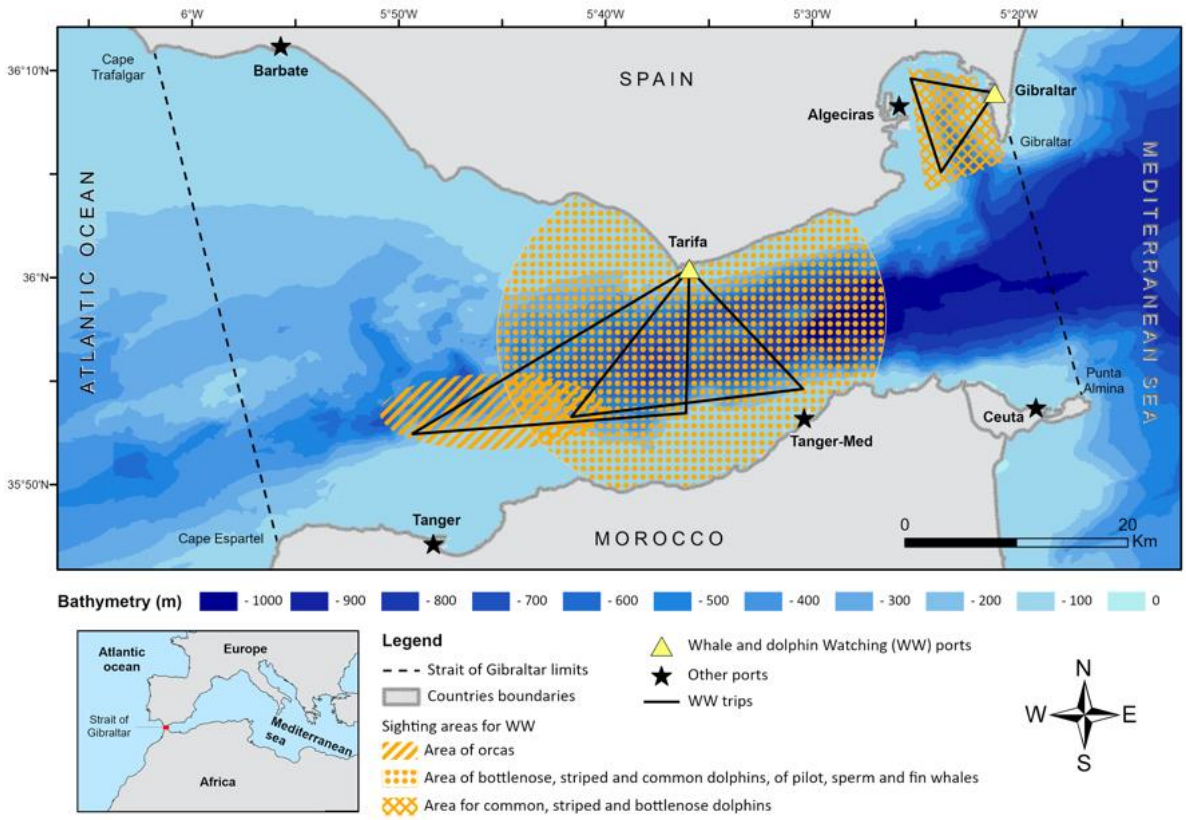

Figure 1.4 Map based on existing knowledge from published literature (Cabaleiro Mora et al., 2007; Elejabeitia et al., 2012; Sequeira et al., 2009) cross-checked with information obtained directly from sailors and naturalists of three Whale and dolphin Watching (WW) companies, two of which are based in Tarifa and one in Gibraltar. The main working areas, the ports and

the typical boat tracks of the companies are highlighted. Vessel tracks for the operators Ecolocaliza (operations started in 2020), Estrecho Natura (operations started in 2021) and Marine Blue were not available for mapping.

National statutory tools regulating WW activities in the Strait are the Royal Decree 1727/2007 (RD), through which protection measures for cetaceans are established in Spain, and the Marine Protection Regulation 2014/180 (MPR), Chapter 4 and Schedule 3, in Gibraltar (both provided as supplementary materials 4.2, I and II). To our best knowledge, no tools regulating WW activities in Moroccan waters are currently in place. These regulations partially overlap in terms of the measures they introduce and both reflect global WW guidelines and regulations (Carlson, 2012b). Specifically, they include:

i. Zoning schemes designed to help minimise disturbance Exclusion Zone (EZ) with a radius of no less of 60 m from the cetacean, Restricted Access Zone (RAZ) between 60 and 300 m from the cetacean, Approach Zone (AZ) from 300 to 500 m).
ii. Regulation of vessel activity in the presence of cetaceans (e.g., maintaining a low speed and constant parallel course , avoiding separating mother and calves).
iii. Prohibiting the release of any substance or object (including food).
iv. Leaving cetaceans when they show any sign of distress (described as signs of alarm, discomfort or alteration of behaviour).

Differences between the RD and the MPR include aspects concerning the maximum number of vessels allowed to stay in the RAZ, with one vessel permitted in Gibraltar waters for 20 minutes, and two in Spanish waters, without time restrictions. The MPR also mention a permit system in the Marine Regulation, not present in the RD; as well as different enforcement systems. The governmental agencies 'Servicio Marítimo de la Guardia Civil', the 'Dirección General de Marina Mercante del Ministerio de Fomento', and the 'Fuerza de Acción Marítima de la Armada' are active in Spanish waters while the Environmental Protection and Research Unit (EPRU) of the Department of the Environment, Heritage and Climate Change – HM Government of Gibraltar[5], are active in the British Gibraltar Territorial Waters. These bodies do not operate synergistically during patrolling activities.

Taking into account that WW is the most relevant economic activity based on cetaceans, that it is highly important for local communities (Guidino et al., 2020; Hoyt, 2001; O'Connor et al., 2009; Parsons et al., 2003), and specifically important for Tarifa (Andreu Cazalla et al., 2016; Cabaleiro Mora et al., 2007; Hoyt, 2001; O'Connor et al., 2009; Tenan et al., 2020), and that **concerns** have been raised by the scientific community pertaining to its potential negative effects on cetacean communities in the Strait of Gibraltar (Espada Ruíz et al., 2018; Herr et al., 2020; Olaya-Ponzone et al., 2020; Tenan et al., 2020), the aims of this thesis are to investigate:

i. the current and the best practices in the presence of cetaceans during WW activities,
ii. the benefits and services determined by the presence of WW, and
iii. to formulate recommendations for sustainable management of WW activities (results in the scientific articles 4.1 and 4.2).

5 https://www.gibraltar.gov.gi/environment

In the article 'Sustainability as a common goal: Regulatory compliance, stakeholder perspectives, and management implications of whale and dolphin watching in the Strait of Gibraltar' (section 4.2), these aims are partially achieved through direct assessments and the evaluations provided by key stakeholders (i.e., WW customers and operators, researchers, environmental NGOs members, technicians, and policymakers), an assessment of the level of compliance with WW rules by WW companies, and an investigation into which management measures could help to improve sustainability.

The economic pillar of WW sustainability in the Strait is investigated, together with its connections within the social sphere, in the articles: 'Insights into sustainable tourism policy: identikit of the whale watcher and their economic contribution in Tarifa (Strait of Gibraltar)' (section 4.1). More specifically, the industry's economic contribution to the economy of the town of Tarifa and the factors influencing the level of satisfaction and the expenditures of the WW customers, are considered. Insights into the development of sustainable tourism policies in the area are also provided in this last scientific article.

In this context, the above mentioned studies form the basis for the development of an integrated management system of WW activities in the Strait and discuss the relevance of such a process in the area.

1.4 Monitoring cetaceans using ferries as the platform of opportunity

The Strait is also an area of high **maritime traffic density**, with an average of 116,128 vessels transiting the Strait every year (data provided by 'Tarifa Tráfico VTS' of the Spanish Maritime Safety and Rescue Society 'Salvamento Maritimo'[6], for 2018 and 2019). Injuries of anthropogenic origin were detected in all of the seven cetaceans species regularly occurring in the area (Herr et al., 2020). Common dolphin injuries amongst the population inhabiting the Bay between Algeciras and Gibraltar are likely to stem from the high intensity of recreational fishing and whale watching activities in the area (Olaya-Ponzone et al., 2020); whilst ferry traffic was negatively correlated to the annual apparent survival of the local bottlenose dolphin population (Tenan et al., 2020). Moreover, ship strikes are considered one of the main threats affecting fin and sperm whales (Grossi et al., 2021), and evidence of past collision events between vessels and fin whales in the population crossing the Strait has been reported (Gauffier et al., 2018).

Monitoring cetaceans using ferries as a platform of opportunity is an environmentally sustainable and cost-effective program that takes advantage of the vessels already sailing in the area. A current long-term program, consistent over space and time and repeatable all year round, is conducted over large geographic sea areas (Arcangeli et al., 2019, 2021; David et al., 2022) in the Mediterranean basin, allowing the detection of eventual changes in the distribution of different species over time (Arcangeli et al., 2013). Furthermore, data collected on cetaceans from ferries has allowed for further investigation into their relationship with environmental parameters (Arcangeli et al., 2013) and pressures, such as maritime traffic (Campana et al., 2015, 2017, 2022) or floating marine macro litter (Arcangeli et al., 2020; Gregorietti et al., 2021). Likewise, dedicated observers could play an important role in

[6] http://www.salvamentomaritimo.es

spotting marine mammals and reducing the risk of collision (Weinrich et al., 2010), detecting rare events such as collisions or near-collisions (David et al., 2022), and, contemporaneously, raising the awareness of sea life conservation among the crew. In addition, data systematically collected from ferries could provide valuable information for the requirements of environmental legislative frameworks such as the Habitats Directive, the Marine Strategy Framework Directive or the Marine Spatial Planning Directive and for the evaluation of local protection measures (Arcangeli et al., 2021).

The monitoring project 'Los ferris, medio para investigar los cetáceos' (Ferries: a way to study cetaceans - https://nereide.org/proyectos/investigacion/proyecto-ferris/) was set up in the Strait of Gibraltar in January 2018 by the PhD candidate with the support of the Fundaciò Baleària and with Ecolocaliza (https://www.ecolocaliza.com), MMIRC (https://www.mmirc.com), the Nereide Association (https://www.nereide.org) and the University of Cádiz as partners' entities. The project is carried out on the ferries of the company Baleària along the lines: Algeciras-Ceuta (Spain) and Algeciras-Tanger Med (Spain-Morocco). The monitoring project of the Strait is part of the Fixed Line Transect Mediterranean monitoring Network (FLT Med Net) which joins research bodies using ferries as the platform of observation to perform systematic surveys along several transboundary transects in the Mediterranean Sea (figure 1.5). The network is coordinated by ISPRA (https://www.isprambiente.gov.it/en/activities/biodiversity/flt-mediterranean-monitoring-network-marine-species-and-threats) and is run in collaboration with research bodies from Italy, France, Spain, Tunisia and Greece. More than 20 scientific partners are involved in the data collection, protocol definition, and data analysis. The aim of the network is the long-term monitoring of key marine species and their main threats (i.e. marine litter and maritime traffic) so that changes in species abundance, distribution and habitat use can be detected early, and can be linked to their main environmental and anthropogenic drivers.

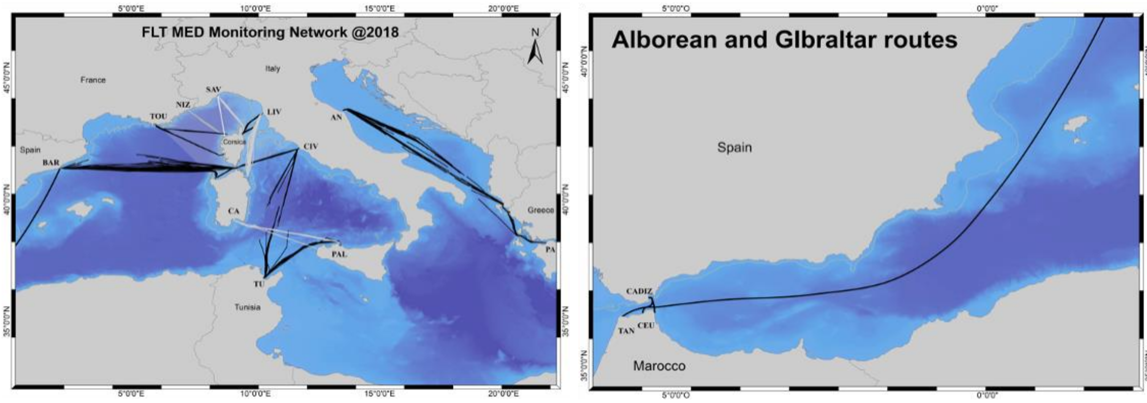

Figure 1.5 Maps of the Mediterranean Sea (on the right) and of the Alborán and Strait of Gibraltar areas (on the left). The black continuous lines indicate the monitoring transect using ferries as the platform for all the parties of the Fixed Line Transect Mediterranean Monitoring Network.

Considering the co-existence of highly protected species of cetaceans with the high density of maritime traffic, along with the complex management framework of this transboundary area, data collected using ferries in the Strait were analysed in order to;

i. contribute to the understanding of cetaceans' seasonal presence, distribution and habitat use,

ii. measure the influence of maritime traffic on cetacean presence and to identify the risk areas for the species in the surveyed zone and

iii. discuss the coherence of the marine conservation and mitigation measures for protecting cetaceans already in force in the Strait of Gibraltar with the achieved results.

Moreover, on the Mediterranean Basin scale, data collected by ferries in the Strait together with data from the entire FLT Med Network, were analysed to improve the knowledge on three low-density cetacean species of the Mediterranean Basin: the long-finned pilot whale (*Globicephala melas*, Gm), Risso's dolphin (*Grampus griseus*, Gg) and Cuvier's beaked whale (*Ziphius cavirostris*, Zc), and to contribute to the evaluation of potential approaches to support legislative requirements.

Results obtained are reported in chapter 5 'Using ferries as a platform for monitoring cetaceans and their threats'. The chapter addresses two scientific articles submitted; section 5.1 'Tie up loose ends together: cetacean, maritime traffic, and spatial management tools in the Strait of Gibraltar' and 5.3 'Testing indicators for trend assessment of the range and habitat of low-density cetacean species in the Mediterranean Sea' along with the short presentation 5.2 'Fixed line transect Mediterranean monitoring network -FLT MED Net, an international collaboration for long term monitoring of macro-mega fauna and its main threats'.

1.5 Hauraki Gulf and global COVID-19 lockdowns

Hauraki Gulf, North Island (New Zealand) is an important natural area and a hotspot for several cetaceans (Baker & Madon, 2007; Barlow et al., 2018; Dwyer et al., 2016), but is at the same time an area characterized by high levels of maritime traffic, where recreational boats are an important sector of the economy (Beca Infrastructure Ltd, 2012). In February 2020, the PhD candidate started a collaboration aiming to better understand the relationship between cetaceans and tourism/recreational operations. Originally, this collaboration should have ultimately visually and acoustically investigated how the engaged vessels may affect the well-being of cetaceans within the Hauraki Gulf. It should have focused on both commercial vessels, such as whale-watching boats and fishing charters, and recreational vessels, such as those commonly interacting with cetaceans within the Hauraki Gulf, investigating their acoustic impacts on cetaceans. The visual surveys were interrupted after three weeks due to the outbreak of the COVID-19 pandemic, while the acoustic surveys were able to continue. The aims of the collaboration were modified due to the COVID-19 lockdown. Relationships between vessel traffic/noise levels and the effects of cumulative vessel noise on the overall communication range of dolphins and fish were tested and results were published and are reported here in section 6.1. Results obtained from the Hauraki Gulf were shared with the international community to monitor the global effects of the COVID-19 lockdown on nature, which resulted in the published article presented in section 6.2.

The Hauraki Gulf and the COVID-19 lockdown: Because of the COVID- 19 pandemic, borders were closed, freedom of movement and commerce was heavily restricted and international trade was substantially reduced within months (Bates et al., 2020), bringing about the 'Anthropause' (Rutz et al., 2020). The response of coastal marine organisms to this new, relatively calm period, was noticed and reported by the scientific community (Rutz et al., 2020). One potential key factor in explaining the observed change in wildlife behaviour during the lockdown was the reduction of anthropogenic noise in the environment. Noise pollution is the most pervasive by-product of urbanisation, transport and industry, and changes the acoustic environment to which many animals are acutely tuned to (Shannon et al., 2016). Marine mammals, fish and invertebrates depend on sound for critical life history processes, such as mate selection and predator avoidance (Peng et al., 2015). Anthropogenic underwater noise has been increasing around the world for decades (Andrew et al., 2011; Frisk, 2012), with rising underwater noise levels in coastal environments due to small boats becoming of substantial concern due to growing evidence of both lethal and sublethal impacts on marine life (Hawkins & Popper, 2014; Hermannsen et al., 2019; Jones, 2019; Popper & Hawkins, 2019). This is particularly relevant in highly productive waters that are near major port cities, such as the Hauraki Gulf (figure 1.6) near New Zealand's largest city, Auckland (Pine et al., 2016; Putland et al., 2018). The city is located within the centre of the Hauraki Gulf Marine Park (HGMP), an area of 4,000 km^2 of outstanding marine biodiversity including more than 700 species of marine intertidal invertebrates, around 80 species of fish and 25 species of marine mammals, at least six of which are resident (Hauraki Gulf Forum, 2014). Auckland residents have the highest recreational vessel ownership per capita in the world, and in 2011, boat ownership was estimated to be 132,000, with numbers expected to reach 183,000 by 2041 (Beca Infrastructure Ltd, 2012). Recent research has shown that increasing vessel noise reduces the ability of dolphins and fish to effectively perceive their acoustic environment (Erbe et al., 2016, 2019; Putland et al., 2018; Stanley et al., 2017). On 26 March 2020, New Zealand entered a strict lockdown of societal activity to combat the spread of COVID-19, with the government placing a complete ban on all non-essential services on both land and sea. Vessel activity in the Hauraki Gulf declined abruptly, with all recreational and non-essential commercial vessels banned from operating for 7 weeks. Shipping and related vessels continued to operate, but traffic was heavily reduced. For the marine animals that depend on underwater sound for critical life history processes, in the Hauraki Gulf the reduction in vessel traffic resulted in significant changes to their acoustic habitat. The situation offered the opportunity to test relationships between vessel traffic and noise levels, and the effects of cumulative vessel noise on the overall communication range of dolphins and fish, specifically on the bottlenose dolphin (*Tursiops truncatus*) and bigeyes fish (*Pempheris adspersa*).

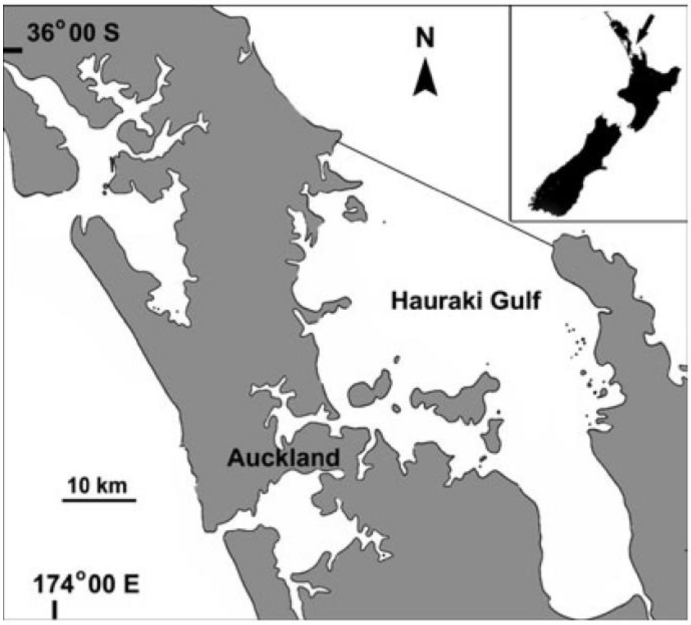

Figure 1.6 Maps of the Hauraki Gulf, North Island, New Zealand (Stockin et al., 2009).

Global COVID-19 lockdown - Considering the global COVID-19 lockdown as a unique, quasi-experimental opportunity, the results of the work done in the Haruaki Gulf (original name: Ko te Pataka kai o Tikapa Moana Te Moananui a Toi) were shared with an international team, in order to test how human activities can both harm and benefit nature (figure1.7). Human-driven alterations of atmospheric conditions, elemental cycles and biodiversity suggest that the Earth has entered a new epoch; the Anthropocene (Crutzen, 2002; Steffen et al., 2007). Negative impacts associated with human activities include a much warmer Earth state, a marked expansion of urbanized areas, and an acceleration of species extinctions (Schipper et al., 2008). The perspective that the main role of humans is a source of threat to species and ecosystems lead to the prediction that the global human lockdown to mitigate COVID-19 health risks may alleviate human impacts, with resulting positive environmental responses (Derryberry et al., 2020; Rutz et al., 2020). Yet a more comprehensive consideration of the links between human activities, species and ecosystems also acknowledge the role of humans as custodians of nature who engage in conservation research, biodiversity monitoring, restoration of damaged habitats, and enforcement activities associated with wildlife protection (Bates et al., 2020; Corlett et al., 2020; Evans et al., 2020; Kishimoto & Kobori, 2021; Manenti et al., 2020; Miller-Rushing et al., 2021; Rondeau et al., 2020; Sumasgutner et al., 2021; Vale et al., 2021; Zambrano-Monserrate et al., 2020). Indeed, the global COVID-19 human confinement has disrupted conservation enforcement, research activities and policy processes to improve the global environment and biodiversity (Corlett et al., 2020; Evans et al., 2020; Quesada-Rodríguez et al., 2021; Zambrano-Monserrate et al., 2020). Here, the global COVID-19 lockdown is considered a unique opportunity to test how human activities both harm and benefit nature (Bates et al., 2020). If the negative roles of humans on species and ecosystems predominate, reports of overwhelmingly positive reports of responses of nature to human lockdowns would be expected. Thirty diverse observations were integrated from before and during the peak lockdown period to examine how shifts in human behaviour impact wildlife, biodiversity threats, and conservation.

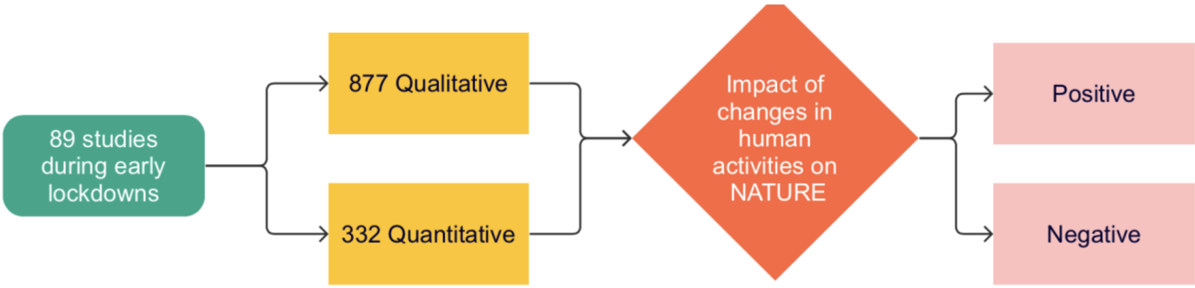

Figure 1.7 Flow chart of the study reporting the immediate impacts of changes in human activities on wildlife and environmental threats during the early lockdown months of 2020, based on 877 qualitative reports and 332 quantitative assessments from 89 different studies.

Analysis included;

i. the study of human mobility on land and waterways, and in the air, to quantify the change in human activities,
ii. the compilation of qualitative reports from social media, news articles, scientists, and published manuscripts, describing seemingly lockdown-related responses from nature,
iii. the mapping of the direction and magnitude of responses from wildlife, the environment and environmental programs, using data provided by scientists that was collected before and during lockdown, representing replicated observations across large geographic areas.

The type, magnitude, and direction of responses that could be confidently linked to the lockdowns were empirically described and offered integrated outcomes supported by examples drawn from the results. Finally, results were used to provide recommendations to increase the effectiveness of conservation strategies.

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CHAPTER 2 - HYPOTHESIS, AIMS AND CONCEPTUAL FRAMEWORK

Integrated management is based on the understanding of ecosystems and the assessment of ocean use, and facilitates integration across sectors and jurisdictions (Foster & Haward, 2003), working with a wide range of stakeholders through a collaborative process (Rutherford et al., 2005), in order to provide necessary planning. The Integrated Management approach was applied in the case of the study of the Strait of Gibraltar, indeed this thesis;

i. provides contributions for a better understanding of the presence, distribution and habitat use of the cetaceans populations of the Strait (sections 5.1 and 5.3),
ii. assesses maritime activities (5.1) and specifically the whale watching activity (4.1 and 4.2),
iii. involves a wide group of stakeholders, including WW customers and operators, researchers, environmental NGOs members, technicians and policymakers (4.1 and 4.2), and
iv. formulates detailed recommendations for the sustainable management of the maritime traffic (5.1) and the WW activities (4.1 and 4.2).

Sustainability is commonly represented as three intersecting circles of the social, economic and environmental spheres, with overall sustainability at the centre (Purvis et al., 2019). This work investigates the social (4.1 and 4.2), the economic (4.1) and the environmental (5.1 and 5.3) components when working toward the sustainability of the maritime activities in the Important Marine Mammal Areas of the Strait.

In the Hauraki Gulf (NZ) small traffic activity, including whale watching, should have been studied. The study was interrupted by the global lockdowns due to COVID-19 thus this investigation was shifted to test the influence of the lockdowns on nature (6.1 and 6.2).

The **hypotheses** (Hs) tested in the main area of study the Strait of Gibraltar and the respective **aims** (As) to achieve are the following:

(H1) Integrated Management (IM) is an effective approach for marine areas characterized by the presence of marine mammals.

(H1.A1) To identify the best practices of IM approach in the presence of marine mammals,

(H1.A2) to contribute to an improved understanding of the seasonal presence, distribution and habitat use of cetaceans,

(H1.A3) to test the influence of maritime traffic on cetacean presence to identify the risk areas for the species in the surveyed zone, and

(H1.A4) to discuss the coherence of the marine conservation and mitigation measures already in force for protecting cetaceans and the areas at higher-risk of exposure to maritime traffic.

(H2) The presence of cetaceans positively affects the coastal communities of the Strait of Gibraltar.

(H2.A1) To collect information about the benefits and services provided through the ecosystem services in the area and

(H2.A2) to evaluate the relationship between the presence of cetaceans and the benefits obtained by coastal communities.

(H3) Sustainable whale watching is more profitable.

(H3.A1) To bring together the current practices in the presence of cetaceans and

(H3.A2) to contribute with suggestions and guidelines that encourage ecotourism and good whale watching practices that lead to a sustainable management strategy.

For the study in the Hauraki Gulf, the original hypothesis and aims changed adapting to the COVID-19 lockdowns. The hypothesis **(H4);** human lockdowns have positively influenced nature, was tested aiming to

(H4.A1) investigate the effects of the reduction of vessel traffic on cetaceans and

(H4.A2) assess how human activities both harm and benefit nature.

Representations of the hypotheses tested, the aims to achieve, the methodologies applied and the results obtained are summarized in table 2.1.

Table 2.1 Research framework of the PhD thesis, describing the hypotheses to test, the aims to achieve, the methods applied and the results obtained.

Hypothesis	Aims	Methods	Results
(H1) Integrated Management is an effective approach for marine areas characterized by the presence of marine mammals.	(H1.A1) to identify the best practices of IM approach in the presence of marine mammals, (H1.A2) to contribute for understanding the seasonal presence, distribution and habitat use of cetaceans, (H1.A3) to test the influence of maritime traffic on the cetacean presence and to identify the risk areas for the species in the surveyed zone, and (H1.A4) discussing the coherence of the marine conservation	Semi - structured questionnaires/interviews. Observation in situ and inquests Analysis of public and institutional official documents Visual surveys using ferries as platform	4.1 Insights into sustainable tourism policy: Identikit of the whale watchers and their economic contribution in Tarifa (Strait of Gibraltar) 4.2 Sustainability as a common goal: Regulatory compliance, stakeholder perspectives, and management implications of whale and dolphin watching in the Strait of Gibraltar 5.1 Tie up loose ends together: cetacean, maritime traffic, and spatial management

	and mitigation measures already in force for protecting cetaceans and the higher-risk areas of exposure to maritime traffic.		tools in the Strait of Gibraltar 5.2 Fixed line transect Mediterranean monitoring network (FLT MED Net), an international collaboration for long term monitoring of macro-mega fauna and main threats 5.3 Testing indicators for trend assessment of range and habitat of low density cetacean species in the Mediterranean Sea
(H2) The presence of cetaceans affects positively the coastal communities of the Strait of Gibraltar.	(H2.A1) To collect information about the benefits and services provided through the ecosystem services (H2.A2) To evaluate the relation between the presence of cetaceans and the benefits obtained by the coastal communities.	Request of information, interviews using semi and structured questionnaire Observation in situ and inquests Analysis of public and institutional official documents	4.1 Insights into sustainable tourism policy: Identikit of the whale watchers and their economic contribution in Tarifa (Strait of Gibraltar) 4.2 Sustainability as a common goal: Regulatory compliance, stakeholder perspectives, and management implications of whale and dolphin watching in the Strait of Gibraltar
(H3) Sustainable whale watching is more profitable.	(H3.A1) To collect the current practices in presence of cetaceans (H3.A2) to contribute with suggestions and guidelines, encouraging ecotourism and whale	Request of information Interviews using semi and structured questionnaire Observation in situ and inquests Analysis of public and	4.1 Insights into sustainable tourism policy: Identikit of the whale watchers and their economic contribution in Tarifa (Strait of Gibraltar) 4.2 Sustainability as a

	watch good practices for a sustainable management strategy.	institutional official documents	common goal: Regulatory compliance, stakeholder perspectives, and management implications of whale and dolphin watching in the Strait of Gibraltar
Vessels engaged in tourism activities influence cetaceans in Hauraki Gulf Changed to >> **(H4) Human lockdowns have positively influenced nature**	To investigate how vessels engaged in tourism activities may affect the wellbeing of cetaceans Changed to >> (H4.A1) to test the effects of the reduction of vessel traffic on cetaceans (H4.A2) to test the role of human activities in both harming and benefiting nature.	Acoustic and visual surveys	6.1 A Gulf in Lockdown: how an enforced ban on recreational vessels increased dolphin and fish communication ranges 6.2 Global COVID-19 lockdown highlights humans as both threats and custodians of the environment

The work developed during the PhD program resulted in the production of different scientific articles, which are currently at different stages of publication. Three published articles in peer-reviewed scientific journals (sections 4.1, 6.1 and 6.2), one in the first revision of *Marine Policy* (4.2), two submitted (5.1 to *Marine Pollution Bulletin* and 5.3 to *Frontiers in Marine Science*) and one short communication (5.2 published in the *Biologia Marina Mediterranea*). Abstracts of the papers are provided in English (EN) and in Spanish (ES) in the respective sections.

Chapter 4 'One team, one dream: the sustainability of whale and dolphin watching in the Strait of Gibraltar' provides an overview and an analysis of the whale watching activities in the area of study. It includes the articles:

i. 'Insights into sustainable tourism policy: Identikit of the whale watchers and their economic contribution in Tarifa (Strait of Gibraltar)' (section 4.1), and

ii. 'Sustainability as a common goal: Regulatory compliance, stakeholder perspectives, and management implications of whale and dolphin watching in the Strait of Gibraltar' (4.2).

These articles are testing the hypotheses H1, H2 and H3 and achieved the following aims:

(H1.A1) To identify the best practices of an Integrated Management approach in the presence of marine mammals,

(H2.A1) to collect information about the benefits and services provided through ecosystem services,

(H2.A2) to evaluate the relationship between the presence of cetaceans and the benefits obtained by coastal communities,

(H3.A1) to bring together the current practices in the presence of cetaceans,

(H3.A2) to contribute with suggestions and guidelines, that encourage ecotourism and good whale watching practices, and that lead to a sustainable management strategy.

Moreover, the aim (H1.A3), to test the influence of maritime traffic on cetacean presence and to identify risk areas for the species in the surveyed zone, is met in section 4.2.

In **Chapter 5** 'Using ferries as a platform for monitoring cetaceans and their threats' the first hypothesis (H1) is tested. The Integrated Management approach is applied to provide knowledge on cetaceans and maritime activities and, through the integration of these results, to formulate suggestions to optimize spatial management. Chapter 5 includes the scientific articles:

i. 'Tie up loose ends together: cetacean, maritime traffic, and spatial management tools in the Strait of Gibraltar' (section 5.1),
ii. 'Fixed line transect Mediterranean monitoring network (FLT MED Net), an international collaboration for long term monitoring of macro-mega fauna and main threats' (5.2),
iii. 'Testing indicators for trend assessment of range and habitat of low-density cetacean species in the Mediterranean Sea' (5.3).

The following aims are achieved in all these articles:

(H1.A2) To contribute to an improved understanding of the seasonal presence, distribution and habitat use of cetaceans, and

(H1.A3) to test the influence of maritime traffic on cetacean presence and to identify the risk areas for the species in the surveyed zone.

By deepening our studies we achieve the aim (H1.A4) aim (to discuss the coherence of the marine conservation and mitigation measures already in force for protecting cetaceans and the areas at higher risk of exposure to maritime traffic) in articles 5.1 and 5.3, and the aim (H1.A1) in the article 5.1.

The hypothesis (H4) is tested in **Chapter 6** which brings together the published papers:

i. 'A Gulf in lockdown: how an enforced ban on recreational vessels increased dolphin and fish communication ranges' (6.1),

ii. 'Global COVID-19 lockdown highlights humans as both threats and custodians of the environment' (6.2).

Through these works the following aims were achieved:

(H4.A1) To test the effects of the reduction of vessel traffic on cetaceans, and

(H4.A2) to test how human activities both harm and benefit nature.

A schematic representation of the thesis framework is provided in figure 2.1.

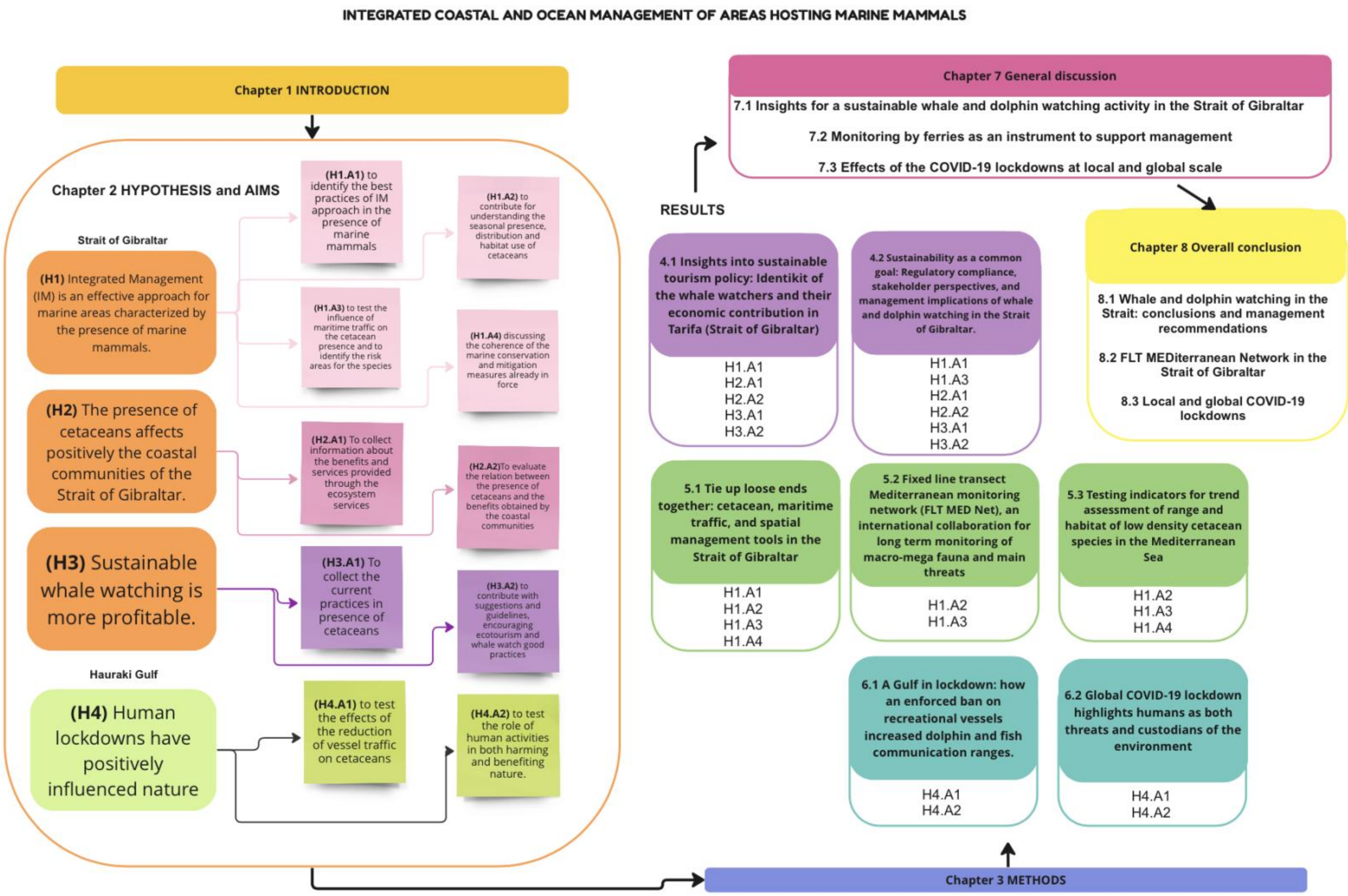

Figure 2.1 Flowchart summarizing the links between the starting hypothesis, the respective aims to test the hypothesis, the methods used and the results obtained.

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CHAPTER 3 - METHODS

Since 2017 in the Strait of Gibraltar, and during 2020 in the Hauraki Gulf (New Zealand), data on Whale Watching (WW), cetaceans and maritime traffic have been collected using opportunistic platforms (i.e., WW vessels and ferries). Methods applied include questionnaires directed to different stakeholders, such as WW customers and scientists, in the Strait, direct assessments, and visual and acoustic surveys in both areas of study. The methods used aimed to identify practices of integrated management when there is a simultaneous presence of marine mammals and anthropogenic activities such as maritime traffic (e.g., ferries, WW and recreational vessels). The scheme of the methods applied is shown in table 3.1.

Table 3.1 Scheme of the methods applied for each investigation carried out, including data on location, dates, how many samples were collected, and the results obtained (i.e., referring to the results chapter). WW acronym for Whale Watching.

<table>
<tr><th colspan="3">Methods</th><th>Locations</th><th>Samples</th><th>Dates</th><th>Samplers</th><th>Results</th></tr>
<tr><td rowspan="3">Questionnaires</td><td>To stakeholders</td><td>Including closed and open-ended questions was sent by e-mail to a group of stakeholders in Spanish or English</td><td>Tarifa and Gibraltar</td><td>42 stakeholders contacted</td><td>November 2019</td><td>PhD candidate</td><td>4.2 Sustainability as a common goal</td></tr>
<tr><td rowspan="2">To customers</td><td rowspan="2">Including closed and open-ended questions provided at the end of the WW trip with at least one cetacean encounter (in Spanish or English)</td><td>Tarifa</td><td>379 in 54 WW trips</td><td>Summers 2017-18</td><td rowspan="2">PhD candidate and colleagues</td><td rowspan="2">4.1 Insights into sustainable tourism policy

4.2 Sustainability as a common goal</td></tr>
<tr><td>Gibraltar</td><td>238 in WW 54 trips</td><td>Summer 2019</td></tr>
<tr><td colspan="2" rowspan="2">WW trip assessment</td><td rowspan="2">An assessment checklist was designed selecting 17 criteria extrapolated by the local WW legislations</td><td>Tarifa</td><td>3 WW trips</td><td rowspan="2">April - October 2019</td><td rowspan="2">PhD candidate and colleague</td><td rowspan="2">4.2 Sustainability as a common goal</td></tr>
<tr><td>Gibraltar</td><td>2 WW trips</td></tr>
</table>

Visual surveys on board of ferries		Data collection followed the standard monitoring protocol of the Fix Line Transect Mediterranean monitoring Network	Algeciras-Ceuta	33 surveys	January 2018 - December 2019	PhD candidate and colleagues	5.1 Tie up loose ends together 5.2 Fixed line transect Mediterranean monitoring network 5.3 Testing indicators for trend assessment
			Algeciras-Tanger Med	26 surveys			
Surveys	Accoustic	Acoustic data were gathered using seafloor-mounted acoustic recording stations	Hauraki Gulf, northern New Zealand (NZ)	5 sites	February-March 2020	Acoustic technicniscian	6.1 A Gulf in Lockdown 6.2 Global COVID-19 lockdown
	Visual	Visual data were collected on board of the WW vessel Dolphin Explorer	Auckland (NZ)	9 WW trips	March 2020	PhD candidate	

3.1. The study areas

The Strait of Gibraltar - also called the Strait, is the main area of study. It separates Africa from Europe and is the only passage between the Mediterranean Sea and the Atlantic Ocean, encompassing Spanish, Moroccan and British territorial waters between -5°W and -6°W (figure 3.1). The bathymetry of the Strait is characterised by a west to east canyon, with shallow waters (200 - 300 m) on the Atlantic side and deeper waters (800 – 1000 m) on the Mediterranean side. The Strait, with its western and eastern borders being located between Cape Trafalgar (Europe) and Cape Espartel (Africa), and Gibraltar and Punta Almina (Africa) respectively, is about 60 km long, and has a minimum width of 14 km between Tarifa (Europe) and Punta Cires (Africa) (de Stephanis et al., 2008).

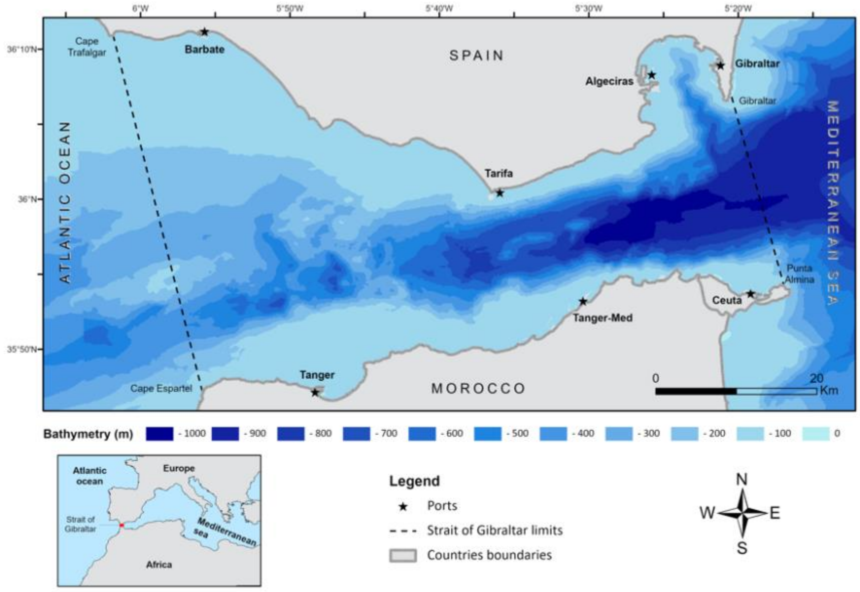

Figure 3.1 – Maps of the Mediterranean basin (bottom left corner) and the Strait of Gibraltar. Map of the Strait highlights the main ports and the study area limits. The map was produced by André Pedrosa, University of Aveiro (Portugal).

The study of the Whale Watching activities covered the entire area, including the Bay between Algeciras and Gibraltar and the central part of the Strait.

To investigate cetacean seasonal distributions, habitat use, and the relationship between cetaceans and marine traffic based on data collected through ferries, a sub-area of the Strait was considered. The sub-area borders are marked as a line from Punta Paloma (Spain) to Punta Bou Maaza (Morocco) to the west, and a line from Punta Mala (Spain) and Punta Almina (Morocco) to the east (figure 3.2). This sub-area was selected because of the data collection monitoring coverage and because of the similarity of the sea floor, in terms of bathymetry and slope.

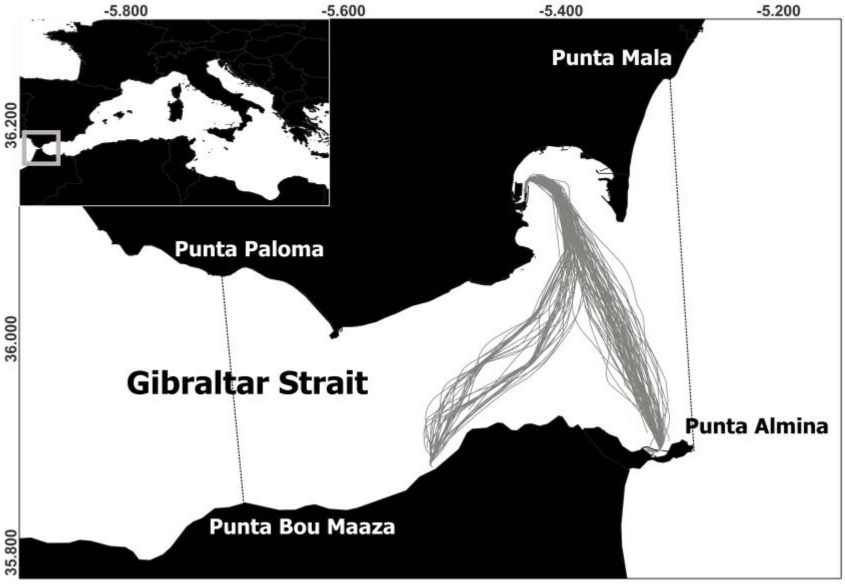

Figure 3.2 Map indicating the sub-area of the Strait considered for the analysis of data collected during cetacean and maritime traffic monitoring on ferries. Transects Algeciras-Ceuta (Spain), and Algeciras - Tangier Med (Spain-Morocco) are highlighted in grey.

Hauraki Gulf – On the eastern coast of New Zealand's North Island (South Pacific Ocean), the Hauraki Gulf runs along Auckland's north-eastern coastline, beginning at Bream Head and extending westward to Cape Colville on the Coromandel Peninsula (figure 3.3). Hauraki Gulf is a Marine Park, with outstanding marine biodiversity including at least six species of resident marine mammals among which common dolphins (Dwyer et al., 2020). Marine traffic in the Hauraki Gulf consists of a wide variety of vessels (e.g. large commercial ships, fishing boats, ferries, cruise ships, recreational power boats, tour boats, yachts, sailing boats and kayaks). The number of recreational vessels owned per person in Auckland is the highest in the world; with 132,000 boats were owned in 2011, and this number is expected to rise to 183,000 by 2041(Beca Infrastructure Ltd, 2012).

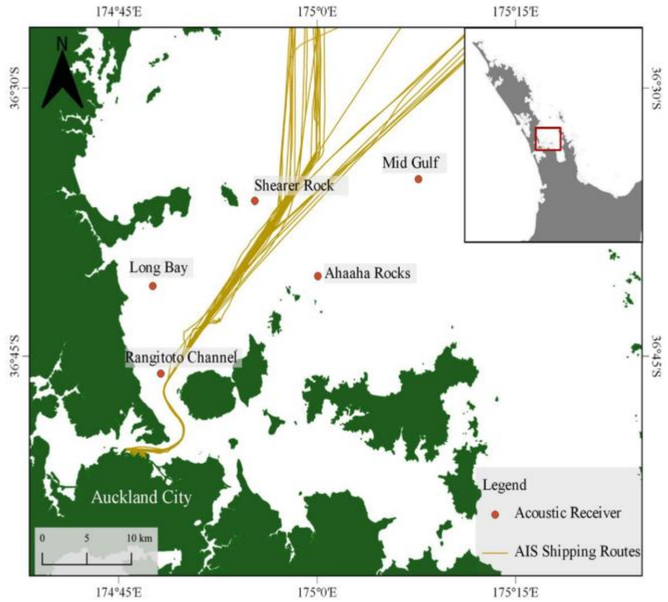

Figure 3.3 Map of the Hauraki Gulf Marine Park showing the location of the sea-mounted acoustic recording stations.

3.2 Questionnaires

Two types of questionnaires; one directed to key stakeholders of the Strait including WW operators, technicians, policymakers, and representatives of the NGO sector, and one directed exclusively to WW customers, were used to collect information on WW activities, evaluate trips and to consider management measures to improve the sustainability of WW and cetaceans conservation.

Key stakeholder questionnaires (not including WW customers) - Using the snowball procedure (Noy, 2008), a questionnaire (supplementary Material 4.2, III) was sent to a group of stakeholders (other than customers) based in the Strait, and was used to assess stakeholders' opinions on the adherence of WW companies to local WW measures, on the values associated with WW experiences (IFAW 1999; Hoyt, 2001) and on the existing approaches to improve the sustainability of the WW industry. A draft of the questionnaire was pre-tested in in-person interviews with two WW professionals; a captain and a naturalist guide, in October 2017. The questionnaires were sent in Spanish or English. The questionnaires' target audience included researchers (i.e. marine biologists and ecologists, geneticists, biostatisticians) and technicians (i.e. veterinarians and naturalists), NGOs settled in areas of study with a focus on conservation and/or cetaceans, WW professionals (i.e. captains, company owners, guides and sailors), policymakers (i.e. mayors and local councils representatives for environment or tourism departments) and environmental surveillance representatives. Interviewees nominated another fourteen further subjects to contact, of which 7 had not previously been listed. Of these seven, five belonged to the public administrations or to the environmental surveillance corps. Of the 42 questionnaires sent, 15 were directed to WW professionals, seven to academics, five to members of environmental NGOs, six to technicians and nine to policymakers. Twenty questionnaires were filled out (47,62%). The average and standard deviation of stakeholders' answers concerning the adherence to WW rules were considered, to assess the adherence to the WW legislations.

Stakeholders were also asked to comment upon management tools that could benefit cetacean conservation but were not specifically designated for the WW industry. The results were qualitatively described.

Questionnaire to WW customers - The sociodemographic profile of the WW customers (i.e. education level, age, gender, nationality, employment type), their knowledge of cetaceans (e.g. previous encounters with and awareness of conservation status of cetaceans), the level of satisfaction with the WW activity (e.g., towards the company and its educational services) and their perception of the behavior of the WW vessel (i.e., time spent with cetaceans and how they were approached, the behavioral response of the observed animals), were assessed using the globally adopted method of questionnaires (Guidino et al., 2020; Mitra et al., 2019; Schwarzmann & Shea, 2020; Shea et al., 2021). Self-administered questionnaires (the form is provided as supplementary materials 4.1), designed to be completed by a respondent without the intervention of the interviewer, and that included a combination of closed and open-ended questions, were supplied to the whale watchers of the WW companies Turmares Tarifa (http://turmares.com) and Dolphin Adventure (http://www.dolphin.gi). Surveys took place during 26 days in the summer of 2017 and 32 days in the summer of 2018 in Tarifa, and 25 days in the summer of 2019 in Gibraltar. Surveys were carried out on the way back to the port, both during weekdays and weekends but only on trips when at least one cetacean species had been encountered. Two trained naturalists, including the PhD candidate, working onboard as WW guides and sailors, briefly presented the purposes of the survey to all passengers of the WW trip, asking for their participation, and then handed out the printed questionnaires to those interested in participating. The questionnaires were provided in Spanish or in English.

Questionnaires to the customers of Turmares Tarifa, which offers trips longer than another operator, also included a section investigating customers' economic contribution to the economy of Tarifa (each participant was responsible for calculating their own expenses), their satisfaction with the WW company on a scale from 1 (completely dissatisfied) to 10 (completely satisfied), and customers' opinions on the values of WW (IFAW 1999; Hoyt, 2001). Values considered included the benefits brought about by the existence of WW, i.e. aesthetic, spiritual/psychological, political, educational, scientific, recreational, cultural, social, hereditary and monetary (list of values adapted by IFAW 1999; Hoyt, 2001).

Data on customer questionnaires were integrated *a posteriori* with total time spent with cetaceans (summing multiple encounters) and the number of species encountered.

The target population considered here were the WW customers partaking in WW activities in the Strait of Gibraltar. Considering estimations calculated in 2008 (O'Connor et al., 2009), there were a total of 91,342 WW customers in the Strait of Gibraltar; 55,971 customers per year in Tarifa (calculated as 75% of the total 74,629 WW customers on the Spanish mainland) and 35,371 per year in Gibraltar. The minimum questionnaire sample size required to represent our target population of 91,342 WW customers (level of confidence 95%, margin of error 4%), was 597. A total of 617 questionnaires were collected in both WW locations. In Tarifa, 379 questionnaires were filled out from the 23 of July to the 27 of September in 2017 and from the 6 of July to the 18 of September in 2018. In Gibraltar, 238 questionnaires were collected from the 2 of August 2019 to the 17 of September 2019.

Expenditure calculations of the WW customers in Tarifa

The economic contribution of whale watchers was estimated by calculating their direct, indirect and total expenditures (hereinafter referred to as DE, IE, and TE, respectively). The price of the WW ticket purchased by WW customers was used to calculate the DE (Hoyt, 2001; O'Connor et al., 2009). The expenses of accommodation, transport, and food supply, together with the expenses correlated to the activities of shopping, sport and leisure made in the local community, were used to calculate the IE (Brenner et al., 2016; Hoyt, 2001; NOAA & McDowell Group, 2020; O'Connor et al., 2009). The TE was obtained by summing DE and IE (Guidino et al., 2020; Hoyt, 2001; O'Connor et al., 2009).

During the surveys, each person interviewed was responsible for indicating their own expenditures. However, if WW customers were travelling in groups, the questions related to expenditures, including the place of overnight accommodation, the duration of the trip and the number of travel companions, were answered only by one customer to avoid IE overestimation. All expenditures were expressed in the local currency (euros).

DE made by all WW passengers in the two seasons was estimated as follows: (a) The average number of passengers in high season (July and August) and low season (September) was calculated based on the data collected during the surveys, (b) the obtained values were multiplied by the price of an adult ticket in low season for the trip lasting 2 hours, and in high season for the trips lasting 2 and 3 hours, (c) results were multiplied by the corresponding number of trips of each type/season surveyed over the two year period. As not all WW customers visited Tarifa for WW, a distinction between Whale Lovers (WL) and opportunistic whale watchers was made, and DE was then estimated considering just WL and specifically, those staying in Tarifa.

IE was calculated as follows: (a) The expenditures made in each category (i.e., accommodation, transport, food supply and other expenses) were summed, and (b) the obtained sum was multiplied by the average of the economic intervals selected by the interviewee in the questionnaires (<10, 10-20, 21-30, 31-40, 31-50, and >51. For the latter interval, a value of 51 was considered for calculations). The average daily expense for WW customers was also calculated by splitting the total IE (2017-2018) by the total number of interviewees (380). For a better assessment of the economic contribution of WW, DE and IE were also multiplied by the average number of travel companions indicated by the interviewee, and IE was multiplied for the average number of days spent in the holiday location. Again, all

IE calculations were first performed including all the WW customers interviewed, and then only considering WW staying overnight in Tarifa, WL, and WL staying overnight in Tarifa.

Finally, the economic data gathered using the self-administered questionnaires were compared with the data publicly available regarding daily expenses of tourists in the area.

Correlation among variables studying the economic contribution

The level of satisfaction (with the company, expressed as a mark on a scale of 1-10, and with the overall WW experience, expressed as yes or not satisfied) was considered as a response variable to assess the relative influence of a series of explanatory variables. The explanatory variables were broadly categorized into the sociodemographic-economic profile of WW customers (i.e., income, education, employment, age, sex, and nationality), previous knowledge/experience on cetaceans (i.e., previous sightings, in the wild or in captivity, awareness of conservation status of cetaceans and the area), expectations (reason for joining the WW trip and for visiting Tarifa), characteristics of the trip attended (i.e. information offered on board and on land, time spent with cetaceans, number of sightings made during the trip, and number of passengers onboard).

Similarly, the overall IE and the different categories of expenditures were tested against the sociodemographic-economic profile of WW customers, their reason for visiting Tarifa, and the total duration and place of stay (i.e., Tarifa vs other locations) of their trip.

The significance of correlations was assessed statistically using either Kruskal Wallis or Spearman rho correlation tests, depending on the nature of the data. Correlation between categorical data was assessed using a Cramer V test. The level of significance was set at 0.05. All tests were performed in R (R Core Team, 2021).

Customers' perceptions of the WW activity

To test the effect of perceived company compliance with WW rules such as effects on cetacean behaviour and approaching speed, on customer satisfaction, we used an Ordinal Logistic Regression model for ordered categorical variables. To this end, we used the function *polr* in the package MASS of the R statistical environment version 4.1.1 (R Development Core Team, 2021). The dependent variable was the mark given by the customers from Tarifa to the WW company. Explanatory variables included i) a three-level factor describing the cetacean behaviour in relation to boat presence (i.e., 'leaving', 'indifference', 'approaching'), ii) two binary variables that indicated whether customers thought the distance of the boat from the cetaceans and iii) its approaching speed to the cetaceans were safe (Y) or not (N) for the animals, and iv) the total encounter duration (in minutes). Before running the model, a visual graphic inspection was used to ensure that the explanatory variables were not intercorrelated. Chi-square was used to test if the model was a good fit.

3.3 Direct assessment of WW trips

At the end of five WW trips an assessment checklist, based on 17 criteria selected from the RD and the MPR (table 3.2), was compiled by two experienced undercover researchers to assess the adherence of each trip with the selected criteria. In particular, compliance (C) or Non-Compliance (NC) was assessed in the approach of the WW vessel to the animals (i.e. maintaining an angle of 30º and on a sideways course in relation to the cetaceans), the course and speed of the WW vessels (i.e. course parallel to and slower than the slowest animal), manoeuvres (i.e. avoiding reversing, circling around animals or separating pairs of adults/calves), the number of WW vessels present during sightings and the coordination between them, the distance between cetaceans and vessels (visual estimation) and the duration of the sightings. Compliance with the ban on feeding and swimming with cetaceans was also assessed. Finally, behavioural responses of sighted cetaceans were recorded and evaluated based on existing regulations requiring WW vessels to "leave cetaceans in case of any sign of evasion, discomfort or alteration of behaviour" (Government of Gibraltar, 2014). WW trip assessment was carried out covertly in order to guarantee that researchers were not perceived by WW operators and when questionnaires were not handed out on board. Different WW companies were assessed in Tarifa and in Gibraltar. Economic constraints and the need for assessments to be conducted anonymously did not allow for further replication, and as such, the sample size could be considered an exploratory study.

Table 3.2 Criteria used to assess respect of the Whale Watching (WW) legislations. Asterisks (*) indicate the presence of differences between legislations of which the strictest criteria were used for this assessment. A calf is an individual whose length is half or less of that of an adult animal. Adult/calf association is considered when the distance between individuals is less than an adult's body length.

	WW local legislations		
Assessment criteria	**RD 1727/2007**	**MPR, Sched.3, Cetacean Protocol**	**How compliance was assessed**
Vessel does NOT approach cetaceans from front or behind.	Annexed II, 1.,C	3	Vessel does NOT approach cetaceans with a angle of 0° or 180° with respect to the path of the animals.
Vessel approaches cetaceans with an angle of 30°.	Annexed II, 1.,C	3	Vessel approaches cetaceans from the side avoiding a 90° approach.
Vessel maintains a parallel route in the approach and in the Restricted Access Zones-RAZ (60-500m from the cetaceans).	Annexed II, 1.,C	3	Vessel keeps a route parallel to the path of the cetaceans in the RAZ (visual estimation of the distance vessel-cetacean).

Vessel keeps a parallel route in the Exclusion Zone-EZ (60m from the cetaceans).	Annexed II, 1.,C	3	Vessel keeps a route parallel to the path of the cetaceans in the EZ (visual estimation of the distance vessel-cetacean).
Vessel's speed during the approach is less than 4 knots or less of the slowest individual of the pod.	Annexed II, 1.,B	3	In the most cases, vessel speed is estimated comparing it to the slowest individual of the pod. When possible, speed value was checked using bridge navigation equipment.
Vessel keeps a constant speed in the approach zone and RAZ.	Annexed II, 1.,B	2	Vessel does NOT accelarate in the approach and RAZ.
Vessel keeps a constant speed in the EZ.	Annexed II, 1.,E	4	Vessel maneuvers gradually and progressively, without sudden changes in speed.
Vessel does NOT use reverse.	Annexed II, 2.,F	3	Vessel does NOT go backwards.
Vessel does NOT manoeuvre through dolphins.	Annexed II, 2.,G	2	Vessel does NOT pass in the middle of the pod.
Vessel NOT navigate by circling.	Annexed II, 1.,G	3	Vessel does NOT surround the pod.
Pairs adult/calf are NOT separated.	Article 4	2	Vessel does NOT navigate between an associated adult and calf.
Vessels are coordinated by radio communication.	Annexed II, 1.,D	3	Asking crew members and, when possible, directly listening to radio communications on main bridge.
1 vessel is present 300-500m from the cetaceans (Approach Zone -AZ).	*2 vessels, Annexed II, 2.,B	*1 vessel, 4	Counting the number of vessels in the AZ, visual estimation of the distance, verifying, when possible, using equipment on main bridge.
1 vessel is present 60-300m from the cetaceans (RAZ).	*2 vessels, Annexed II, 2.,B	*1 vessel, 4	Counting the number of vessel in the RAZ, visual estimation of the distance, verifying, when possible, using equipment on main bridge.
Leave cetaceans in case of any sign of evasion, discomfort or alteration of behaviour.	Article 5	2	Vessel stops the encounter and keeps a route to move away from the pod.
Feeding, swimming with or touching cetaceans is forbidden.	Article 4	2	No food is thrown overboard in presence of cetaceans, there is no touching of or swimming with the animals.
Vessel remains for less than 20 minutes in the RAZ.	*No	*4	Start and end contact time between vessel and cetaceans in the RAZ is noted.

3.4 Monitoring cetaceans using ferries as a platform

Monitoring data were gathered thanks to the support of Baleària Foundation (http://fundaciobalearia.org), using the ferries Poeta López Anglada, Passió per Formentara and AMMAN as platforms of observation along the transects Algeciras-Ceuta (Spain, ALCE), and Algeciras - Tangier Med (Spain-Morocco, ALTA). Data collection followed the standard monitoring protocol of the Fixed Line Transect Mediterranean monitoring Network - FLT Med Net[7], an international project coordinated by ISPRA since 2007, and carried out systematically along 16 cross-border transects, using scheduled ferries as observation platforms[8].

During the monitoring surveys, a minimum of two expert dedicated observers (DOs) were located on the main bridge of the ferries, scanning both sides of the vessel (from 0º to 130º) to record data on cetacean sightings and maritime traffic. Binoculars and cameras were used by the DOs to optimize the monitoring. Although data were collected under all weather conditions, notwithstanding only data collected in good conditions (Beaufort ≤ 3) were used for analysis. Whenever possible, five surveys per summer (July-September), autumn (October-December), winter (January-March) and spring (April-June), were sampled for each transect all year-round except in August and keeping a minimum of one monthly survey per transect. Data collection depended on the sea state, weather conditions and availability of the ferry company. Surveys were carried out from January 2018 until December 2019.

Data collected on cetaceans include records of species, group composition and behaviour, as well as the distance between the platform and species sighted. The speed and the route of the ferries were also noted. Scan sampling to count all vessels visible by eyesight all around the ferry was performed each time a cetacean sighting occurred (presence dataset). Additionally, scan sampling of vessels was conducted along the transect when animals were not sighted (absence or pseudo-absence dataset). Vessels were classified as small (smaller than 5 m), medium (between 5 and 20 m, distinguished in: motor, sailing, fishing) and big (longer than 20 m, such as cargos ships, tankers or passenger ships). Near Miss Events (NMEs) of collisions were also documented and qualitatively described. NMEs are defined when the animal is at 50 m in front of the bow or 25 m aside and it does not show approaching behaviour and/or a signal of evasion (David et al., 2022).

Moreover, monitoring data of the Strait of Gibraltar were shared with the FLT Med Net for the long-term monitoring of key marine species and their main threats, in order to detect early signs of changes in species abundance, distribution and habitat use, and link these to the main environmental and anthropogenic drivers. All the partners of the FLT Med Net share the same protocol for the systematic survey of the marine species listed in the Habitat Directive 92/43/EEC (e.g. cetaceans, marine turtles and seabirds) and their main threats (i.e. maritime traffic, marine litter). Transects cross the high sea and national waters between Italy,

[7] https://www.isprambiente.gov.it/en/activities/biodiversity/technical-annex-i_monitoring-protocol_dec2020-1.pdf
[8] https://www.isprambiente.gov.it/en/activities/biodiversity/flt-mediterranean-monitoring-network-marine-species-and-threats

France, Spain, Greece, Tunisia, and, since January 2018, Morocco. Five ferry companies collaborate on the project. Data on marine fauna are collected using the distance sampling method, while marine litter data are collected using the strip transect protocol (ISPRA, 2016). Since 1989, the cetacean protocol has been improved in order to strengthen the systematic approach of surveys and the transboundary nature of transects.

Species composition and seasonal distribution

Cetacean records were first stratified per year and season. All records were investigated in GIS software (the Free and Open Source QGIS 3.10 and 3.22, 2020) in order to calculate the relative length of the survey tracks within the study area, along with the number of cetacean sightings for each transect. Each survey transect was used as a replicate for temporal comparisons.

The diversity of cetacean species was investigated for each transect and season as species presence and as percentage composition (i.e. number of sightings of a species relative to the total number of sightings of all species). Relative abundance was expressed as Sightings Per Unit of Effort (SPUE), calculated as the number of sightings per km travelled on effort in standard conditions within each transect; SPUE was computed seasonally for all cetacean species and compared with the two monitored transects and the two investigated years using the Mann Whitney (MW) test. Specific seasonal differences were tested with the Kruskall-Wallis test (KW) and the MW post-hoc comparison using PAST 2.17 software (Hammer et al., 2001).

For the spatial analysis, the study area was divided on a grid cell basis of 5 × 5 km to analyse and compare the spatial distribution of all records in the four seasons. For each cell, the total effort involved in cetacean monitoring was associated with the number of cetacean sightings for each species, in order to calculate in each cell the SPUE (Sighting Per Unit of Effort) value as SPUE=(Number of sightings/Km in good weather conditions) x10. Only cells where more than 10 km was covered on effort were considered, to reduce outliers (Arcangeli et al., 2017; Zuur et al., 2010).

Important areas for bottlenose dolphin (habitat suitability model)

To identify the important areas for the priority species bottlenose dolphin (*Tursiops truncatus*), Species Distribution Modelling (SDM) was used to characterize suitable habitats and predict the core areas of distribution in the whole of the Strait of Gibraltar. The software MaxEnt was used, as it proved to be particularly appropriate for species-only data when the number of presences used is low (Baldwin, 2009; Giannini et al., 2013). Four explanatory variables, selected from the factors already considered predictive of bottlenose dolphin habitat, were used in the model: bathymetry (m), bathymetric slope (degrees), distance from the nearest coast (m), and mean Sea Surface Temperature (SST, C°). Bathymetry values were obtained from the GEBCO raster file (GEBCO Compilation Group (2020) GEBCO 2020 Grid, doi:10.5285/a29c5465-b138-234d-e053-6c86abc040b9), while the SST raster file was downloaded from NASA Ocean Colour (http://oceancolor.gsfc.nasa.gov) and was averaged for the entire period (2018-2019). For the habitat modelling, N=22 sightings of bottlenose dolphins were used, pooling together the seasons in order to obtain a better predictive result. Maxent setting was: "Autofeatures" for the feature types, and rm=1. No correlation was found among variables, therefore none was removed. Starting from the species occurrences and the predictive variables, the R package "ENMeval" was used to obtain the bias file, a function that permits the correction irregular distribution of the sampling effort (Phillips et al., 2006).

Maritime traffic and cetaceans

The public corporate entity 'Salvamento Maritimo' (SM) works to improve the safety of maritime traffic by monitoring and facilitating traffic in the Traffic Separation Devices of Tarifa: 'Tarifa Tráfico VTS' of SM provided data on the vessels identified crossing the Strait of Gibraltar or entering and/or exiting the Spanish ports in the years 2018 and 2019. A preliminary analysis was performed to compare the seasonal pattern of total maritime traffic of the two investigated years obtained from SM using the two samples Kolmogorov-Smirnov (KS) and Mann-Whitney (MW) tests. Then, information on vessel types sampled along the monitored transects was used to characterise seasonal composition in maritime traffic and then used as an indicator of real-time vessel abundance, for comparison with the seasonal pattern obtained from SM.

To verify the influence of the year, season and transect on traffic intensity, comparisons were performed with non-parametric statistics of two-way PERMANOVA with Bray-Curtis dissimilarities, with results allowing for the grouping of data and the maintenance of separation exclusively on a seasonal basis. Differences were tested with the Kruskall-Wallis test (KW) with the Bonferroni correction for multiple comparisons and the MW post-hoc comparison between the two groups.

To study the relationship between maritime traffic and cetacean sightings, all records of the presence and absence datasets were compared to test the null hypothesis that the number of ships does not differ between them. The two datasets (with at least 10 records) were statistically compared using the KS test and the mean percentage difference between the number of vessels recorded in the sighting locations (Npres) and those recorded randomly in the absence of sightings (Nabs) was reported as: [(Npres − Nabs) / Nabs] * 100 (Campana et al., 2017). The analysis was performed on all maritime traffic and single vessel categories, pooling all seasons and sightings of all species together, and then sorting by season. Finally, an investigation at the species level was made for the most frequently sighted species: common dolphin, striped dolphin, bottlenose dolphin and pilot whale. To study the distribution and intensity of maritime traffic in the area, the total number of vessels counted in the presence and absence of cetacean sightings was linked to the grid cells, and the mean value was calculated for each season. The same was done for all five vessel categories. To identify the overlapping of cetacean hotspots with higher intensities of maritime traffic (3.1), the Kernel density estimate was used to identify areas with higher intensities of maritime traffic, by weighting the analysis on the mean number of vessels and considering a radius of 10 km. The 70% isopleths were used to define areas of the major density of vessels (Campana et al., 2022), to be compared with the cells of higher SPUE. In this way, it was possible to highlight the potential risk areas for cetacean species, first by considering total traffic and all the species together, then specifying the overlap for each species in each season. The NMEs of collision (3.2) were qualitatively described and geo-referenced.

Spatial protection measures

The marine spatial protection measures in force in the Strait of Gibraltar were mapped using GIS software (QGIS 3.22, 2020), and then overlapped with cetacean hot spots and high-risk marine traffic zones.

The presence or absence of a management plan was highlighted and, when possible, practical measures to protect cetaceans were extrapolated from the respective plans (table 1.3).

Sharing data of the Strait with the FLT Med Net to study low-density cetacean species

The network study area - Cetacean monitoring was carried out from passenger ferries travelling along 11 trans-border transects, covering the Mediterranean Sea within the latitudes 43.6° N - 35.8° S and longitudes -5.5° E - 20.8° E, and connecting Italy, France, Spain, Greece, Tunisia and Morocco. These transects are included in the Fixed Line Transect Mediterranean Network (FLT Med Net, Arcangeli et al., 2019), and are representative of a large proportion of the Western Mediterranean, and the Adriatic sub-regions, and the Eastern Ionian Sea in the Central Mediterranean Subregion. Transects considered for the baseline period (2008-2012) covered the effort area shown in dark grey in figure 3.4. In the second period (2013-2019) monitoring was also extended to the area in light grey.

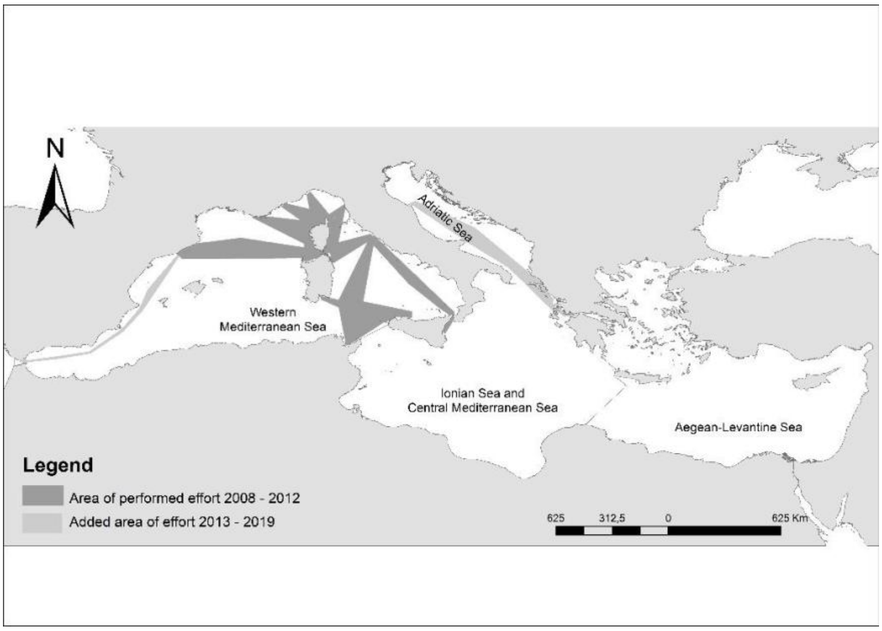

Figure 3.4 Study Area with the survey effort performed by the FLT Med Net during 2008-2012 (I baseline period, dark grey) and 2013-2019 (II period, dark and light grey). The four Mediterranean MSFD Subregions are shown in the figure: Western-Mediterranean (WMED), central-Mediterranean (Central MED), Adriatic, and Aegean-Levantine Seas (downloaded from the European Environment Agency www.eea.europa.eu).

Data analysis - All the analyses performed for this study considered the sighting as a statistical unit, regardless of the number of animals. However, the mean group size was preliminarily reported to verify potential differences over the two periods. Data were analysed considering the different Mediterranean sub-regions of the MSFD: Western-Mediterranean (WMED), central-Mediterranean (Central MED), Adriatic, and Aegean-Levantine Seas.

Observed Distributional Range, ODR - As suggested by the HD Guidelines (DG ENV, 2017), the Kernel Density estimator (KDE) was used to spatially generalize the distribution of the species occurrence, identifying the extent and the core areas of species within the area covered by effort. After initial testing, the KDE analysis was set with a resolution cell of 500 m, and a search radius of 50,000 m. The 95% isopleth was used to define the extent of the Observed Distributional Range (ODR), calculated in km2. After calculating the area covered by the effort for each time period (EffortArea), the proportion of species ODR inside the effort area was calculated for each sub-region and time period. Subsequently, the ODRs of the two periods were displayed and overlapped, and the temporal trend in the ODR extent was estimated as: Δ distribution = [(ODR/EffortArea(2nd period) – ODR/EffortArea(1st period)) x 100]. Following the OSPAR indicators for seals (Palialexis et al. 2019), threshold values were defined as: if index > 10% = increase, if index < -10% = decrease, otherwise = no change.

Ecological Potential Range, EPR - The changes in the Ecological Potential Range (EPR) between the two periods were assessed based on projected sites of species occurrence, using spatially predicted sites based on the habitat map models (also called Extent of Suitable Habitat) (IUCN Guidelines 2011, 2022). The following criteria were preserved: i) Use of adequate spatial resolution for the species knowing their range in the Mediterranean Sea, key variables, and appropriate model validation, ii) validation of suitable maps with independent datasets not used to build models and iii) estimate of the proportion of suitable habitat likely occupied by the species (within the area of effort).

Maximum Entropy (MaxEnt version 3.3.3, http://www.cs.princeton.edu/~schapire/maxent/) was applied to model the relationships between environmental predictors and the occurrence records, and to build the Suitable Habitat Maps for each species over the two periods. MaxEnt was chosen as it provided more consistent results than the most common modelling approaches and is generally more adequate for low presence records and deep divers or elusive species, for which the absence data cannot be assured. MaxEnt is a machine learning method commonly used in systems with restricted information based on a probability distribution with maximum entropy (the most spread out, closest to uniform), and subject to known constraints (Phillips et al., 2006). MaxEnt generates a probability distribution of suitable habitats over pixels in the grid, starting from a uniform distribution and repeatedly improving the fit to the data. Since MaxEnt accounts for sampling biases via correction features that consider area of sampling effort used to generate pseudo-absence points ('background points'), a bias file of effort was built using the Minimum Convex Polygon (MCP) around the surveyed sites. The spatial resolution of the dataset used for modelling was adequate for the species distribution and their known ranges in the Mediterranean Sea. Indeed, the model was built based on heterogeneously distributed effort in the Western-Mediterranean Sea and Adriatic-eastern Ionian Region, largely representing the variability of the environmental parameters in these areas, while the projection was performed on a Mediterranean Basin wide scale and the outputs were successively tested for reliability. Two datasets were used: 1) The dataset obtained from the systematic long-term monitoring along the FLT routes, including the effort track lines to build the background file and sightings as presence points, and 2) sighting data gathered by ORCA NGO during cruises in the Mediterranean Basin (2016-2018), by the ACCOBAMS Survey Initiative on a Mediterranean scale (2018), as well as local scale data from Ketos-MareCamp organizations (Catania Gulf – East Sicilian Ionian coast) as an independent dataset for the validation of the model results. The preparation of data for modelling included; 1) a Bias file (background file) built as a Minimum Convex Polygon (MCP) around the tracklines of effort, 2) presence data per each species prepared as a .csv file with information on Species, Longitudes, and Latitudes, and, 3) environmental variables prepared as raster files with the same scale, extension and resolution. Nine key predictor variables, known to be relevant for the biology of the species (e.g. Fullard et al., 2000, Moors-Murphy 2014, Breen et al., 2020, Dede et al., 2022) were included in the model (i.e., depth, standard deviation of depth, distance from the coast, distance from seamount, distance from canyon, slope, aspect north, aspect south, Chl mean and SST mean) and used as proxies of the factors that could affect species presence and distribution. After a preliminary test to verify the correlation among the variables, the standard deviation of depth was excluded as being correlated with slope.

MaxEnt was run splitting the dataset into two periods, using 2008-2012 as a reference baseline to compare with the more recent 2013-2019 period (almost corresponding to the third and fourth HD reporting cycles). The effort area was consistent between the two periods, except for the Adriatic-Eastern Ionian Region, the Barcelona-Tanger route and the Strait of Gibraltar routes, which were only surveyed during the second period (shown in light grey area in figure 5.12). Thus, two bias files were used to define the area from which to extract the background points. For each period, distinct MaxEnt models were run, using the same settings and set of variables. After preliminary runs with different setting parameters, the default recommended feature classes (hinge, linear, quadratic) and regularization parameters (i.e., =1) were used, with 10,000 background points and maximum iterations of up to 500 to reach convergence at a threshold of 0.00001. Duplicates were removed to reduce problems of pseudo-replication and spatial autocorrelation of samples. Random seeds bootstrap replication type over 34% of test samples (Efron and Tibshirani, 1997) and 100 iterations were used to obtain a summary output and response curves with statistical indication on standard deviation and error bars. A Jackknife test was conducted to obtain alternative estimates of the variable contribution to the MaxEnt run. The logistic format was used to improve model calibration, displaying output maps that better highlighted the continuum of differences in the suitable maps produced, so that large differences in output values corresponded better to large differences in suitability (Phillips and Dudík, 2008). As suggested by Pearson et al. (2007), more than 15 presence points were used for each model: 86 presence points were used for Gg (N1st period = 27; N2nd period = 59), 68 for Gm (N1st period = 16; N2nd period = 52), and 142 for Zc (N1st period = 27; N2nd period = 115). The descriptive power of each model was evaluated by the Area Under the receiver operating characteristic Curve (AUC), a threshold-independent metric of overall accuracy (AUC; Thorne et al., 2012), and by the 'omission rate', i.e., the proportion of test localities falling outside the prediction. The AUC metric determines model discriminatory power by comparing model sensitivity (i.e., true positives) with model specificity (i.e., false positives). The AUC values range from 0 to 1, with values below 0.5 indicating worse model predictions than random, and values over 0.5 indicating improved model precision. The output maps were visually inspected by experts to check for overfitting problems and the general reliability of results. The suitable output maps of the whole study period were first visualized as a continuous colour scheme of suitable-unsuitable prediction and then reclassified in binary suitable-unsuitable predictions under three threshold scenarios (i.e., minimum training presence logistic threshold, equal training sensitivity and specificity logistic threshold, maximum training sensitivity plus specificity logistic threshold). The three thresholds were chosen among the most commonly used available in MaxEnt (e.g., Merrow et al., 2013), considering the balance between the proportional predicted area (proportion of pixels that are predicted as suitable for the species) and the extrinsic omission rate (proportion of test localities that fall into pixels not predicted as suitable for the species). The best threshold method was then chosen based on expert considerations, following a visual inspection of the suitable maps, in order to include the areas likely to reflects the range of the species, considering the biology and ecology of the species, the confirmed sites of occurrence, and the species dispersal capability. An independent dataset was also used to assess the power of the resulting binary maps.

To calculate the extent of suitable area (Ecological Potential Range, EPR), the output binary suitable-unsuitable predictions rasters were converted into polygon layers including the highest suitable class for each species and period and were then used to measure the EPR in km2. Then, the percentage difference in the EPR between periods was calculated for each species as: [(EPR(2nd period) - EPR(1st period)) / EPR(1st period))].

Range Pattern - The trend in the distributional pattern was calculated in terms of shift either in the surface or in the centre of gravity (centroid) of range areas (ODR, EPR), assessing: a) the overlapping area between the two periods; b) the percentage of overlapping area compared to the first period, and c) the direction and magnitude of the shift in the centroids of the range area between the two periods (calculated through the geometric spatial zonal statistic in GIS).

Observed Distributional Range vs Ecological Potential Range, ODR/EPR - The proportion of suitable habitat effectively occupied by the species (ODR vs EPR) was calculated for each period considering only the areas covered on effort, as identified by the MaxEnt bias files. Within these areas, the extent of suitable habitats (Ecological Potential Range, EPR) was estimated in km2. The percentage proportion of the predicted EPR occupied by the species (ODR) was calculated as: [(ODR / EPR) * 100], and differences between periods were computed as: [(%(2nd period) - %(1st period)) / %(1st period))].

3.5 Visual and acoustic surveys in the Hauraki Gulf adapted to the lockdown due to COVID-19

A visual survey was carried out by the PhD candidate from the 26 of February to the 21 of March 2020, on board of the WW vessel Dolphin Explorer of the company Auckland Whale & Dolphin Safari (https://whalewatchingauckland.com). The visual survey was carried out to assess the influence of the vessels engaged in tourism activities on cetaceans in the Hauraki Gulf, to study the behaviour of the vessels in presence of the cetaceans within the entire survey area, with special attention paid to areas around the listening stations (i.e. where were deployed seafloor-mounted acoustic recording stations were deployed), and to calibrate the vessel detectors of the recording stations to better track non-Automatic Identification System vessel activity. Data collected during the visual survey included qualitative and quantitative information on the vessel and on the number of vessel/cetacean encounters, for a planned study period of 21 days on board. Data collected include the total number of vessels present in the area, the number of vessels present at the beginning, during and at the end of the encounter with cetaceans, data on cetaceans (i.e., species identification, group size and position of the encounter) and on the cetacean behaviour (e.g., resting, travelling and foraging) at the beginning, during and at the end of the encounter. Moreover, to better describe small-traffic activity in the survey area, highly accurate rangefinders (Vector 21 and Vetronix PLRF25) were used to collect vessels' data (e.g., collecting the distance of another vessel from the WW vessel, or the distance between vessel and cetaceans). The dataset obtained by the visual survey was compared to the acoustic dataset (i.e., calibrate the vessel detectors and the performance of the acoustic recording stations). Data collection was subjected to constraints due to weather conditions and to the availability of the local WW company. The PhD candidate worked from the 26 of February to the 21 of March 2020 in Auckland, for eight days of active visual surveys and during ten WW trips. Visual surveys were interrupted after three weeks due to the outbreak of the COVID-19 pandemic, while the acoustic surveys were able to continue.

Acoustic data were gathered between February and May 2020 using seafloor-mounted acoustic recording stations (ST300HF, Ocean Instruments NZ) at five sites within the Hauraki Gulf, northern New Zealand (figure 3.3). Recorders captured a two minute sample of ambient sound (digitized as a.WAV file) every ten min at a 48 - kHz sampling rate and high gain setting. Deployment was two months prior to the community lockdown due to COVID- 19 which started at 23:59h on the 25 of March 2020. The acoustic recorders were field-calibrated before and after deployment using a calibrated piston phone. Each recorder was located in open water in frequented vessel routes that were of varying distances from Auckland City. The different channel sites were located at varying offshore distances from Auckland, on different substrates (i.e., silty seafloor, rocky reef and sandy seafloor) and at a depth range between 13 and 50 m. The positions of the recorders were selected to capture the changes in vessel activity within a major thoroughfare for both recreational and commercial marine traffic.

Data collected during the surveys were shared with colleagues in a scientific global monitoring effort to study the immediate impacts of changes in human activities on wildlife and environmental threats during the early lockdown months of 2020. This study was coordinated by Amanda E. Bates of the Memorial University of Newfoundland (Canada), and is based on 877 qualitative reports and 332 quantitative assessments from 89 different studies by 84 research teams that maintained or accessed existing monitoring programs during the lockdown period in 67 countries. In this global collaborative study:

I. The mobility of humans on land and waterways, and in the air, was analysed to quantify the change in human activities,
II. qualitative reports from social media, news articles, scientists, and published manuscripts, were compiled, describing seemingly lockdown-related responses of nature, encompassing 406 media reports and 471 observations from 67 countries,
III. the direction and magnitude of responses from wildlife, the environment and environmental programs, were mapped using data collected before and during lockdown provided by scientists, representing replicated observations across large geographic areas,

IV. factors including autocorrelation and observation bias were accounted for using mixed-effects statistical models, and the most robust available baselines were selected for each study to report lockdown-specific effect sizes,

V. the type, magnitude, and direction of responses for those linked with confidence to the lockdown were empirically described and integrated outcomes were offered supported by examples drawn from our results, and

VI. these results were used to provide recommendations to increase the effectiveness of conservation strategies.

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Chiara Mancin

Whale watching vessel and sperm whale fluke in the Strait of Gibraltar - How to be sustainable? #1

Mixed media, 2023, Tarifa

CHAPTER 4 – ONE TEAM, ONE DREAM: THE SUSTAINABILITY OF WHALE AND DOLPHIN WATCHING IN THE STRAIT OF GIBRALTAR

Whale and dolphin watching (WW) is the world's largest cetacean-related economic activity. Its growth in the Strait of Gibraltar calls for adequate management in order to achieve social, economic and ecological sustainability. This study aims to gain a multi-stakeholder perspective of WW activities, and assess the socio-economic profile of WW customers, their economic contribution to the local community, and their level of satisfaction with WW. In Tarifa (Spain) and Gibraltar (UK), key stakeholders such as WW customers and operators, researchers, NGOs, and policymakers were invited to fill out 637 questionnaires and a direct assessment of the WW trips between 2017 to 2019 was conducted. The type of data was analysed either qualitatively or quantitatively. Results suggest that; (1) local WW operators only partially follow WW legislation, (2) a large majority of whale watchers had a high level of education and of purchasing power, and many were national tourists who showed signs of loyalty to WW and support for conservation, (3) 51% of the expenses made by WW customers (total expenditure of €855,604 in 2 trimesters) directly benefited the local economy of Tarifa, (4) WW customers better value operators when cetaceans are indifferent to or approach vessels, and the education provided before and during the WW trip improves their satisfaction, and (5) interviewed stakeholders recognize the scientific, recreational and educational values of WW. Our recommendations for sustainable management of WW include structuring educational programmes, launching a national publicity campaign directed at whale watchers, implementing administrative facilities for WW companies, improving the monitoring of WW activities (e.g., land-based monitoring and AIS data analysis) and enforcing WW legislation (e.g., patrols, maximum vessel number controls and the revoking of licenses for breaches of legislation). Furthermore, the designation of Marine Protected Areas, a regional shipping plan, and an integrated management approach could benefit the WW industry and improve its sustainability.

4.1 Insights into sustainable tourism policy: Identikit of the whale watchers and their economic contribution in Tarifa (Strait of Gibraltar)

Perspectivas de la política de turismo sostenible: DNI de las observadoras de cetáceos y su contribución económica en Tarifa (Estrecho de Gibraltar)

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CRediT (Contributor Roles Taxonomy) author statement: https://www.elsevier.com/authors/policies-and-guidelines/credit-author-statement of the PhD Candidate: conceptualization, methodology, investigation, resources, data curation, writing the original draft, review & editing, project administration

This paper aims to assess the economic contribution of WW customers to the economy of the town, and to investigate the factors influencing their level of satisfaction and their expenditures, so as to provide insights for the development of sustainable tourism policies in the area.

Highlights

- Whale Watching (WW) customers positively contribute to the economy of Tarifa.
- Education provided and time spent with cetaceans influence customers' satisfaction.
- Whale watchers have a pro-conservation attitude and show signs of touristic loyalty.
- National tourism is an economic resource for the WW sector even in crisis' periods.

Abstract Globally, whale watching (WW) is the greatest economic activity that is based on cetaceans, and in mainland Spain the town of Tarifa (Strait of Gibraltar) is the main WW port. Despite it being such an economically relevant sector, little is being done to monitor and guarantee its sustainability. Dedicated questionnaires were designed and delivered to WW customers of Turmares Tarifa during the summers 2017 and 2018, to delineate the socio-economic profile of WW customers, evaluate their economic contribution to the local economy and assess their level of satisfaction with WW activities. Results obtained from the 380 questionnaires analysed showed that whale watchers generally had a university level education and a high purchasing capacity. Most came from Spain and showed signs of touristic loyalty to WW and of being in favour of conservation. Their satisfaction was influenced by the time spent with cetaceans and the education provided prior to and during the WW trip. The average daily expenditure of WW customers was €97, and their total expenditure in the period considered was €855,604, of which 51% contributed directly to the economy of Tarifa. We advocate the improvement of education, a national publicity campaign addressed to whale

watchers, and the implementation of administrative facilities for WW companies, as actions to improve the management of WW towards a sustainability.

Resumen *A nivel mundial, el avistamiento de cetáceos (Whale Watching – WW) es la mayor actividad económica basada en los cetáceos, y en la España peninsular la ciudad de Tarifa (Estrecho de Gibraltar), es el principal puerto de WW. A pesar de ser un sector tan relevante económicamente, poco se está haciendo para controlar y garantizar su sostenibilidad. Se diseñaron y entregaron cuestionarios específicos a las/os clientes de WW de Turmares Tarifa durante los veranos de 2017 y 2018, para delinear el perfil socioeconómico de las personas observadoras de cetáceos, evaluar su contribución económica a la economía local y valorar su nivel de satisfacción con las actividades de WW. Los resultados obtenidos de los 380 cuestionarios analizados mostraron que las/os observadores de cetáceos tenían, en general, un nivel de estudios universitario y una alta capacidad adquisitiva. La mayoría procedía de España y mostraba signos de fidelidad turística a WW y de estar a favor de la conservación. Su satisfacción estaba influida por el tiempo que pasaban con los cetáceos y por la educación impartida antes y durante el viaje de WW. El gasto medio diario de las/os clientes de WW fue de 97 euros, y su gasto total en el periodo considerado fue de 855.604 euros, de los cuales el 51% contribuyó directamente a la economía de Tarifa. Abogamos por la mejora de la educación, una campaña nacional de publicidad dirigida a las observadoras de cetáceos y la implementación de facilidades administrativas para las empresas de WW, como acciones para mejorar la gestión de WW hacia una sostenibilidad.*

Keywords: cetaceans, Mediterranean Sea, Atlantic Ocean, ecotourism, management, tourism expenditure

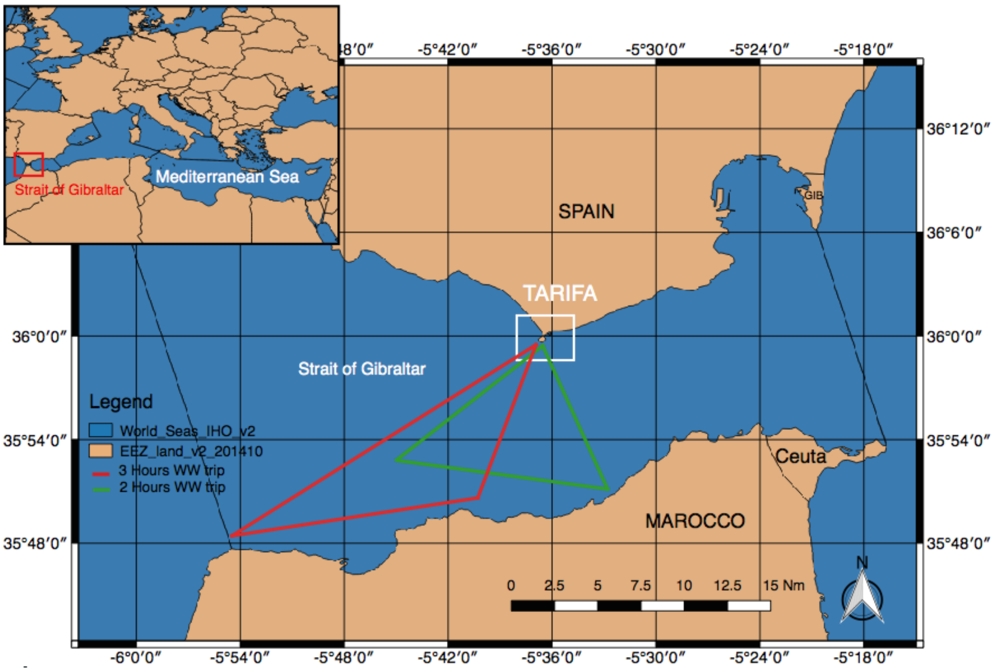
4.1.1 Introduction

Whale and dolphin watching (henceforth WW) is worldwide the most relevant economic activity based on cetaceans (Hoyt, 2001; O'Connor et al., 2009). O'Connor et al. estimated that, in 2009, up to 13 million people in 119 countries participated in WW activities, generating a total expenditure of $2.1 billion (O'Connor et al., 2009). Indeed, Cisneros-Montemayor and co-authors estimated in 2010 that the potential development of WW activities in maritime countries could generate an additional yearly revenue of $413 million, and support 5,700 jobs, leading to an overall 19,000 positions and potential revenue of over $2.5 billion globally (Cisneros-Montemayor et al., 2010).

In Peru, WW involving humpback whales has grown in the last ten years, reaching an annual input of $3 million (Guidino et al., 2020), whilst in the Gulf of California and Baja California Peninsula (Mexico), whale and shark watching, and recreational fishing attract 896,000 visitors a year, generating $518 million, and directly supporting 3,575 jobs (Cisneros-Montemayor et al., 2020). Even though in Scotland the number of WW passengers declined 17.3% from 2000-2018, possibly due to shorter operational seasons with fewer tours due to adverse weather, WW remains an important source of employment and revenue in isolated coastal communities (Ryan et al., 2018).

Mainland Spain witnessed a year on year increase in the number of whale watchers and related expenditures between 1998 (Hoyt, 2001; O'Connor et al., 2009; Tenan et al., 2020) and the beginning of the COVID-19 pandemic in 2020[9]. Indeed, the number of whale watchers grew from 38,000 in 1998 to 74,629 in 2008, leading to an increase in total expenditures, from $1,925,000 to $8,155,446 respectively (Hoyt, 2001; O'Connor et al., 2009). In the Strait of Gibraltar**,** WW is a well-established industry with a strong socio-economic role (Andreu Cazalla et al., 2016; Cabaleiro Mora et al., 2007; Elejabeitia et al., 2012; Sequeira et al., 2009), and is recognised as one of the fastest growing economic sectors in the area (Tenan et al., 2020). The town of Tarifa (Cádiz, Andalusia), located on the northern coast of the Strait of Gibraltar (figure 4.1), was identified in 2009 by O'Connor and colleagues as the main WW departure port on the Spanish mainland, hosting around 75% of the country's total whale watchers (O'Connor et al., 2009).

Ecosystem Services (ESs) are the benefits obtained by human beings from healthy ecosystem (Millennium Ecosystem Assessment, 2005), with whales being recognised as providers of food and other products (i.e. meat, oil-based products deriving from blubber, bones, teeth and baleen), as contributing to ecosystem regulation and maintenance by enhancing biodiversity and regulating climate through carbon sequestration, and as supporting various cultural services, including the WW industry (Cook et al., 2020). ESs make a significant contribution to human wellbeing (Costanza et al., 2017), thus the services provided by WW must be managed using an integrated approach that takes ecological, social and economic perspectives into account.



[9] https://www.firmm.org/es/news/article/items/recordando-la-corta-temporada-del-2020

Figure 4.1 Maps of the Mediterranean Sea (top left corner) and of the Strait of Gibraltar. The two triangular tracks represent the standard routes of the 2 - hours (green line) and 3 - hours (red line) Whale Watching (WW) trips.

Sustainability is generally represented by three intersecting circles referring to social, economic and environmental pillars, with overall sustainability represented by the intersection of these circles (Purvis et al., 2019). The economic sustainability of the WW sector results in the stability of the tourist industry due to income generated, and is thus linked to both social and cultural sustainability (Amerson & Parsons, 2018). In this paper the economic pillar of WW sustainability is investigated, together with its connections within the social sphere. The ecological sustainability of the WW industry is not analysed. Through the consideration of the importance of the WW industry for local communities (Guidino et al., 2020; Hoyt, 2001; O'Connor et al., 2009; Parsons et al., 2003), and specifically for Tarifa (Andreu Cazalla et al., 2016; Cabaleiro Mora et al., 2007; Hoyt, 2001; O'Connor et al., 2009; Tenan et al., 2020), this paper aims to assess the economic contribution of WW customers to the economy of the town, and to investigate the factors influencing their level of satisfaction and their expenditures, so as to provide insights for the development of sustainable tourism policies in the area.

4.1.2 Materials and methods

Questionnaires

The sociodemographic-profile and economic contribution of WW customers to Tarifa's economy, as well as their levels of satisfaction, were assessed using the globally adopted method of questionnaires (Guidino et al., 2020; Mitra et al., 2019; Schwarzmann & Shea, 2020; Shea et al., 2021). Self-administered questionnaires (annex I), designed to be completed by the respondent without intervention of an interviewer, and which included a combination of closed and open-ended questions, were supplied to the customers of the WW company Turmares Tarifa (http://turmares.com). These questionnaires aimed to:

- Estimate customers' daily expenditures;
- Define their sociodemographic and economic profile, and their knowledge of cetaceans,
- Evaluate levels of satisfaction derived from the activity.

Surveys took place during 26 days in the summer of 2017 (July 23rd to September 26th), and 32 days in the summer of 2018 (July 6th to September 18th), on both weekdays and weekends. Surveys were carried out as customers returned to port, and only on trips featuring at least one cetacean species encounter. Prior to the distribution of the surveys, two trained naturalists working onboard as WW guides and sailors, briefly presented the purposes of the survey to all passengers of the WW trip, and requested their participation. The printed questionnaires were then provided to those interested in participating. The questionnaires were provided in Spanish or in English.

Expenditure calculations

The economic contribution of whale watchers was estimated by calculating their direct, indirect and total expenditure (hereinafter referred as DE, IE, and TE, respectively). The price of the WW ticket purchased by WW customers was used to calculate DE (Hoyt, 2001; O'Connor et al., 2009). Expenses incurred due to accommodation, transport, food supply, together with the expenses associated with shopping, sport and leisure in the local community, were used to calculate IE (Brenner et al., 2016; Hoyt, 2001; NOAA & McDowell Group, 2020; O'Connor et al., 2009). TE was obtained by summing DE and IE (Guidino et al., 2020; Hoyt, 2001; O'Connor et al., 2009).

During the surveys, each participant was responsible for calculating their own expenses. For participants travelling in groups, questions related to expenditure, including the place of accommodation, the duration of the trip, and the number of travel companions, were filled out by one member of the group only, in order to avoid IE overestimation. Expenditure was expressed in the local currency (euros).

DE made by all WW passengers of the two seasons was estimated as follows: (i) the average number of passengers in high season (July and August) and in low season (September) was calculated based on the data collected during the surveys; (ii) the obtained values were multiplied by the price of an adult ticket in low season for the 2 hour trip, and in high season for the 2 and 3 hour trips; (iii) results were multiplied by the corresponding number of trips of each type/season surveyed during the two years. As not all WW customers visited Tarifa for WW, a distinction among Whale Enthusiasts (WEs) and opportunistic whale watchers was made, and DE was also then estimated using only the data provided by WEs and for WEs staying in Tarifa.

IE was calculated as follows: (i) the expenditures made for each category (i.e., accommodation, transport, food supply and other expenses) were summed, and (ii) the obtained sum was multiplied by the average of the economic intervals selected by the interviewed in the questionnaires (<10, 10-20, 21-30, 31-40, 31-50, and for >51, a value of 51 was considered for calculations). The average daily expense for WW customers was also calculated by splitting the total IE (2017-2018) by the total number interviewed (380). For a better assessment of the economic contribution of WW, DE and IE were also multiplied by the average number of travel companions indicated by the interviewed, and IE was multiplied by the average number of days spent in the holiday location. All IE calculations were first performed including all the WW customers interviewed, and then only considering WW staying overnight in Tarifa, WEs, and WEs staying overnight in Tarifa.

Finally, the economic data gathered using the self-administered questionnaires were compared with publicly available data of the *Instituto Nacional de Estadística* and of the *Instituto de Estadística y Cartografía de Andalucía* regarding tourist daily expenditures in the area.

Correlation among variables

Participants were asked to express their level of satisfaction with the company on a scale 1-10, and with the overall WW experience using a yes or no response. Satisfaction was considered as a response variable in order to assess the relative influence of a series of explanatory variables. The explanatory variables were broadly categorised as: sociodemographic-economic profile of WW customers (i.e., income, education, employment, age, gender, and nationality), previous knowledge/experience of cetaceans (i.e., previous sightings, in the wild or in captivity, awareness of conservation status of cetaceans and of the area), expectations (i.e., reasons for joining the WW trip and for visiting Tarifa), and characteristics of the trip attended (i.e., information offered on board and on land, time spent with cetaceans, number of species encountered during the trip, and number of passengers onboard).

Similarly, the overall IE and the various expenditure categories were tested against the sociodemographic-economic profile of WW customers, their reason for visiting Tarifa, the total duration of their stay and their place of stay (i.e., Tarifa versus other locations).

Correlation significance was assessed statistically using either Kruskal Wallis or Spearman's Rho correlation tests, depending on the nature of data. Correlation between categorical data was assessed using a Cramer V test. A Kruskal Wallis correlation test was used to assess the significance of correlation between customer satisfaction and their sociodemographic-economic profile, as well as between the categorical sociodemographic-economic variables (e.g., employment, level of education, etc.) and indirect expenditure. A Spearman's Rho correlation test was used to assess the significance of correlation between the numerical sociodemographic-economic variables (i.e., age, income) and indirect expenditures, while the correlation between categorical data was assessed using a Cramer V test. Level of significance was set at 0.05. All tests were performed in R (R Core Team, 2021).

4.1.3 Results

A total of 380 questionnaires were completed during the summers of 2017 (n= 170) and 2018 (n = 210).

Among the 380 participating customers, 53% (201) were classified as WEs, as the main purpose of their visit to Tarifa was to see cetaceans. Of the remaining, 18% (67) visited Tarifa for the natural value of the site, and 29% (112) visited for other reasons. However, the decision to join the WW trip in order to observe animals was confirmed by 94% (359).

Regarding accommodation, 63% (238) of customers overnighted in Tarifa, with the remaining staying in 35 other localities, of which the closest (Algeciras) is located at 23 km from Tarifa and the furthest (Almería) at 361 km. A total of 55% (111) of WEs spent the night in Tarifa.

The majority of participants had a university level education (74%), and almost half of them had a monthly income higher than €1,000 (25% of customers had incomes higher than 2,000 and 22% between €1,000 and 1,500). 60% of the participants were between 29 and 48 years old and 63% were employed. Slightly more females answered the questionnaires (57%) than males. A total of 22 nationalities were represented among the interviewed, of which 78% were Spanish, 3% were British or German, and 2% were Italian or Dutch.

More than half (69%) of the customers had previously seen cetaceans, 37% of which in the wild. Most customers were aware of cetaceans' presence in the Strait of Gibraltar (74%), an area that they define as in 'Good Environmental Status' (66%). However, most respondents also considered cetaceans to be threatened (87%), and not sufficiently protected (65%), with 50% considering the effort made towards their conservation as fair or poor (figure 4.2).

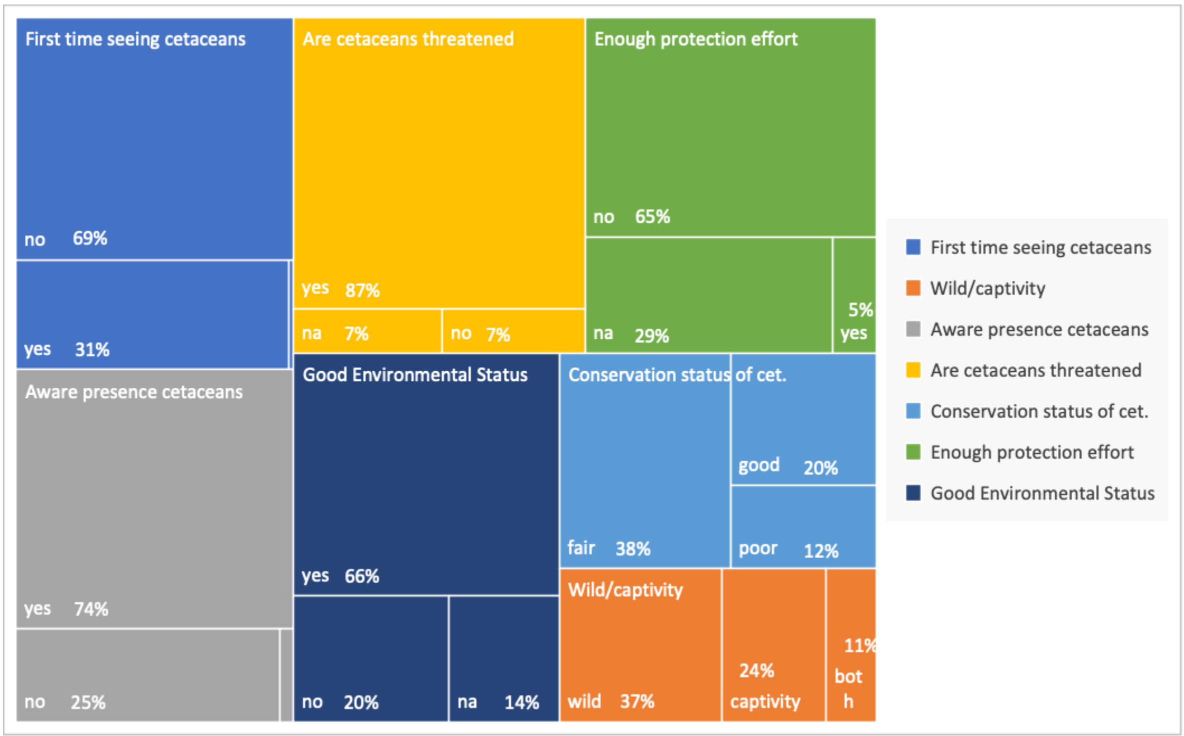


Figure 4.2 Graph representing WW responses regarding their previous knowledge of cetaceans (i.e., previous sightings, in wild or in captivity, awareness of conservation status of cetaceans and of the area). The size of each rectangle is proportional to the number of answers received for each question and the percentage is also reported.

Expenditures 2017-18

Direct expenditures: The total DE calculated based on all WW customers interviewed during our surveys was €14,290, while that based only on customers staying overnight in Tarifa was €8,950. DE calculated for WEs was €7,559 in total, and €6,665 for WEs staying overnight in Tarifa. As each customer answering the questionnaire participated in the WW trip with an average of 3 companions, total DE increased to €57,160 and €30,236 for WEs.

Overall DE was calculated based on the total number of 595 WW customers attending WW trips in the two trimesters (number of customers estimated using data collected on board), multiplied by the 194 average of the total number of trip and the price of the tickets. It was €438,555 in 2017, and €306,470 in 2018, resulting in an overall DE of €745,025 over the two trimesters. The overall DE multiplied by the average number of customers (4) participating in the WW trip was €2,980,100 (figure 4.3).

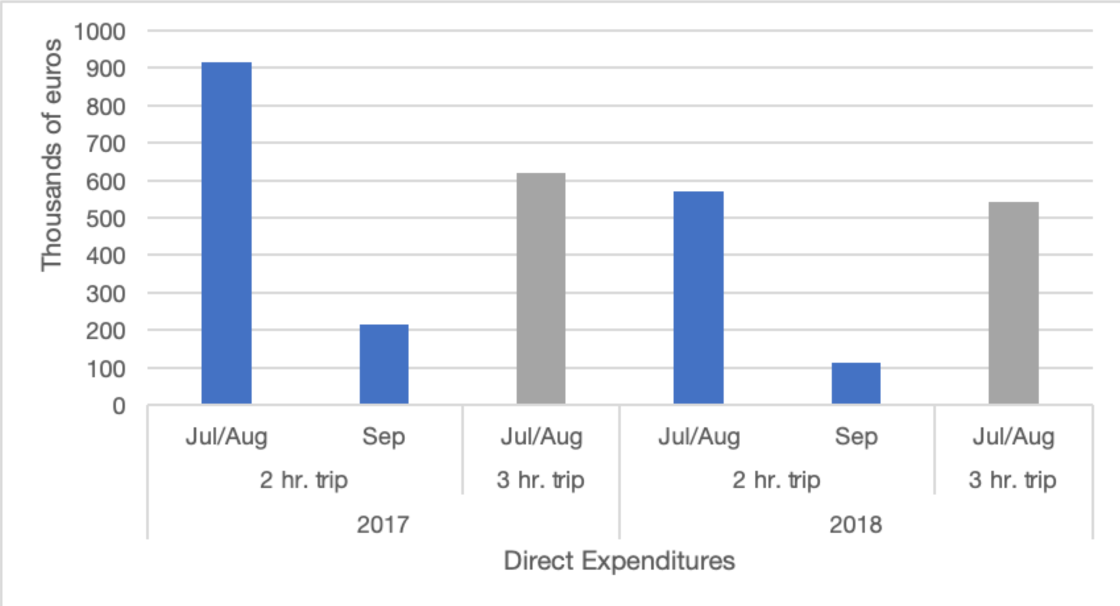


Figure 4.3 Histogram of the estimated Direct Expenditures (DE) during the two trimesters of the summers 2017-18. DE was estimated based on all of the company's WW customers, and taking into consideration the difference in the ticket price between the 2 (in blue) and the 3 (in grey) hour trip and between high (July and August) and low (September) season.

Indirect expenditures: Accommodation expenditure (representing 25% of all expenditures), transport (2%), food supply (25%), and others (48%), made by all the WW customers during the two trimesters considered, was €36,965. The highest contributors within the categories of accommodation, other expenses and food supply were accommodation rental (26%), leisure activities (42%), and bar-restaurant expenditures (76%) respectively.

Table 4.1 Indirect Expenditures (IE, expressed in euros) estimated per each category: transport, accommodation, food supply and other expenses. IE was first calculated considering all Whale Watching (WW) customers interviewed and then only considering those visiting Tarifa specifically for seeing cetaceans (WEs). For both groups, IE made only by customers staying overnight in Tarifa was also estimated.

Categories of Indirect Expenditures	All WW customers	WW customers staying in Tarifa	WEs	WEs staying in Tarifa
No. customers	380	238	201	111

Transport					
	public	100	55	65	40
	car rental	565	330	305	120
	Tot. transport	665	385	370	160
Accommodation		9,251	5,993	3,532	1,706
Food expenses		9,205	6,089	4,267	2,329
Other expenses					
	shopping	4,640	3,016	1,895	902
	sport	2,234	1,553	760	375
	leisure	7,513	5,233	3,489	2,061
	other	3,457	2,275	1,464	776
	Tot. other expenses	17,844	12,077	7,608	4,114
	Total	36,965	24,544	15,777	8,309

When the travel companions of each customer were taken into account for IE calculation, and considering that their average stay in Tarifa was 5.4 days, total IE increased to €147,860, and €798,444, respectively (table 4.2). The IE generated by the 238 WW customers staying overnight in Tarifa was €24,544 (table 4.1), which increased to €98,176 and €402,522, when including travel companions and when considering the average duration of customers' stay (4,1 days). "Other expenses" (49%), mainly represented by leisure, was the category which most contributed to IE, followed by food supply (25%), accommodation (24%), and transport (2%) (table 4.1). The average daily expense per day-tripper was €97, while that of the WW customers that stayed overnight in Tarifa was €103.

The total IE values only for WEs and WEs staying in Tarifa, were €372,337 and €129,620 (with an average daily expense of €78 and €75), respectively (table 4.2).

Total Expenditures: The TE made by all WW customers was €855,604, 51% of which was spent in Tarifa. The TE calculated for WEs was €402,572, of which 39% was made by customers staying overnight in Tarifa. Further details on DE, IE and TE are shown in table 4.2.

Table 4.2 Estimated Direct, Indirect and Total Expenditure (DE, IE and TE, expressed in euros) for all Whale Watching (WW) customers and for Whale Enthusiasts (WEs), and for customers staying overnight in Tarifa. The average customer group size was 4 and the average duration of the holiday stay was 5.4 days for all customers, 4.1 days for customers staying in Tarifa, 5.9 days for WEs and 3.9 for WEs staying in Tarifa. Multiplying the expenditures by the number of travel companions and of holiday days provided more accurate results.

WW customers	DE	DE (×) Companions	IE	IE (×) companions	IE (×) days	TE	Daily Expenses
All customers	14,290	57,160	36,965	147,860	798,444	855,604	97
Customers staying in Tarifa	8,950	35,800	24,544	98,176	402,522	438,322	103
All WEs	7,559	30,235	15,777	63,108	372,337	402,572	78
WEs staying in Tarifa	6,665	26,659	8,309	33,236	129,620	156,279	75

Correlation among variables

Customers' satisfaction

Two questions were included in the questionnaire to assess WW customer satisfaction; question 13 (q13) was related to the overall WW experience, and allowed for a yes/no response, and question 14 (q14) was related to the WW company, and allowed responses in the form of a mark on a scale of 1-10.

Overall Satisfaction - The great majority of customers stated that they were satisfied with the overall experience, with only 7 (1.8%) unsatisfied customers and 11 (2.9%) not answering the questions. Due to the homogeneous nature of responses to q13, and to the low number of unsatisfied customers, no statistical tests were performed to assess the relevance of any of the variables when determining overall satisfaction, and this result was only qualitatively described.

Of the unsatisfied customers, 2 declared they were not satisfied with the information received onboard, and 3 on land.

Only 2 customers indicated a low level of satisfaction to the company (i.e., a score of 5 out of a possible 10), and 3 customers (including those providing a mark of 5 for satisfaction with the WW company) indicated that the time spent with cetaceans was insufficient, independent of the number of sightings made (ranging from 1 to 4).

Satisfaction to the company - Regarding satisfaction with the WW company, apart from the 24 customers (6.3%) who did not answer the question, the great majority of customers provided scores above 6, with only 4 (1.1%) customers providing scores of 5 or less. As this type of satisfaction was expressed as an ordinal variable, potential correlations between the satisfaction marks and the above-mentioned variables (see paragraph 2.3) were assessed using a Kruskal Wallis test, with results indicating that none of the sociodemographic-economic variables had a significant effect on customer satisfaction. This parameter was significantly influenced by the information received onboard (q7) and on land (q8), ($p < 0.0001$ in both cases) and by the time spent with cetaceans (q9, $p = 0.004$), resulting in slightly lower satisfaction marks if the information received and the time spent with the animals were not considered sufficient (the average mark provided by satisfied clients and that provided by unsatisfied clients differed by 2.34, 0.4 and 0.47 points for questions 7, 8 and 9, respectively) (figure 4.4 and table 4.3).

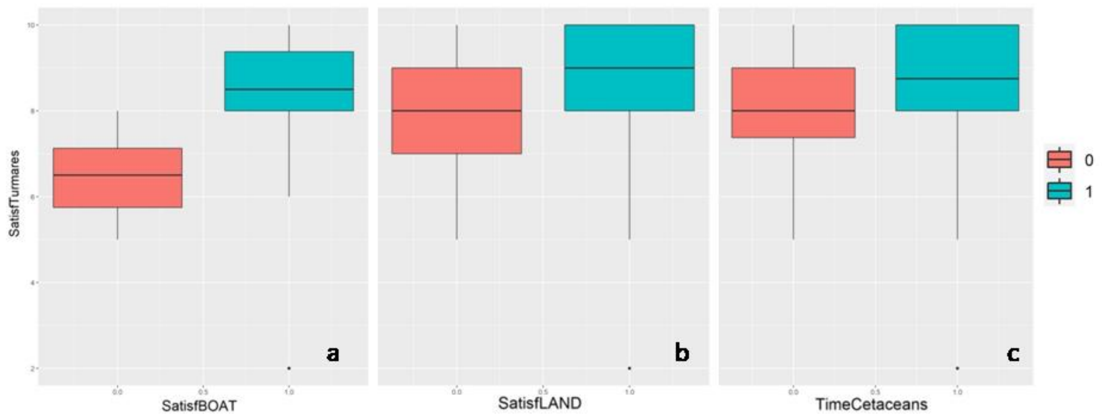


Figure 4.4 Boxplots showing the level of satisfaction with the WW company (expressed with a mark on a scale between 1 and 10) provided by clients that were satisfied (pink) and unsatisfied (blue) with the information received on board (graph a, p-value < 0.001), on land (b, p-value < 0.001), and with the time spent with cetaceans (c, p-value < 0.005). Horizontal lines correspond to the median; lower and upper hinges correspond to the 25th and 75th percentiles; whiskers extend to the highest value no further than 1.5*IQR from the hinge. Mean and standard deviation of the satisfaction marks for each variable are showed in table 4.3.

Finally, neither previous knowledge/experience of cetaceans nor trip expectations and characteristics had significant influence on WW customer satisfaction ($p>0.005$ for all these variables).

Table 4.3 Variables that significantly influenced customer satisfaction with the WW company. Values of mean, standard deviation and variance are reported.

Variable with significant influence	**Satisfied**	**No.Answers**	**Mean**	**Standard deviation**	**Variance**
Information received onboard (q7)	Yes	362	8.627	1.06	1.12
	No	10	6.286	1.11	1.24
Information received on the land (q8)	Yes	238	8.539	1.14	1.31
	No	82	8.135	1.24	1.54
Time spent with cetaceans (q9)	Yes	294	8.645	1.09	1.19
	No	79	8.173	1.27	1.60

Customers' indirect expenditures

As the distribution of the overall IE departed from normality, the correlation between this variable and the sociodemographic-economic profile of WW customers, their reason for visiting Tarifa, and the total duration and place of stay were assessed using non-parametric tests. All sociodemographic-economic parameters had a significant effect on IE with the exception of gender and age, which seemed to influence IE through a non-linear relation, with increased values among 30 to 60 year olds. (Spearman $r = 0.094$; $p = 0.076$).

IE significantly increased with income (Spearman $r = 0.2$, $p < 0.001$), were higher in customers with secondary education or above (Kruskal Wallis test, $p < 0.001$) and in employed/self-employed customers (Kruskal Wallis test, $p < 0.001$). The nationality of customers also had a significant effect on IE, which were higher in customers from Northern Europe (Kruskal Wallis $p = 0.005$). Additionally, the reason for visiting Tarifa, duration and location of stay significantly influenced IE, which were higher overall for tourists visiting Tarifa for sports and for periods lasting between 2 and 20 days (Kruskal Wallis test, $p < 0.001$ and $p < 0.01$, respectively). See table 4.4.

Table 4.4 Summary of the correlation tests performed between the socioeconomic-demographic variables and IE, including the relative chi-squared and/or rho values, degrees of freedom (df) and level of significance. Significant correlations are marked with an asterisk.

Variable	Test	chi-squared	rho	df	p-value
Gender	Kruskal-Wallis	16.869		1	0.291
Age group	Spearman		0.094		0.075
Income	Spearman		0.201		<0.001*
Education	Kruskal-Wallis	28.542		4	<0.001*
Employment	Kruskal-Wallis	36.225		6	<0.001*
Nationality	Kruskal-Wallis	20.474		7	0.005*
Reason for visiting Tarifa	Kruskal-Wallis	50.657		6	<0.001*
Time spent in Tarifa	Kruskal-Wallis	64.508		7	<0.001*

The place of stay showed a high level of correlation with the reason for visiting Tarifa (Cramer V = 0.25, 6 df). As for the correlation between the typologies of expenses and the reason for visiting Tarifa, Kruskal Wallis results indicated a significant correlation between the reason for visiting Tarifa and accommodation ($p < 0.001$), food ($p < 0.001$), shopping ($p < 0.001$), sport ($p < 0.001$) and leisure ($p < 0.005$) expenses. In most cases, expenses were higher for customers visiting Tarifa for sports. Transport expenses were not significantly affected by the reason for visiting.

4.1.4 Discussion

Economic contributions of WW and the post-pandemic contest

The DE calculated in this study for the summer seasons 2017-2018 of the company Turmares Tarifa is €2,980,100; much higher than the value of €624,000 estimated for the same company in 2015 (the overall annual DE was €960,000, with high season corresponding to 62% of DE) (Andreu Cazalla et al., 2016).

Previous estimations of IE and TE are hard to compare with our results based on data collected from a single WW company during two trimesters. The IE and TE estimated for the Spanish WW industry in 2011 were $4,579,482 and $7,548,443, respectively (Elejabeitia et al., 2012), corresponding to €3,266,544 and €5,384,304, respectively (calculation based on the average euro-dollar exchange rate in 2011: $1 = €0.7133[10]). The economic contributions here calculated are only based on two summer semesters and thus cannot used to assess any economic trend. However, these results increase the knowledge of the economic impact of the WW on the local community of Tarifa. To our knowledge, no other quantitative data on the economic indirect contributions of the WW customers has been published before.

Regarding the **typologies of expenditures** made by WW customers, it is worth noting the slight reduction in the percentage of WW customers renting accommodation or staying in hotels compared to data from 2007 (Cabaleiro Mora et al., 2007), probably due to the increase of rental apartments offers. The expenses related to leisure activities resulted here are significant, whilst in a similar study in Mexico, accommodation and restaurants were the most represented expenditures (Brenner et al., 2016).

The **average daily expenses** per person calculated considering all the WW customers interviewed (€97), fall well within the values of €124 published by the INE - *Instituto Nacional de Estadística* (Instituto Nacional de Estadistica, 2022), and €65 published by the IECA – *Instituto de Estadística y Cartografía de Andalucía* (Instituto de Estadística y Cartografía de Andalucía, 2022) for tourists visiting Andalusia in the same trimesters of the same years. The IECA also estimated an average daily expense of €73 for tourists visiting the province of Cádiz, where Tarifa is located. The higher average daily expenses in this study may indicate that customers visiting Tarifa for WW activities are willing to spend more than a general visitor to the province of Cádiz as a whole.

Finally, our results show that **the sociodemographic-economic profile** of WW customers in the Strait of Gibraltar affects their IE, which is consistent with the findings of a study by Mitra et al. (2019) in Australia, in which income, educational qualifications and employment status were among the most important factors influencing expenditure (Mitra et al., 2019). Furthermore, our results confirm that aside from WW, the village of Tarifa is an important location for sports tourists, whose expenditures contribute the most to the town's economy.

The curtailment of international travel in 2020 due to the **outbreak of COVID-19** (Hoque et al., 2020; Uğur & Akbıyık, 2020; United Nations World Tourism Organization - UNWTO, 2020b) was reflected in Tarifa, due to a short WW season and a reduction in the presence of international tourists[11]. Despite this, national tourism grew in Spain at the end of 2020 (Moreno-Luna et al., 2021) and local tourism was consequently considered as an important opportunity (United Nations World Tourism Organization - UNWTO, 2020a). Additionally, the global increase in the demand for nature-based tourism that was seen before the pandemic (Balmford et al., 2009; Goodwin, 1996; Orams, 1996) was enhanced by the imposition of lockdowns and the subsequent need for outdoor, natural experiences (Venter et al., 2020). With WW representing not only a nature-based activity, but also by far the most remunerative economic activity based on cetaceans (Cisneros-Montemayor et al., 2010, 2020;

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10 https://www.exchangerates.org.uk/USD-EUR-spot-exchange-rates-history-2011.html

11 https://www.firmm.org/es/news/article/items/recordando-la-corta-temporada-del-2020

Guidino et al., 2020; Hoyt, 2001; O'Connor et al., 2009), two new WW companies (Ecolocaliza - https://ecolocaliza.com and Estrecho Natura - https://estrechonatura.com) were recently settled in the Strait of Gibraltar. Additionally, the company Turmares Tarifa raised their ticket prices by almost 20% (from €30/35 low/high season to €45 all year for 2 h trip and from €40 to €65 for 3 h trip). The foundation of new WW companies along with price increases could suggest that the WW sector is confident in its recovery and is aware of its customers purchasing power. Indeed, tourism has previously shown a fast recovery following periods of crisis (i.e., after September 11th attack, SARS outbreak in 2003, or the global economic crisis of 2009) (United Nations World Tourism Organization - UNWTO, 2022a) and the presence of national tourists in the growing industry of WW, as well as the outdoor nature of this activity, are good indicators of the economic relevance of this sector for Tarifa.

Customers profiles and their satisfaction with the WW experience

According to the results of our questionnaires, 69% of the WW customers interviewed had previous experiences with cetaceans. This proportion was almost twice the one observed among the customers interviewed in the same area in 2007 (Cabaleiro Mora et al., 2007), which could indicate the development of a form of loyalty amongst WW customers to the activity. Most of our respondents were aware of the presence of cetaceans in the Strait, and assumed that the animals are threatened, and in a poor or fair conservation status. More than half of those interviewed considered protection efforts in place to be insufficient but, at the same time, that the Strait of Gibraltar is in a Good Environmental Status. These results could suggest a pro-conservative attitude towards cetaceans of the customers attending WW trips in 2017-18. In this study, it appears that place-based approaches to cetacean conservation are undervalued by the general public, as WW customers do not seem to correlate cetaceans' conservation state with the Good Environmental Status of the area in which they inhabit.

Our study also confirmed that the majority of whale watchers in the Strait of Gibraltar had a university level education, were employed and that almost half of them had a monthly income higher than €1,500, as previously reported in literature (Cabaleiro Mora et al., 2007). Compared to the customer profile observed in 2007, the most common age-range increased from 35 to 48 years with the presence of national tourists increasing from 59.9% (Cabaleiro Mora et al., 2007) to 78%. Among international tourists, Spanish, British and German were the most common nationalities. In line with the reported growth of the local WW industry (Tenan et al., 2020), we also observed that the percentage of WW customers spending the night in Tarifa and/or visiting the town with the intention of seeing cetaceans almost doubled compared to 2007 (Cabaleiro Mora et al., 2007). As previously reported, WW customers that did not spend the night Tarifa travelled mainly from localities in the provinces of Cádiz and Málaga (Cabaleiro Mora et al., 2007), but in ours study there were also customers from the district of Almería, located over 300 km from Tarifa.

Similar to that which was reported for the WW customers of the Pelagos Sanctuary, in the Mediterranean Sea (Tepsich et al., 2020), our participants had an overall high level of satisfaction, independent from their prior cetacean experience. Whilst a previous study in the Azores suggested that WW customer satisfaction was correlated to their place of residence or nationality (Bentz et al., 2016; Vieira et al., 2018), in the current study nationality did not seem to have any influence.

According to our results, the customer satisfaction with both the experience as a whole, as well as with the company were consistent.

Whale watchers unsatisfied with the experience pointed to the lack of information provided and to the limited time spent with the cetaceans, factors that also influenced the satisfaction score given to the company. Findings of a previous study, specifically for the WW industry of the Strait of Gibraltar (Cabaleiro Mora et al., 2007), pointed to a lack of communication (i.e., derived by a poor participative guide and/or a bad sound system on the boat) as an issue. Input provided by WW workers for customers has previously been recognised as key in increasing customer satisfaction (Xie et al., 2020), resulting in the requirement of a complete interpretation program on marine mammal tours in WW locations such as New Zealand and Panama (Lück, 2003; Lück & Porter, 2019; Sitar et al., 2017). In this way, a better and more structured education programme onboard could lead to an increase in both the satisfaction level of WW customers, and customer loyalty, which in turn, by word-of-mouth effect, could be converted into more profit for the company.

Insights for a sustainable tourism policy in Tarifa

To guarantee the long-term sustainability of WW, it will be necessary to find a good balance between the economic, socio-cultural and environmental dimensions, which minimises the negative impacts and maximises the positive impacts of WW. Indeed, to achieve sustainability, tourism policy should consider the current and future economic, social, and environmental impacts; and simultaneously respond to the needs of the visitors, the industry, the environment, and the local community (United Nations World Tourism Organization - UNWTO, 2022b).

Our results showed that the WW industry contributes to Tarifa's economy through the direct and indirect expenditures made by WW customers, and that customers generally have a high spending capacity and are inclined to repeat the WW experience (i.e., loyalty to the activity). These findings highlight the importance of WW for the local community and thus the need for its well-targeted management in the area.

The most relevant local policies that are currently in place in the area to address this issues are the Touristic Strategic Plan of Tarifa (Ayuntamiento de Tarifa, 2015) and the Touristic Action Plan of Cádiz (Diputación de Cádiz, 2021).

The Council of Tarifa planned to organise an international conference on marine mammals in the village, and to renew and activate the local Centre of Interpretation of Cetaceans (Ayuntamiento de Tarifa, 2015), but these actions were only partially achieved during the 2015-2020 plan implementation period. Moreover, despite recognising the importance of WW defined as a not-fully exploited resource, the Touristic Strategic Plan of Tarifa underestimated the importance of national tourism and of the WW sector to generate employment. Actions such the reactivation of the Cetaceans' Interpretation Centre in Tarifa, in which a dedicated section on the WW code of conduct could be developed, and the organisation of thematic events, such as an international conference on cetaceans, whale festival or cetaceans week, could engage the community and attract WW customers. We strongly recommend that all the actions mentioned in the Touristic Strategic Plan of Tarifa are reviewed and carried out, thus shifting the focus of current marketing campaigns from international to the national tourism.

The relevance given to the WW activity by the Touristic Action Plan of Cádiz is scarce; while it recognises the importance and sustainability of nature-based tourism, as well as that of the use of open-air spaces, it rarely mentions WW and does not foresee any action to support the sector (Diputación de Cádiz, 2021). The importance of national tourism that emerged in our study seems underestimated by the district strategy and remains an unexploited source of opportunities. A national WW marketing campaign targeted to the specific profile of the customers described by our results could positively affect the WW sector and, consequently, the economy of Tarifa.

In terms of education, the Council of Tarifa and the District of Cádiz could boost WW trips as extra-curricular activities for local schools to extend the working season of the WW companies, whilst the Spanish department for education could be engaged to incorporate lessons focusing on cetaceans and local marine wildlife into teaching curriculums.

Improving communication and collaboration between the public administrations/entities and WW operators could result in mutual benefit. WW companies should regularly provide the data collected on cetaceans during their activities[12] to the Spanish Ministry MITERD (*Ministerio para la Transición Ecológica y el Reto Demografico*). However, as these data cover mainly the spring and summer seasons, it would be beneficial for public administrations to finance cetacean monitoring campaigns in order to support the WW companies during the low touristic season and to obtain data of all year round. This would provide economical support to the WW sector and valuable data on the presence and distribution of cetaceans in the area throughout the year.

To promote best practice, public administrations could also develop an award or certificate of WW sustainability for those WW companies that respect WW rules, that provide high quality programs of environmental educational, and that adopt measures to reduce the activity's environmental impact both onboard and on land.

To support long-term study on the economic impact of the WW activity on the local communities, a permanent fund could be generated with the contributions of the WW companies and of the public administrations.

Taking into account WW customers' pro-conservative attitude that emerged in this study, any marketing campaign should also focus also on the respect of the WW rules and should promote respectful and environmentally sustainable WW. The enforcement of WW rules by public bodies could notably reduce the potential impact of WW on the cetaceans and increase the overall respect of these rules. In addition, the improvement of educational programs throughout the WW sector would facilitate to communicate why the respect of the WW roles is important, clarifying why time with cetaceans is limited, which in turn, could further increase customer satisfaction and their awareness of sustainability.

[12] https://www.miteco.gob.es/es/biodiversidad/temas/biodiversidad-marina/habitats-especies-marinos/especies-marinas/AROC.aspx

All the measures previously described, along with a participative process that would allow the inclusion of all relevant stakeholders to design the management of the WW activity, could positively influence both the economic and the socio-cultural dimensions of this activity, and, indirectly, its ecological dimension.

4.1.5 Conclusions

The identification of the expectations and sociodemographic profile of WW customers, and the assessment of their expenditures, represents important knowledge for providing satisfactory WW experiences and for improving the management of the industry.

Although the TE calculated based on the two summer trimesters of 2017 and 2018 are probably an underestimate of the overall expenditures generated by WW in the area, it is relevant to consider that more than half of these expenditures contributed directly to the economy of Tarifa, and that the daily expenses of WW tourists, especially those spending the night in Tarifa, are higher than those of a generalist tourist in the Province of Cádiz. In spite of the relevant expenditures made by Northern European customers, national tourism represents a good opportunity for the WW industry, even more so after the COVID-19 pandemic. A national advertisement campaign targeted at a well-defined whale watcher profile, and focused on a respectful and responsible WW activity, could notably increase the economic input of WW to Tarifa.

Considering the pro-conservation attitude of WW customers and that their satisfaction is affected by the information provided during the WW experience, the improvement of a structured education programme during WW excursions is strongly recommended. Moreover, actions such as the support for WW companies from administrative bodies, and an inclusive participative process with all relevant stakeholders, would substantially improve the sustainability of the industry.

By delineating the profile of whale watchers and assessing their economic contributions, our results provide relevant insights for better management of the WW industry in the area. However, a future analysis of the economic impact of WW that includes a wider range of data involving all the area's WW companies is strongly recommended.

4.2 Sustainability as a common goal: Regulatory compliance, stakeholder perspectives, and management implications of whale and dolphin watching in the Strait of Gibraltar.

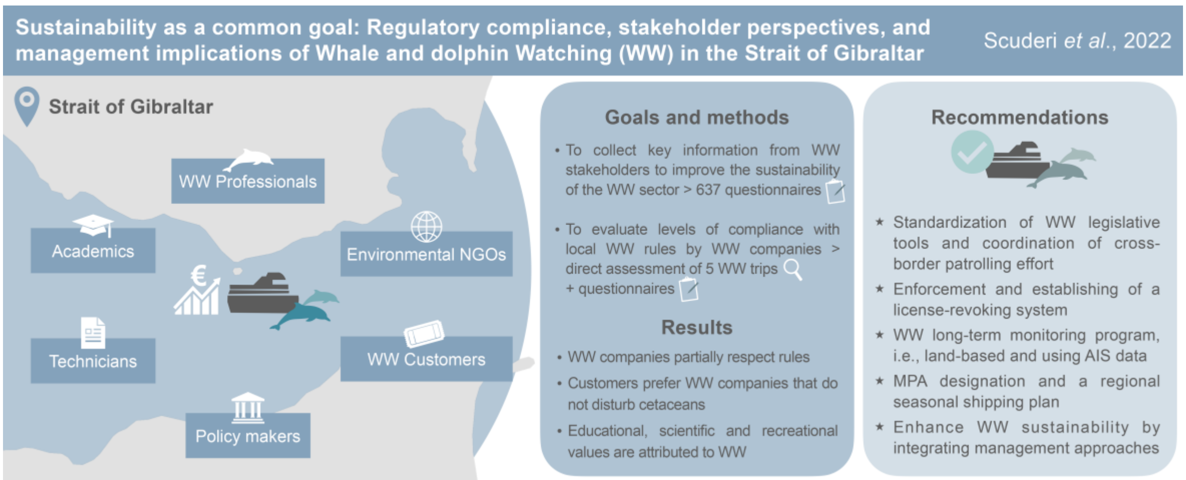
La sostenibilidad como objetivo común: Cumplimiento de la normativa, perspectivas de las partes interesadas e implicaciones en la gestión de la observación de ballenas y delfines en el Estrecho de Gibraltar

Scuderi A., Tiberti R., García Sanabria J., Merino L., Otero-Sabio C., Pedrosa A. and Cardoso Martins F. (2022). *First revision in Marine Policy.*

CRediT of the PhD candidate: conceptualization, methodology, investigation, resources, data curation, writing the original draft, review & editing, project administration.

This study evaluates the level of adherence of local companies to existing WW measures and collates key stakeholders' information and expertise on WW activities. In this context, the study sets the bases for the development of an inclusive and adaptive management of the WW activities in the Strait and discusses the relevance of such a process in the area.

Graphical abstract



Highlights

- WW companies partially abide by WW rules in the Strait of Gibraltar
- Customers prefer when cetaceans to be indifferent to or to approach WW vessels
- Enforcement, licensing and monitoring support the management of WW activities
- MPAs and shipping planning could positively influence WW activities
- WW needs an integrated coastal and ocean management approach

Abstract As the Whale and dolphin Watching industry grows, so does the need for better industry management. A total of 637 questionnaires filled out by stakeholders including WW customers and operators, researchers, environmental NGOs, technicians, and policy makers in Tarifa and Gibraltar between 2017 and 2019, together with a direct assessment carried out in 2019, were used to evaluate the compliance of WW operators with existing rules and to gather a multiple-perspective view of WW. Results suggest that (1) local operators only partially follow rules, (2) customers prefer, and give higher ratings to, operators when cetaceans are indifferent to or approach vessels and (3) stakeholders recognize the scientific, recreational and educational values of WW. Land-based monitoring of WW activities, the analysis of AIS data and improvements in patrolling and enforcement (e.g. revoking of licenses) are suggested as way in which compliance could be improved. Moreover, structured educational programmes, the designation of Marine Protected Areas and of a regional shipping plan together with an integrated management approach could benefit the WW industry and improve its sustainability in the Strait.

Resumen A medida que la industria de la observación de ballenas y delfines (*Whale Watching* - WW) crece, también lo hace la necesidad de una mejor gestión de la industria. Un total de 637 cuestionarios rellenados por las partes interesadas, incluidos las clientes y los operadores de WW, investigadores, ONG ambientales, técnicas/os y responsables políticos en Tarifa y Gibraltar entre 2017 y 2019, junto con una evaluación directa llevada a cabo en 2019, se utilizaron para evaluar el cumplimiento de los operadores de WW con las normas existentes y para recopilar una visión de múltiples perspectivas sobre la industria de WW. Los resultados sugieren que (1) los operadores locales solo siguen parcialmente las reglas, (2) las/os clientes prefieren y dan una mayor puntuación a los operadores cuando los cetáceos son indiferentes o se acercan a las embarcaciones y (3) las partes interesadas reconocen los valores científicos, recreativos y educativos de WW. Se sugiere para aumentar el respecto de las norma de WW una supervisión desde tierra de las actividades de WW, el análisis de los datos AIS, un aumento de la vigilancia y mejora en la aplicación de la ley (por ejemplo, la revocación de las licencias). Además, los programas educativos estructurados, la designación de Áreas Marinas Protegidas y de un plan regional de navegación, junto con un enfoque de gestión integrada, podrían beneficiar a la industria de WW y mejorar su sostenibilidad en el Estrecho.

Keywords: Atlantic Ocean; cetaceans; Mediterranean Sea; tourism; integrated management, questionnaires.

4.2.1 Introduction

Whale and dolphin Watching (hereafter "WW") is the most remunerative economic activity based on cetaceans (Cisneros-Montemayor et al., 2010, 2020; Guidino et al., 2020; Hoyt, 2001; O'Connor et al., 2009). It is linked to social, educational, environmental and scientific benefits (Cisneros-Montemayor et al., 2010; Cisneros-Montemayor & Sumaila, 2010;

Hoyt, 2001; O'Connor et al., 2009), as well as to an increased community sense of identity and pride (Hoyt, 2001). However, WW operations can also have adverse affects on cetaceans (Argüelles et al., 2016; Marega-Imamura et al., 2018; Sprogis et al., 2020) by inducing avoidance (Arias et al., 2018), disrupting behaviour patterns (Barra et al., 2020; Fumagalli et al., 2018) and influencing female reproductive success and calf survival (Senigaglia et al., 2019). WW can be therefore considered as **a sub-lethal stressor** (Fumagalli et al., 2021) and a form of capitalist exploitation (Higham et al., 2016; Higham & Neves, 2015) that requires management.

Integrated Coastal and Ocean Management (hereafter integrated management) (Chircop & O'Leary, 2012; UNESCO, 2006) is applied in multi-jurisdictional coastal areas (Bellanger et al., 2020) and recognizes the importance of stakeholders participation (Dinkel & Sánchez-Lizaso, 2020; Elliott et al., 2020; Páez et al., 2020). It was identified as a practical approach in the obtention of sustainable ocean economy (Winther et al., 2020) and could also help to achieve cetacean conservation objectives (Abate, 2009). Management of the WW industry needs to move towards an integrated and adaptive site and species-specific approach, and must consider both social and ecological contexts by establishing genuine relationships with the local community (Fumagalli et al., 2021).

Despite the existence of **regulations, legislations and guidelines** used to mitigate the detrimental effects of boat-based WW, such as the reduction in approach speed and in the time spent with cetaceans, (Carlson, 2008, 2012a; International Whaling Commission, 2020b, 2020a), they are often disregarded by WW operators (Avila et al., 2015; Fraser et al., 2020; Kessler & Harcourt, 2013; Parsons & Brown, 2017; Seely et al., 2017), including in the **Strait of Gibraltar** (hereafter also referred to the Strait) (Andreu Cazalla et al., 2016; Cabaleiro Mora et al., 2007; Espada Ruíz et al., 2018). The Strait hosts a high diversity of cetacean fauna of conservational interest (Espada Ruíz et al., 2018; Ruth Esteban et al., 2016; Gauffier et al., 2018; Laplanche et al., 2004; Verborgh et al., 2009), and since 1986 the WW industry has acquired an ever increasing socio-economic role (Andreu Cazalla et al., 2016; Cabaleiro Mora et al., 2007; Elejabeitia et al., 2012; Scuderi et al., 2022; Sequeira et al., 2009; Tenan et al., 2020). Within the scientific community, the development of the WW industry raises concerns pertaining to the potential negative effects of WW on cetacean communities (Espada Ruíz et al., 2018; Herr et al., 2020; Olaya-Ponzone et al., 2020; Tenan et al., 2020). Considering the rapid growth of WW activities in the Strait (Elejabeitia et al., 2012; Tenan et al., 2020) and that WW is a **a sub-lethal stressor** (Fumagalli et al., 2021)**,** there is the need to develop management measures that support the protection of cetacean populations and that encourage sustainability (Andreu Cazalla et al., 2016; Espada Ruíz et al., 2018; Higham et al., 2009, 2016; Higham & Neves, 2015; Pirotta & Lusseau, 2015). The current paper aims to further assist in the improvement of the sustainability of WW activities; firstly, by using direct assessments and the evaluations given by key stakeholders (i.e. WW customers and operators, researchers, environmental NGOs members, technicians, and policy makers) to assess the level of respect WW companies have for WW rules, and secondly by investigating management measures which could help to improve sustainability. In this context, this study forms the basis for the development of an integrated management system of WW activities in the Strait and discusses the relevance of such a process in the area.

4.2.2 Materials and methods

The study area, its whale watching activities and their regulatory framework

The Strait of Gibraltar (hereafter "the Strait") is the only passage between the Mediterranean and the Atlantic Ocean and encompasses Spanish, British, and Moroccan territorial waters (figure 4.5). Since 2006, it has been part of the Intercontinental Biosphere Reserve of the Mediterranean, established by the United Nations Educational Scientific and Cultural Organization (UNESCO). The Spanish State secretary for Environmental Affairs also recently announced the future designation of a new Marine Protected Area (MPA) in the Strait's waters (Our Ocean, 2019; Presidencia del Gobierno de España, 2019). Due to the fact that it provides critical habitats to several species of cetaceans, including the Endangered Mediterranean short-beaked common dolphin (*Delphinus delphis*) (Bearzi, 2003; Espada Ruíz et al., 2018), the Critically Endangered resident subpopulations of killer whales (*Orcinus orca*) (R. Esteban et al., 2016; R. Esteban & Foote, 2019) and long-finned pilot whales (*Globicephala melas*) (Verborgh & Gauffier, 2021), the Strait was also identified as an Important Marine Mammal Area (IMMA), by the International Union for the Conservation of Nature Marine Mammal Protected Areas Task Force. In addition, the area is also a migration corridor for the Vulnerable fin whale (*Balaenoptera physalus*) (Gauffier et al., 2018; Panigada & Notarbartolo di Sciara, 2012) and for the Endangered Mediterranean subpopulation of sperm whales (*Physeter macrocephalus*) (Carpinelli et al., 2014; Notarbartolo di Sciara et al., 2012). Striped and bottlenose dolphins (*Stenella coeruleoalba* and *Tursiops truncatus*) also inhabit the waters of the Strait (Espada Ruíz et al., 2018; Tenan et al., 2020).

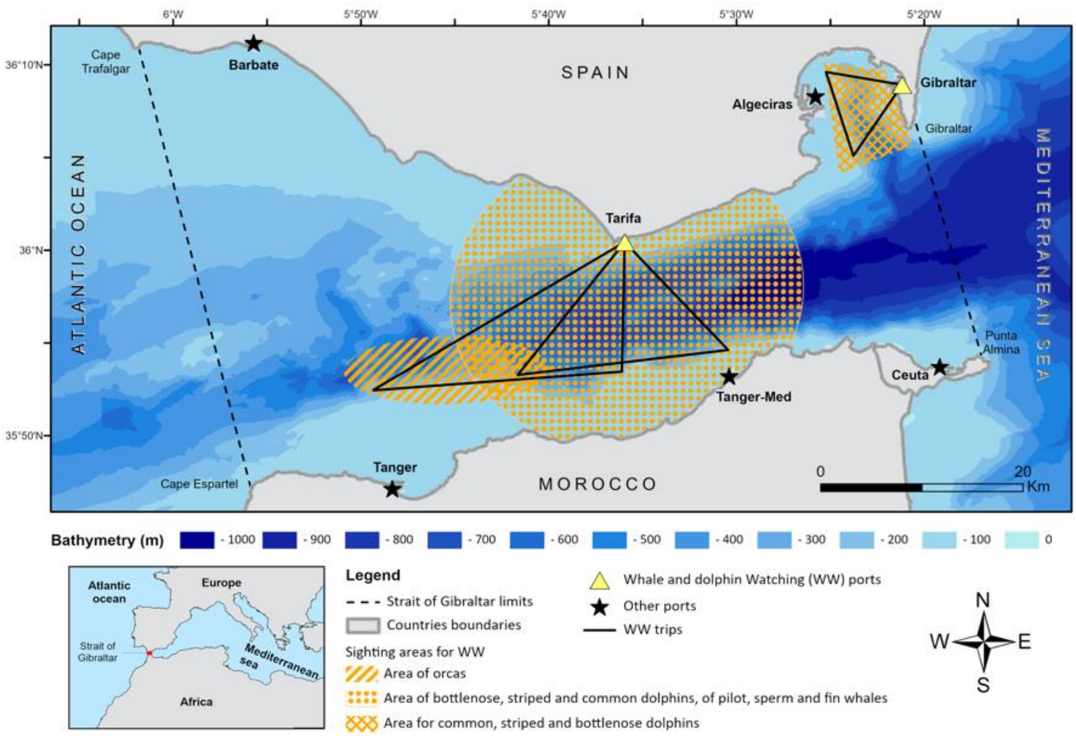


Figure 4.5 Map based on existing knowledge from published literature (Cabaleiro Mora et al., 2007; Elejabeitia et al., 2012; Sequeira et al., 2009) cross-checked with information obtained

directly from sailors and naturalists of three Whale and dolphin Watching (WW) companies, two of which based in Tarifa and one in Gibraltar. The main working areas, the ports and the typical boat tracks of the companies are highlighted. Vessel tracks for the operators Ecolocaliza (operations started in 2020), Estrecho Natura (operations started in 2021) and Marine Blue were not available for mapping.

Eight WW operators dedicated to observing cetaceans are currently active in the Strait (table 4.1), with the number of active companies having varied between 7 to 12 (Hoyt, 2001, 2003; O'Connor et al., 2009) before stabilizing at 7-8 companies (Andreu Cazalla et al., 2016; Sequeira et al., 2009) in the past decade, with the total fleet increasing from 5 (Hoyt, 2003) to 12 vessels in summer 2022. The eight companies are based in the central-northern and central-eastern part of the Strait, operating in its central-western and central-eastern sectors (figure 4.5). More specifically, seven vessels operate from Tarifa, one from Algeciras (both locations in Spain), three from Gibraltar (UK) and one is based in La Línea de la Concepción (Spain). These companies offer between two and six trips each day, lasting between one hour and 15 minutes and five hours long, with the cost for each trip ranging from 27 to 150 euros (table 4.1). Whilst **Error! Bookmark not defined.**Spanish and Gibraltarian WW companies operate in Moroccan waters on a regular basis, we are not aware of any Moroccan WW boats operating in Spanish waters and Gibraltar.

Table 4.5 Summary details of WW operators in the Strait of Gibraltar. Seasonally represents companies operating from March/April to September/October. Information is updated for Summer 2022.

Companies	Port-based	Web pages	No. and type of boats	Duration of trip	Price adults	Pax carry capacity	Operations
Aventura Tarifa	Tarifa	http://www.aventuratarifa.com/contactar/	1 rigid-hulled inflatable boat	2 h 3 h	60 euros 75 euros	10	Seasonally
Firmm	Main in Tarifa, rarely Algeciras	https://www.firmm.org/es/	2 covered motor boats	2 h 3 h	45 euros 65 euros	100 60	Seasonally
Marine Blue	Tarifa and Algeciras	https://marinablue.es	1 yacht	2 h 3 h	100 euros 150 euros	na	All year round
Turmares Tarifa	Mainly in Tarifa, rarely Algeciras	https://www.turmares.com	2 covered motor boats 1 motor boat	2 h 3 h	45 euros 65 euros	150 60 6	Seasonally

Dolphin Adventure	Gibraltar	http://www.dolphin.gi	2 catamarans	1 h 15 min/ 30 min	25 pounds (≃ 27 euros)	70 49	All year round
Dolphin Safari	Gibraltar	https://www.dolphinsafarigibraltar.site	1 motor boat	1 h 15 min/ 30 min	25 pounds (≃ 27 euros)	25	All year round
Ecolocaliza	La Línea de la Concepción	https://ecolocaliza.com	1 sailing boat	2 h 4 h	60 euros 95 euros	6	All year round
Estrecho Natura	Algeciras	www.estrechonatura.es	1 motor boat	2 h 5 h	65 euros 150 euros	6	Seasonally, potentially all year round

Figure 4.5 shows the main ports, the main WW routes in the Strait, the areas with the highest probability of cetacean encounter, and the most commonly sighted species for each area. WW companies based in Tarifa and Algeciras focus on bottlenose dolphins, long-finned pilot whales and orcas, while those based in Gibraltar commonly report common, striped and bottlenose dolphins (Andreu Cazalla et al., 2016; Espada Ruíz et al., 2018; Sequeira et al., 2009). The number of fin whale and sperm whale sightings has increased in the area during the period between April and July (Sequeira et al., 2009) and between September and October (personal communication).

National statutory tools regulating WW activities in the Strait are the Royal Decree 1727/2007 (RD), through which protection measures for cetaceans are established in Spain, and the Marine Protection Regulation 2014/180 (MPR), Chapter 4 and Schedule 3, in Gibraltar (both provided as supplementary materials 4.2, I and II). To our best knowledge, tools regulating WW activities in Moroccan waters are not currently in place. These regulations partially overlap in terms of the measures they introduce and both reflect global WW guidelines and regulations (Carlson, 2012). Specifically they include:

1. Zoning schemes designed to help minimise disturbance (Exclusion Zone – EZ with a radius of no less of 60 m from the cetacean, Restricted Access Zone – RAZ between 60 and 300 m from the cetacean, Approach Zone – AZ from 300 to 500 m).
2. Regulation of vessel activity in the presence of cetaceans (e.g., keeping low speed and constant parallel course, to avoid separating mother and calves).
3. Prohibiting the releasing of any substance or object (including food).

4. Leaving cetaceans when they show any sign of distress (described as sign of alarm, discomfort or alteration of behaviour).

Differences between the RD and the MPR include points concerning the maximum number of vessels allowed to stay in the RAZ, with one vessel permitted in Gibraltar waters for 20 minutes, and two in Spanish waters, without time restrictions. The MPR also mention of a permits system in the Marine Regulation, not present in the RD; as well as different enforcement systems. The *Servicio Marítimo de la Guardia Civil*[13], the *Dirección General de Marina Mercante del Ministerio de Fomento*, and the *Fuerza de Acción Marítima de la Armada* are active in Spanish waters while the Environmental Protection and Research Unit (EPRU) of the Department of the Environment, Heritage and Climate Change – HM Government of Gibraltar[14], are active in the British Gibraltar Territorial Waters. These bodies do not operate synergistically during patrolling activities.

Methods

Two questionnaires; one directed to key stakeholders of the Strait including WW operators, technicians, policy makers, and representatives of the NGO sector, and one directed exclusively to WW customers, were used to collect information on WW activities, to evaluate trips and to select management measures.

A direct assessment of levels of adherence to WW rules during the excursions was also carried out. See table 4.7 for further details.

Table 4.6 Summary details of the questionnaires used to collect key information on Whale and dolphin Watching (WW) activities that were distributed to the WW customers and other stakeholders.

Assessing WW trips	Methods	Locations	Dates	No.Samples	Samplers	Analysis
WW stakeholder perspective	Questionnaires (supplementary materials 4.1) were provided to the stakeholders WW customers at the end of the trip when at least one encounter of cetacean was done, including closed and open ended questions (in Spanish or English)	Tarifa	July-September 2017	170 in 24 trips	WW guides	Ordinal logistic regression model and qualitative description
			June-September 2018	209 in 30 trips		
		Gibraltar	August-September 2019	238 in 54 trips		

13 https://www.guardiacivil.es/es/institucional/Conocenos/especialidades/ServicioMaritimo/index.html
14 https://www.gibraltar.gov.gi/environment

	A survey (supplementary materials 4.2, III) including closed and open ended questions was sent by e-mail to a group of other stakeholders (in Spanish or English)	Both	November 2019	42 stakeholders contacted	Main researcher	Average and standard deviation of answers to assess the adherence to the WW rules and qualitative description
Direct observation	An assessment checklist was designed selecting 17 criteria extrapolated by the local WW legislations and was filled at the end of WW trips	Tarifa	September - October 2019	3	2 researchers	Qualitative descriptions
		Gibrlatar	April and August 2019	2		

Questionnaires

WW customers - Structured questionnaires specifically designed for the customer group of stakeholders (supplementary material 4.1) were offered to all passengers over the age of 18 on WW boats following a short presentation on the survey. The questionnaire draft was firstly presented to and feedback was requested from the managers of the two WW companies involved. Based on the managers' suggestions, a few minor rewording modifications were made, and a pre-survey directed to all passengers of Turmares Tarifa was carried out in July 2017.

Two WW guides handed out the hard copy questionnaires in Spanish or English to those WW customers interested in participating. The same guides also gave the oral presentation of the survey and were available to give unbiased and impartial answers to customer doubts. The target population considered here was the WW customers partaking in WW activities in the Strait of Gibraltar. Considering the estimations calculated in 2008 (O'Connor et al., 2009), there were a total of 91,342 WW customers in the Strait of Gibraltar; 55,971 customers per year in Tarifa (calculated as 75% of the total 74,629 WW customers on the Spanish mainland) and 35,371 per year in Gibraltar. The minimum questionnaire sample size required to represent our target population of 91,342 WW customers (level of confidence 95%, margin of error 4%), should be 597. A total of 617 questionnaires were collected in both WW locations. In Tarifa, 379 questionnaires were filled out from the 23rd of July to the 27th of September in 2017 and from the 6th of July to the 18th of September in 2018. In Gibraltar

238 questionnaires were collected from the 2nd of August 2019 to the 17th of September 2019.

Questionnaires were primarily used to characterize customer profiles (education level, age, gender, nationality, employment type, previous encounters with cetaceans), and customer perception of the WW vessel behaviour, by evaluating their perception of:

a. time spent with cetaceans (satisfied or not),
b. cetacean approach (slowly, slowly and keeping distance, fast and keeping distance, fast),
c. behavioural response of the animals observed (i.e. approaching, leaving or indifferent to vessel presence).

Questionnaires to the customers of Turmares Tarifa, who offer longer trips than Gibraltarian operators, also included an evaluation of their satisfaction with the WW company on a scale from 1 (completely dissatisfied) to 10 (completely satisfied), as well as a section investigating customers' opinion on the values associated with WW. Values considered included the benefits brought about by the existence of WW i.e. aesthetic, spiritual/psychological, political, educational, scientific, recreational, cultural, social, hereditary and monetary (list of values adapted by IFAW 1999; Hoyt, 2001). Data from customer questionnaires were integrated with total time spent with cetaceans *a posteriori* (summing multiple encounters).

To test the effect of perceived company compliance with WW rules such as effects on cetacean behaviour of cetaceans and approaching speed, on customer satisfaction, we used an Ordinal Logistic Regression model for ordered categorical variables. To this end, we used the function *polr* in the package MASS of the R statistical environment version 4.1.1 (R Development Core Team, 2021). The dependent variable was the mark given by the customers from Tarifa to the WW company. Explanatory variables included i) a three-level factor describing the cetacean behaviour in relation to boat presence (i.e., 'leaving', 'indifference', 'approaching'), ii) two binary variables that indicate whether customers think the distance of the boat from the cetaceans and iii) its approaching speed to the cetaceans were safe (Y) or not (N) for the animals, and iv) the total encounter duration (in minutes). Before running the model, a visual graphic inspection was used to ensure that the explanatory variables were not intercorrelated. Chi-square was used to test if the model was a good fit.

Other key stakeholders - Using the snow ball procedure (Noy, 2008), a questionnaire (supplementary material 4.2, III), used to assess non-customers stakeholders' opinion on the adherence of WW companies to local WW measures, on the values associated with WW experiences (IFAW 1999; Hoyt, 2001) and on the existing approaches to improve the sustainability of the WW industry, was sent to a group of stakeholders (other than customers) based in the Strait. A draft of the questionnaire was pre-tested in in-person interviews with two WW professionals; a captain and a naturalist guide, in October 2017. The questionnaires' target audience included researchers (i.e. marine biologists and ecologists, geneticists, biostatisticians) and technicians (i.e. veterinarians and naturalists), NGOs settled in areas of study with focus on conservation and/or cetaceans, WW professionals (i.e. captains, company owners, guides and sailors), policy makers (i.e. mayors and local councils representatives for environment or tourism departments) and environmental surveillance representatives. Interviewees nominated another 14 subjects to contact, of which seven had not previously been listed. Of these seven, five belonged to the public administrations or to the environmental surveillance corps. Of the 42 questionnaires sent, 15 were directed to WW professionals, seven to academics, five to members of environmental NGOs, six to technicians and nine to policy makers. Twenty questionnaires were filled out (47,62%). The average and standard deviation of stakeholders' answers concerning adherence to WW rules were considered, to assess the adherence to the WW legislations.

Stakeholders were also asked to comment upon management tools that could benefit cetacean conservation but that were not specifically designated for the WW industry. The results were qualitatively described.

Direct assessment of WW trips

At the end of five WW trips an assessment checklist, based on 17 criteria selected from the RD and the MPR (table 4.7), was compiled by two experienced undercover researchers in order to assess the adherence of each trip with the selected criteria. In particular, compliance (C) or Non-Compliance (NC) with the approach of the WW vessel to the animals was assessed (i.e. maintaining an angle of 30º and on a sideways course in relation to the cetaceans), the course and speed of the WW vessels (i.e. course parallel to and slower than the slowest animal), manoeuvres (i.e. avoiding reversing, circling around animals or separating pairs of adults/calves), the number of WW vessels present during sightins and the coordination between them, the distance between cetaceans and vessels (visual estimation) and the duration of the sightings. Compliance with the ban on feeding and swimming with cetaceans was also assessed. Finally, behavioural responses of sighted cetaceans were recorded and evaluated based on existing regulations requiring WW vessels to "leave cetaceans in case of any sign of evasion, discomfort or alteration of behaviour" (Government of Gibraltar, 2014). WW trip assessment was carried out covertly in order to guarantee that researchers were not perceived by WW operators, when questionnaires were not handed out on board. Different WW companies were assessed in Tarifa and in Gibraltar. fin whale

constraints and the need for assessments to be conducted anonymously did not allow for further replication, and as such, the sample size could be considered an exploratory study.

Table 4.7 Criteria used to assess respect of the Whale Watching (WW) legislations. * signals presence of differences between legislations of which the strictest criteria was used for this assessment. A calf is an individual of which the length is half or less of that of an adult animal. Adult/calf association is considered when the distance between individuals is less than an adult body length.

	WW local legislations		
Assessment criteria	**RD 1727/2007**	**MPR, Schedule 3, Cetacean Protocol**	**How compliance was assessed**
Vessel does NOT approach cetaceans from front or behind.	Annexed II, 1.,C	3	Vessel does NOT approach cetaceans with a angle of 0° or 180° respect to the path of the animals.
Vessel approaches cetaceans with an angle of 30°.	Annexed II, 1.,C	3	Vessel approaches cetaceans from the side avoiding a 90° approach.
Vessel maintains a parallel route in the approach and in the Restricted Access Zones-RAZ (60-500m from the cetaceans).	Annexed II, 1.,C	3	Vessel keeps a route paralle to the path of the cetaceans in the RAZ (visual estimation of the distance vessel-cetacean).
Vessel keeps a parallel route in the Exclusion Zone-EZ (60m from the cetaceans).	Annexed II, 1.,C	3	Vessel keeps a route paralle to the path of the cetaceans in the EZ (visual estimation of the distance vessel-cetacean).
Vessel's speed during the approach is less than 4 knots or less of the slowest individual of the pod.	Annexed II, 1.,B	3	In the most cases, vessel's speed is estimated comparing to the slowest individual of the pod. When possible, speed value was checked using bridge navigations equipments.
Vessel keeps a constant speed in the approach zone and RAZ.	Annexed II, 1.,B	2	Vessel does NOT accelarate in the approach and RAZ.
Vessel keeps a constant speed in the EZ.	Annexed II, 1.,E	4	Vessel manouvres gradually and progressively, without sudden changes in speed.
Vessel does NOT use reverse.	Annexed II, 2.,F	3	Vessel does NOT go backwards.
Vessel does NOT manoeuvre through dolphins.	Annexed II, 2.,G	2	Vessel does NOT pass in the middle of the pod.
Vessel NOT navigate by circling.	Annexed II, 1.,G	3	Vessel does NOT surrond the pod.

Pairs adult/calf are NOT separated.	Article 4	2	Vessel does NOT navigate between an associated adult and a calf.
Vessels are coordinated by radio communication.	Annexed II, 1.,D	3	Asking to the crew members and, when possible, directly listening to radio communications on main bridge.
1 vessels is present 300-500m from the cetaceans (Approach Zone -AZ).	*2 vessels, Annexed II, 2.,B	*1 vessel, 4	Counting the number of vessel in the AZ, visual estimation of the distance, verifying, when possible, using equipment on main bridge.
1 vessel is present 60-300m from the cetaceans (RAZ).	*2 vessels, Annexed II, 2.,B	*1 vessel, 4	Counting the number of vessel in the RAZ, visual estimation of the distance, verifying, when possible, using equipment on main bridge.
Leave cetaceans in case of any sign of evasion, discomfort or alteration of behaviour.	Article 5	2	Vessel stops the encounter and keeps a route to move away from the pod.
Feed, swimming with or touching cetaceans is forbidden.	Article 4	2	No food is throught overboard in presence of cetaceans, there is no touching of or swimming with the animals.
Vessel remains for less than 20 minutes in the RAZ.	*No	*4	Start and end contact time between vessel and cetaceans in the RAZ is noted.

4.2.3 Results and discussion

Questionnaires

WW customers interviewed were between 26 and 55 years old, with the age range most represented being between 36 and 45 years, which has increased when compared with earlier reports from 2009 (O'Connor et al., 2009). Most customers had a university level education (in the 73% in Tarifa and 59% in Gibraltar) and were employed, in line with that which was reported in 2007 (Cabaleiro Mora et al., 2007). Females responded more often than males; 54% in Tarifa and 60% in Gibraltar. Further details on the WW customer profiles can be found in figure 4.6. A total of 30 different nationalities were recorded on board, with domestic tourism being the most highly represented in both locations, (i.e. Spanish in Tarifa and British in Gibraltar). Spanish tourism presence increased from 40%, estimated in 2001, and 43%, in 2009 (Hoyt, 2001; O'Connor et al., 2009), to 74% in the current study. This shows the importance of the domestic WW tourist as described by Scuderi et al. (2022). In Gibraltar 49% of customers were from the United Kingdom followed by 6% from Germany. Although this contrasts with results from 2009 showing 90% British customers among WW customers in Gibraltar reported (O'Connor et al., 2009), the data aligned with official Gibraltarian reports that 53% of tourists in 2001 were British, 58% in 2009 and 44% in 2019 (Government of Gibraltar, 2002, 2010, 2020).

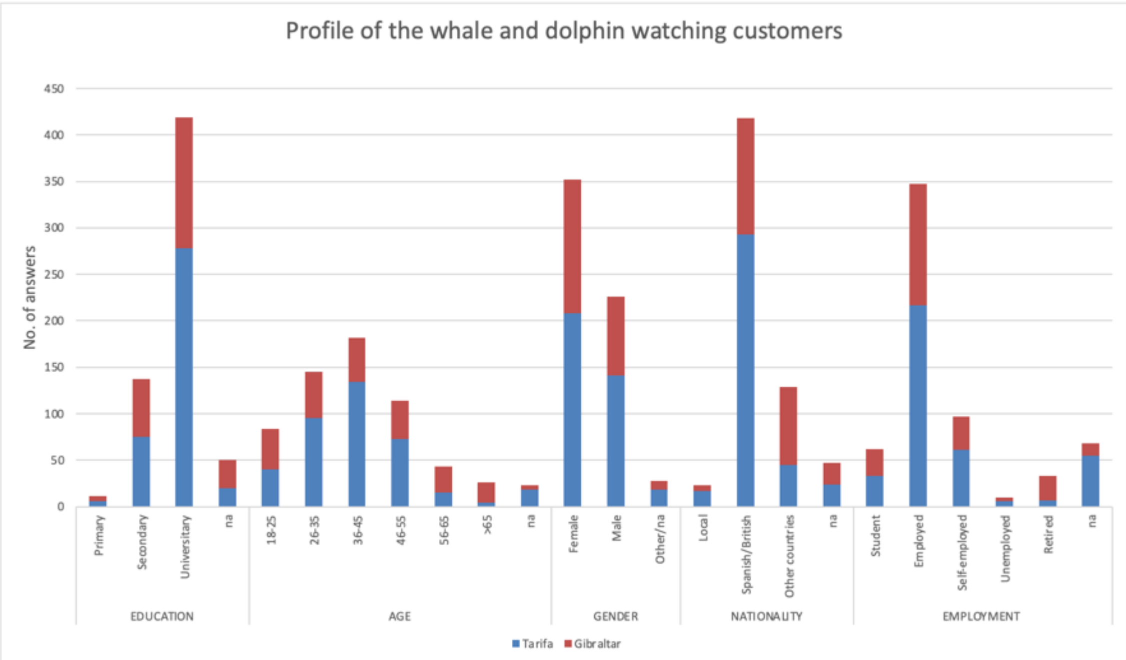


Figure 4.6 Whale and dolphin watching customer profiles. Number of answers considering level of education, age, gender, nationality and employment type. Na represents no answer given.

In Tarifa 28% (n= 107) of customers (n= 379) had seen cetaceans before the trip, 24% in the wild, and 16% only in captivity. In Gibraltar 78% (n= 185) of customers (n= 238) had had previous encounters with cetaceans, 35% in the wild and 20% in captivity. 23% specified having seen cetaceans before but without specifying in which context. The remaining did not provide information on this matter.

In our study customers gave **positive evaluations to WW companies** (i.e. never ranking companies below 5 on a 0 to 10 scale), similar to previous findings in other areas (Tepsich et al., 2020; Trianasari et al., 2021). Despite the questionnaires being anonymous and despite the two on-board guides have received training on avoiding influencing customer responses, social-desirability could have played a role, resulting in generally high ratings for the WW companies.

According to the results of the Ordinal Logistic Regression model (table 4.8), customers ranked the WW company based on cetacean behaviour, giving better ratings when cetaceans autonomously approached the boat or were indifferent to it, rather than when they left the sighting site.

Table 4.8 Results from an Ordinal Logistic Regression model testing the effects of the Whale Watching (WW) customers' perceived respect of WW rules on customer satisfaction with the WW company (rank from 1 to 10). Model results are based on the analysis of 357 questionnaires completed in Tarifa (out of a total of 379) by randomly selected WW customers'. p-value of the Chi-square goodness of fit test for the model was > 0.05, indicating that the model was good fit.

	Estimate	**SE**	**z**	**p**	
Cetacean behaviour					
indifference vs. approaching	-0.15	0.22	-0.71	0.48	
leaving vs. approaching	-1.19	0.48	-2.48	**<0.05**	*
leaving vs. indifference	-1.04	0.50	-2.02	**<0.05**	*
Safe distance vessel/cetaceans	-0.48	0.36	-1.33	0.18	
Slow vessel approach	0.58	0.35	1.67	0.09	
Respect of time rules	0.00	0.00	0.37	0.71	

The proximity to cetaceans, the approaching speed, and time spent with the cetaceans did not show any significant relationship with customers' ranking of the WW company (figure 4.8).

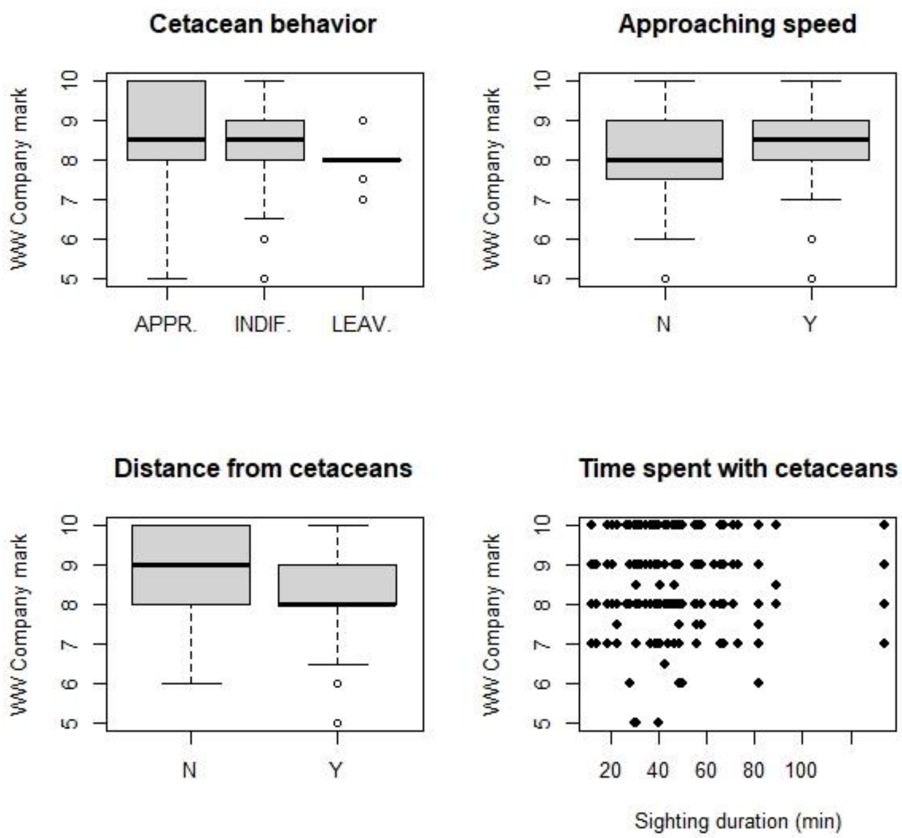


Figure 4.9 Boxplots showing in the y axis the level of Whale Watching (WW) customer satisfaction with the WW company (mark 1 to 10), and in the x axis cetacean behaviour in relation to boat presence (i.e., approaching, indifference, leaving,), with approach speed and with the perceived safety level of the distance between cetaceans and vessels. Final graph shows the mark assigned to the WW company in the y axis, with the total duration of the encounters (in minutes), in the axis x.

The latter result is in apparent contradiction with the results achieved by Scuderi et al. (2022) in the same study area, where customer satisfaction was indeed influenced by the **time** spent with cetaceans. However, this result was based on time categories, distinguishing whether customers considered the time spent with cetaceans sufficient or not, and not on the real time spent with cetaceans, as in the present study. This inconsistency may be an interesting example of how personal perceptions, rather than the actual characteristics of the sighting, may have major effects on customer satisfaction. The importance given by customers to the cetaceans' behaviours of **approaching or being indifferent** to the WW vessel presence, could be due to the attitude of 'environmentally friendly' customers. In other areas a strong preference for minimizing impact on the animals was identified (Kessler et al., 2014), and environmentally friendly conditions were shown as the most important expectation (Bentz et al., 2016), and as an important factor influencing customer satisfaction (Tkaczynski et al., 2022). Similar to that which was observed in Queensland (Orams, 2000), the current study shows that the **proximity between** cetaceans and vessels is not linked to higher ratings. Also in Sydney, despite customers preferring close proximity to whales, proximity was not a guarantee of a positive WW experience (Kessler et al., 2014). Considering this, better evaluations of the WW companies could depend on leaving cetaceans when they show signs of evasion, discomfort or alteration of behaviour (i.e. the opposite of approaching or indifferent behaviours to the vessel) and does not depend on getting close to the cetaceans (i.e. approaching them from the front or rear, without maintaining a parallel course or moving faster than the slowest individual of the pod). Furthermore, it is more likely that WW tourism education will indirectly influence tour operators whereas regulatory enforcement will directly do so (Mallard, 2019). Results of the current study could be used to increase respect accorded to WW rules by those companies in the Strait looking to ensure customer satisfaction.

Other key stakeholders - Overall, of the 42 questionnaires distributed to the non-customer key stakeholders, 20 were received fully completed. A heterogeneous group, including five cetacean researchers, seven WW professionals, four members of NGOs working in the environmental sector and three technicians provided answers to the questionnaires. Only 1 policy maker of the local government participated in the survey and this might not fully reflect the current policy perspective of local government bodies.

Overall seven stakeholders recognized that WW vessels generally approach cetaceans slowly and keep a safe distance from the animals. Six stakeholders highlighted that respecting WW rules depends on factors related to each single trip such as the captain and crew, the behavior of the cetaceans sighted, the time of the day, the weather conditions and the sea state. Stakeholders estimated that the RD and the MPR are fully respected on **average of 35% of the WW trips (σ= 17,72).** Six respondents argued that a lack of enforcement is the main reason for this low level of compliance and two stressed the need to increase enforcement and patrolling.

About half of the stakeholders that responded to the survey (n= 11) recognized that **government legislation and regulations**, including a mandatory code of conduct and a licensing system for WW tour operators, are needed for ensuring the sustainability of the activity. One respondent suggested that no vessels should be allowed in areas considered as hot-spots for pilot and sperm whales and that mandatory **speed restrictions** should be in place. It was also recommended that training for ferry professionals and, more in general, educational activities for the citizen, should be implemented to inform them on the presence of cetaceans in the area and showing the importance of reducing speed. One of the respondents advocated for the development and use of a real-time information system, alerting on the presence of cetaceans.

Legislative tools for regulating WW activities, such as the RD and MPR, are in place in the Strait but effective **enforcement** isn't, despite its importance being widely recognized (Allen et al., 2007; Howes et al., 2012; Wiley et al., 2008) and despite a substantial increase in vessel compliance in its presence (Seely et al., 2017). Sanctions, such as revoking licenses, are also considered as the most effective method for increasing compliance (Gjerdalen & Williams, 2000; Tyne et al., 2014). Accordingly, we suggest such measures to be considered in the Strait together with a long-term monitoring program of WW activities that could be also land-based and integrated with an Automatic Identification System (AIS) datas analysis.

Stakeholders underlined that statutory tools should be integrated into an overarching **participative process** and six of these interviewed highlighted the important role that the non-governmental sector can have in managing WW. To our knowledge, there are no on-going public participative processes regarding cetaceans and WW activity in the Strait, despite the fact that a combination of top-down, (e.g. enforcement), and bottom-up (e.g. participative process) approaches should be essential in the management of maritime spaces and activities (Gaymer et al., 2014). We suggest that a working group, that takes into consideration the expertise and needs of all the actors (Howes et al., 2012), be assembled by the local governments of the Strait with the aim of improving cetacean conservation. Cetacean conservation in the Strait could benefit from the assembly of a structured, multi-jurisdictional participative process similar to that which has been assembled in the Salish Sea (Canada) for protecting orcas (Southern Resident Orca Task Force, 2018, 2019).

19 stakeholders favored the designation of new **MPAs** or the enlargement of existing MPAs as valuable management tools for the conservation of cetaceans in the Strait. One respondent pointed out the importance of extending the cetacean migration corridor between the Balearic Islands and the Spanish mainland, recently recognized as an MPA in Spain (Ministerio para la Transición Ecológica y el Reto Demográfico, 2020), to the Strait. Stakeholders also showed consensus on the introduction of more restrictive rules for vessel speed (n= 19), not only for WW operators but for all commercial, recreational or private vessels in general. The creation of a **conservation-minded regional and seasonal shipping-plan** was selected by 14 stakeholders as a further management tool, alongside the creation of quiet areas, i.e. areas with reduced underwater noise, and the adoption of new fishing regulations (n= 11 and 10, respectively). A dedicated **shipping plan** could include speed reduction, zoning and/or quiet areas. These tools are commonly proposed to promote and enhance marine conservation (Cañadas et al., 2005; Hooker et al., 1999; Hoyt, 2011), and could also be important for the protection of cetaceans alike (Laist et al., 2014). A local shipping plan should take into consideration the fact that cetaceans are highly mobile species with possible seasonal distribution and should therefore be adaptable (Dwyer et al., 2020). Seasonal and dynamic regional shipping plans, including mandatory rerouting and reductions in speed, have been adopted in portions of the Salish Sea[15] and the North Atlantic[16] to protect southern resident killer whales and North Atlantic right whales whilst still allowing for maritime activities. A local example could be the declaration of a temporal no-vessel entry sub-area as suggested for the bay between Algeciras and Gibraltar to protect short-beaker common dolphins mothers with calves (Espada Ruíz et al., 2018) .

Values associated with WW - WW customers mostly associated WW with educational values (85%, n=323), followed by scientific (63%, n=237), recreational (46%, n=175) and cultural (46%, n=174) values. The majority of the other, non-customer stakeholders (85%, n= 17) associated WW with scientific and recreational values and also acknowledged its educational value (80%, n= 16). The economical relevance of WW activities was highlighted by

15 https://www.pac.dfo-mpo.gc.ca/fm-gp/mammals-mammiferes/whales-baleines/srkw-measures-mesures-ers-eng.html#maps

16 https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales

13 non-customer stakeholders while social, spiritual, cultural and psychological values were recognized only by a minority (figure 4.10).

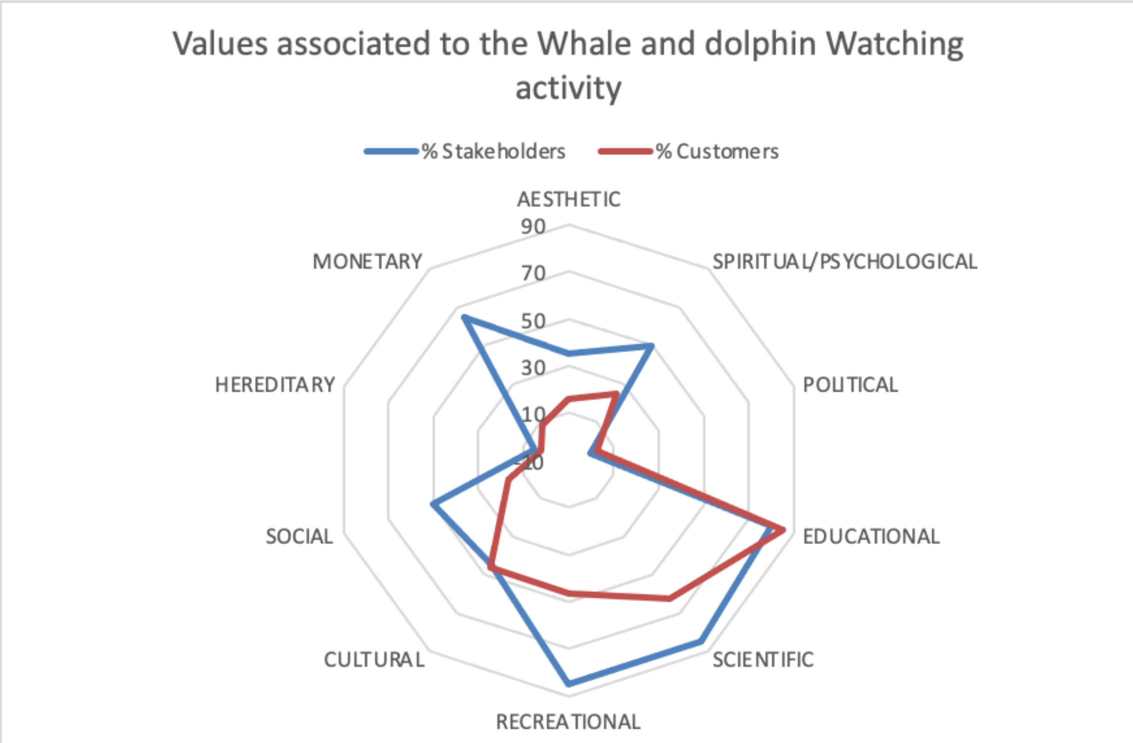


Figure 4.10 Radar chart of the values associated with Whale Watching (WW) activities in the Strait of Gibraltar area by WW stakeholders, including customers (red line) and other stakeholders interviewees (blue line).

The importance of the **educational** value of WW was recognized by all stakeholders consulted. This result is in line with that which was previously reported in Tarifa, where education provided prior to and during the WW trip influenced the level of WW customer satisfaction (Scuderi et al., 2022). Our results could also support the theory that customers would be interested in a more structured interpretation programme during WW activities (Lück, 2003; Lück & Porter, 2019). Recognizing the importance of the experience and the attitudes of onboard guides (Andersen & Miller, 2008; Schwarzmann & Shea, 2020), as well as the customers' preference for interactive tours (Lee et al., 2019), and the importance given by customers to the possibility of actively speaking with staff and other tourists during their trip (Xie et al., 2020); we accordingly suggest that a structured educational programme should be compulsory. Educational programs during WW activities should be based on robust research and should be conducted by formally trained guides with a scientific background (Constantine, 2021). Such programs could also include interactive land-based activities (Lee et al., 2019), such as guided visit to the Centre of Interpretation of Cetaceans of Tarifa.

Scientific values may been selected due to ongoing collaborations between WW companies and the academic sector in the Strait, with companies providing their vessels as research platforms, collaborating on the production of reports (Andreu Cazalla et al., 2016;

Cabaleiro Mora et al., 2007), and supporting scientific contributions at international conferences (European Cetacean Society, 2018; European Cetacean Society and Society for Marine Mammology, 2019) and in peer-reviewed journals (Espada et al., 2019; Herr et al., 2020; Olaya-Ponzone et al., 2020, 2022; Scuderi et al., 2022).

Although **recreational** values were globally associated with WW (Hoyt, 2001; O'Connor et al., 2009), they were only selected by 46% of WW customers as opposed to 85% of other stakeholders. WW customers seem to give more importance to the educational component of the activity rather than recreational aspects, confirming the importance of a structured educational programme as previously discussed.

Direct assessment of WW trips

The direct assessment for each trip shows that:

Trip I (Gibraltar, on 3rd of April 2019) complied with 82% of the criteria evaluated in the assessment checklist but did not respect the criteria of keeping a parallel route in the EZ and of coordinating manoeuvres with other vessels in the area.

Trip II (Gibraltar, on 6th of August 2019) respected 35% of the criteria and there was no evidence of changes in the cetaceans' behaviour.

Trip III (Tarifa, on 11st of September 2019) respected 76% of criteria, but broke the 30□ angle of approach rule, manoeuvred through the pod of dolphins, stayed in the AZ with other vessels and did not leave the area when animals showed sign of evasion.

Trip IV (Tarifa, on 26th of September 2019) respected 76% of the criteria but approached cetaceans from the front or rear, did not respect the 30□ angle of approach rule and maintained a higher speed than the slowest individual of the pod.

Trip V (Tarifa, on 6th of October 2019) did not adhere to the majority of the selected criteria. (compliance with 41% of criteria). See figure 4.11 for further details.

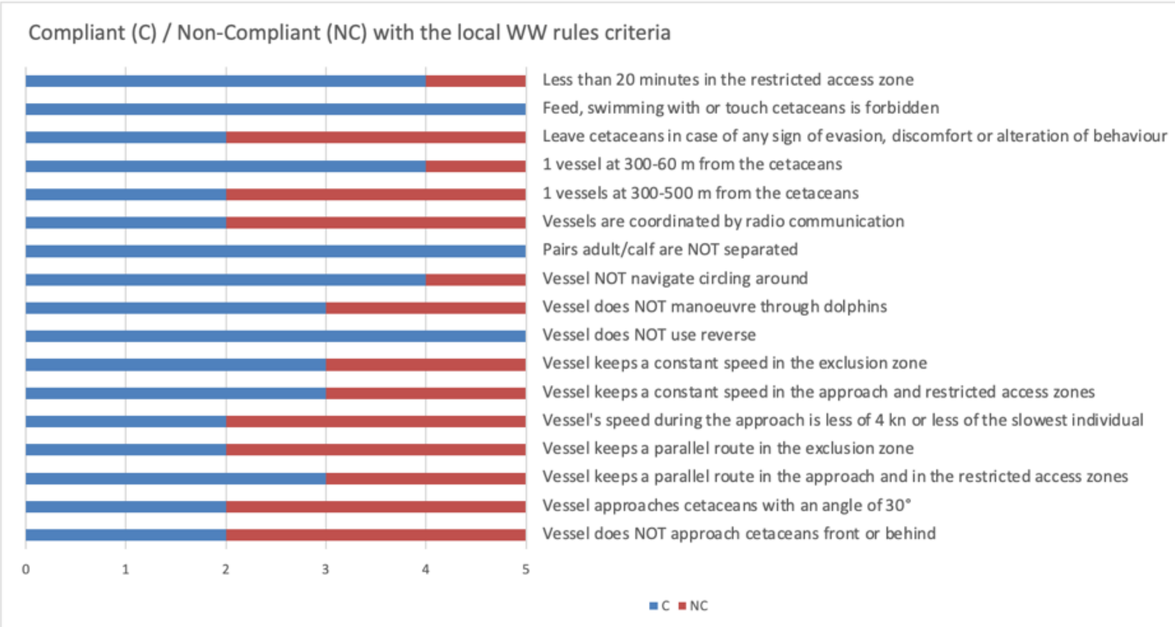


Figure 4.11 Assessment of adherence Compliant (in blue)/Non-Compliant (in red) to the local Whale Watching (WW) rules (Spanish Royal Decree 1727/2007 and Gibraltar Marine Protection Regulation 2014/180) of five WW trips in 2019.

Although variability among operators and trips exists, WW companies tended to follow existing rules with an average of 62% of compliance to the assessed criteria. Tarifa-based operators respected 65% of criteria and those based in Gibraltar respected 59% of criteria. During all of the five trips assessed, the ban on feeding, swimming with, or touching animals was respected, together with not manoeuvring backward and not separating associated adults and calves. During four trips vessels avoided surrounding the pod of cetaceans and respected the restriction of maximum one vessel for 20 minutes in the RAZ rule. The most frequent illegal behaviours (n=3) were approaching animals from the front or rear without maintaining a parallel course, maintaining a speed higher than the slowest individual of the pod, the simultaneous presence of more than one vessel in the AZ, the absence of radio coordination between vessels, and not leaving cetaceans displaying signs of evasion, discomfort or alteration of behaviour (figure 4.11). These illegal behaviours had already been observed in 2007 (Cabaleiro Mora et al., 2007) in the Strait and, with the infringement of the maximum numbers of vessels having been observed in the Bay between Algeciras and Gibraltar in 2018 (Espada Ruíz et al., 2018). Both WW professionals interviewed in the pre-test survey mentioned adverse weather conditions (affecting approaching manoeuvring), the lack of knowledge of cetacean behaviour and the competition among WW companies for the best position (resulting in poor radio coordination), as **factors that could lead to the non-observance o**f WW rules. Cooperation among WW operators and an increase in radio communication is essential in the sustainable planning of the trips, in order to both reduce the simultaneous presence of various vessels with animals, as well as to improve the quality of approach manoeuvres.

Enforcement agencies were not seen in the area during the assessment, even though their presence would increase rule compliance and would therefore reduce risks to cetaceans

(Andreu Cazalla et al., 2016; Cabaleiro Mora et al., 2007; Espada Ruíz et al., 2018).

Results on the compliance with local WW rules of the evaluation given by stakeholders (35%) do not align with that which was observed in the direct assessment (62%), this incongruence should be investigate in the future setting of a long-term WW monitoring program. Despite this, both results confirming the partial respect of the WW legislations in the Strait.

Considering that the Strait includes various IMMAs (https://www.marinemammalhabitat.org/imma-eatlas/) and considering the growth of the WW sector (Elejabeitia et al., 2012; Scuderi et al., 2022; Tenan et al., 2020), a long-term WW monitoring programme is necessary together with an increase in surveillance. Land-based surveys and analysis using AIS data are commonly used in maritime research (Robards et al., 2016; Shelmerdine, 2015; Svanberg et al., 2019; Yang et al., 2019), for the planning, management and conservation of cetacean critical habitats (Almunia et al., 2021; McWhinnie et al., 2021) and to monitor WW activities (Marega-Imamura et al., 2018; Schaffar et al., 2009), and could therefore be useful tools in augmenting cost-effectiveness of monitoring and surveillance in the Strait of Gibraltar.

4.2.4 Conclusions and management recommendations

Scientists, policy makers, Whale Watching (WW) operators, environmental NGO representatives and WW customers were able to provide important insights into WW activities in the Strait. The collaboration of WW customers and other stakeholders is essential when facing the challenge of creating sustainable WW industry.

Local statutory tools regulating WW activities are only partially respected by the WW fleets in the Strait, despite the fact that their customers give better rankings to companies that abide by WW rules.

Management proposals for WW:

- **Royal Decree 1727/2007 and Marine Protection Regulation 2014/180** should be uniform, i.e., adding to the Spanish Decree the maximum time permitted to spend with the cetaceans during each encounter and the maximum number of vessels allowed to remain in the RAZ.

- A more structured **system of sanctions**, that includes the revoking of licenses, could be further added to the current legislations.

- A coordinated effort among **patrolling forces** is also highly desirable in order to optimize the efficiency of surveillance.

- There is a need for **dedicated, long-term monitoring programme** to accurately assess levels of compliance. A land-based programme together with AIS data analysis could provide important information and could minimize economic effort.

Management proposals for the conservation of cetaceans and, indirectly, the improvement of the WW industry sustainability:

- Designation of a **MPA and of a seasonal regional shipping** plan are the most appropriate tools for the conservation of cetaceans throughout the Strait.
- A **structured multi-jurisdictional participative process** headed by governments, but with the inclusion of all stakeholders, that is based on scientific knowledge is strongly recommended.

Considering the valuable environmental resources at stake, the only partial respect of WW rules, the amount of stakeholders involved, the consistent presence of economic activities and the multi-jurisdictional nature of the Strait, it is imperative that WW activities be managed using an integrated management approach.

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Chiara Mancin

Ferry and fin whale in the Strait of Gibraltar - How to be sustainable? #2

Mixed media, 2023, Tarifa

CHAPTER 5 – USING FERRIES AS A PLATFORM FOR MONITORING CETACEANS AND THEIR THREATS

Monitoring highly mobile species such as cetaceans is challenging, but long-term datasets based on repeated surveys over several seasons can provide important insights for understanding the main drivers of species movements and for the timely identification of changes in behaviour. Synoptic monitoring of threats is also a powerful technique for assessing risks based on the current situation. In the Mediterranean Sea, a stable and growing collaboration of international research institutions called 'Fix Line Transect Mediterranean monitoring Network - FLT Med Net' has been providing large scale, long-term continuous information on a seasonal basis since 2007, contributing to a better understanding of species conservation status and to a more effective mitigation strategy. Network partners follow a standardized protocol, using ferries as platform of opportunity for monitoring cetaceans, sea turtles, maritime traffic and marine litter.

The FLT Med Net protocol was also followed in place in the Strait of Gibraltar in 2018 and 2019. During 59 surveys, 264 sightings of cetaceans were reported, including seven species and four near-miss events of collisions involving pilot, sperm, and fin whales. Data collected were used to i) investigate seasonal presence and distribution of cetaceans and, for the bottlenose dolphin, habitat suitability in the Strait, ii) consider relationships between cetaceans and different maritime activities, by identifying risk areas and investigating the consistency of the spatial conservation spatial management measures in force, and iii) compare data with the other partner of the FLT Med Net across two Habitat Directive six-year periods (2013-2019/2008-2012), testing four potential indicators to assess range and short-term habitat trends of Risso's dolphin, pilot and Cuvier's whale (low-density species).

In conclusion, together with international surveillance, the designation of a micro-sanctuary in the Bay and a mandatory speed reduction to 13 knots in an extended Cetacean Critical Navigation Zone can positively optimize conservation efforts in the Strait of Gibraltar. Low-density species exhibit changes in the extent of their distribution (contraction or expansion) and in an offshore shift, indicating an exploitation of new areas or increased operating pressures. The FLT Med Net sampling design proved adequate for trend assessment in the Western-Mediterranean and Adriatic, while more transects are needed to understand the ecological variability of the central-Mediterranean and Levantine ecological areas.

5.1 Tie up loose ends together: cetacean, maritime traffic, and spatial management tools in the Strait of Gibraltar

Atando cabos: cetáceos, tráfico marítimo y herramientas de gestión espacial en el Estrecho de Gibraltar

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CRediT of the PhD candidate: Conceptualization, Methodology, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Project administration.

Through this study we aim: contributing to the understanding the seasonal presence, distribution and habitat use in the Strait thanks to data collected year around; to test the influence of maritime traffic on cetacean presence and to identify the risk areas for each species on two of the main ship lines; and to test the coherence of the marine spatial tools used for protecting cetaceans comparing with their habitat use (hot spot areas), with the maritime traffic (high risk areas) and in between seasons.

Highlights

• A cost-effective way to monitor maritime traffic and cetaceans is by using ferries

• Specific conservation measures can be proposed by characterizing maritime traffic

• Micro-sanctuary is recommended for common, striped and bottlenose dolphins in the Bay

• International surveillance should be implemented in the Bay from April to September

• In the Cetacean Critical Navigation Zone, speeds of 13 kn should be mandatory

Abstract Coexisting with maritime traffic, seven protected species of cetaceans, and complex transboundary management framework in the Strait of Gibraltar call for deepening and integrating the respective knowledge. The FLT Mediterranean Monitoring Network protocols were followed for 59 visual surveys using ferries as observation platforms along the routes Algeciras-Ceuta and Algeciras-Tanger-Med, in 2018 and 2019. A total of 264 cetaceans' sightings, including the 7 species, and 4 Near Miss Events of collision (pilot, sperm and fin whales), were reported. This study investigates cetaceans' seasonal presence and distribution and, for the bottlenose dolphin, habitat suitability. It considers cetaceans relationships with different maritime activities identifying risk areas and the consistency of the spatial conservation spatial management measures in force. Designations of a micro-sanctuary in the Bay and of a mandatory speed reduction to 13 kn in an extended Cetacean Critical Navigation

Zone, together with international surveillance, could positively optimize conservation effort in the Strait.

Resumen *La coexistencia con el tráfico marítimo de siete especies protegidas de cetáceos y el complejo marco de gestión transfronteriza en el Estrecho de Gibraltar exigen profundizar e integrar los respectivos conocimientos. Se han llevado a cabo 59 muestreos visuales utilizando buques ferris como plataformas de observación a lo largo de las rutas Algeciras-Ceuta y Algeciras – Tanger-Med, en 2018 y 2019, siguiendo los protocoles de la Red Mediterránea de Seguimiento por Transectos Fijos (FLT MED Net). Se reportaron un total de 264 avistamientos de cetáceos, incluyendo 7 especies, y 4 eventos de casi colisión (con calderones, cachalotes y rorcuales). Este estudio investiga la presencia y distribución estacional de los cetáceos y, para el delfín mular, la idoneidad del hábitat. Considera las relaciones de los cetáceos con las diferentes actividades marítimas identificando las zonas de riesgo y la coherencia de las medidas de gestión espacial de la conservación en vigor. La designación de un micro santuario en la bahía y de una reducción obligatoria de la velocidad a 13 kn en una zona de navegación crítica para los cetáceos ampliada, junto con la vigilancia internacional, podría optimizar positivamente el esfuerzo de conservación en el Estrecho.*

Key words: coastal zone, conservation, Ecosystem management, monitoring, whales, dolphins, ferry, marine sanctuary, Mediterranean Sea, Atlantic Ocean

5.1.1 Introduction

The Strait of Gibraltar (from now on the Strait) host seven protected species of **cetaceans**. Among which the Endangered short-beaked common dolphins (hereafter common dolphin), *Delphinus delphis* (Bearzi et al., 2021), the Critically Endangered populations of long-finned pilot (henceforward pilot whale), *Globicephala melas* (Verborgh & Gauffier, 2021) and killer whales, *Orcinus orca* (Esteban & Foote, 2019), and the Endangered Mediterranean subpopulations of the fin whale, *Balaenoptera physalus* (Panigada et al., 2021) and sperm whales, *Physeter macrocephalus* (Pirotta et al., 2021), classification based on the IUCN Red List of Threatened Species. The striped and bottlenose dolphins (*Stenella coeruleoalba* and *Tursiops truncatus*) also inhabit the waters of the Strait (Espada Ruíz et al., 2018; Tenan et al., 2020), being the latest a priority species listed in Annex II of the Habitats Directive (92/43/CEE, HD) for which conservation Special Areas of Conservation are required. Species as pilot-whales (Cañadas et al., 2005; Cañadas, 2008; de Stephanis, García-Tíscar, et al., 2008; de Stephanis, Verborgh, et al., 2008; de Stephanis et al., 2014; Giménez, Cañadas, et al., 2018; Giménez, Louis, et al., 2018) and orcas (de Stephanis et al., 2014; Esteban et al., 2013, 2014, 2016) are among the most studied in the Strait and a specific Conservation Plan for Critically Endangered orcas was designed in 2017 (BOE, 2017). Even though there are still knowledge gaps on the seasonal presence distribution and habitat use of all cetaceans inhabiting the Strait, probably due to the difficulties of performing year-round monitoring. These gaps could affect the effectiveness of management measure towards the conservation of the protected species. Additionally, an update on the species' use of habitat in the Strait could be useful to verify and potential changes that require further mitigation or conservation measures.

The Strait is also a high **maritime traffic area**, with an average of 116,128 vessels transiting the Strait every year (data provided by *Tarifa Traffico VTS* of *Salvamento Maritimo*[17], for the 2018 and 2019). Injuries of anthropogenic causes were detected on the seven cetaceans species regularly occurring in the area (Herr et al., 2020). The high intensity of recreational fishing and whale watching activities had probably damaged the common dolphins inhabiting the Bay among Algeciras and Gibraltar (henceforth called the Bay) (Olaya-Ponzone et al., 2020); and the ferry traffic was negatively correlated to the annual apparent survival of the local bottlenose dolphin population (Tenan et al., 2020). Moreover, ship strike is considered one of the main threats affecting fin and sperm whales (Grossi et al., 2021), and evidence of past collision events were reported on the fin whale population crossing the Strait (Gauffier et al., 2018).

Monitoring cetaceans using ferries as the platform of opportunity is an environmentally sustainable and cost-effective program that takes advantage of the vessels already sailing in the area. A current long-term program, consistent over space and time repeatable all year round, is conducted over large geographic sea areas (Arcangeli et al., 2019, 2021; David et al., 2022) in the Mediterranean basin, allowing the detection of eventual changes in distribution of the different species during time (Arcangeli et al., 2013). Furthermore, data collected on cetaceans from ferries allowed the investigation of their relationship with environmental parameters (Arcangeli et al., 2013) and pressures, such as maritime traffic (Campana et al., 2015, 2017, 2022) or floating marine macro litter (Arcangeli et al., 2020; Gregorietti et al., 2021). Likewise, the dedicated observers could play an important role in spotting marine mammals and reducing the risk of collision (Weinrich et al., 2010), detecting rare events such as collisions or near-collisions (David et al., 2022), and, contemporaneously, raising the awareness about sea life conservation with the crew. In addition, data systematically collected from ferries could provide valuable information for the requirements of the environmental legislative framework (e.g. Habitats Directive, Marine Strategy Framework Directive, Marine Spatial Planning) and for the evaluation of local protection measures (Arcangeli et al., 2021).

The Strait of Gibraltar (figure 5.1) is a transborder marine area connecting the Mediterranean Sea and the Atlantic Ocean. In this area, the coastal countries Spain, Morocco, and Gibraltar had ratified **international conventions** to protect cetaceans, including the International Convention for the Regulation of Whaling (ICRW), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Bern Convention (BCCEW) and the Bonn Convention (CMS). Other protection tools include the **spatial management measures** in force in the Strait. For instance, the UNESCO (United Nations Educational Scientific and Cultural Organization) established the Intercontinental Biosphere Reserve that includes both Spanish and Moroccan marine and terrestrial habitats. Other spatial protection measures are in place under the Bird and Habitat Directives, Ramsar Convention, and local governments (Gibraltar, Spain, Morocco) (see Table 1 for further

[17] http://www.salvamentomaritimo.es

details). The whole Strait was also designed as Important Marine Mammals Area (IMMA) from the IUCN IMMA task force, and as Cetacean Critical Habitats (CCH) by ACCOBAMS, definition resulting from a threat management approach used to combine human activities and cetaceans distribution (ACCOBAMS, 2017).

Considering the co-existence of protected species of cetaceans with the high level of maritime traffic, along with the complex management framework of this transboundary area, this study aims at:

i. contributing to the understanding the seasonal presence, distribution and habitat use in the Strait thanks to data collected year around;

ii. testing the influence of maritime traffic on cetacean presence and to identifying the risk areas for the species in the surveyed zone;

iii. discussing the coherence of the marine conservation and mitigation measures already in force for protecting cetaceans in the Strait of Gibraltar taking in account the update information on their seasonality, occurrence and, for the priority bottlenose dolphin species (Annex II, Habitat Directive), its habitat use, and the higher risk areas to the exposure to the maritime traffic.

5.1.2 Materials and methods

Study area

The Strait of Gibraltar (hereafter also called the Strait) separates Africa from Europe, is the only passage between the Mediterranean Sea and the Atlantic Ocean and includes the waters between -5°W and -6°W (figure 5.1). Approximately 60 km long and 20 km wide, the Strait is characterized by deep waters reaching 1000 m in its eastern part, and shallow waters in its western part that can get less than 300 m deep. A sub-area of the Strait was considered for investigating the seasonal distribution, habitat use, and the relationship between cetaceans and marine traffic. The sub-area borders are marked as a line from Punta Paloma (Spain) to Punta Bou Maaza (Morocco) to the west, and a line from Punta Mala (Spain) and Punta Almina (Morocco) to the east (figure 5.1, b). This sub-area was selected by reason of monitoring coverage (figure 5.1, A) and of similarity of the sea bottom, in terms of bathymetry and slope.

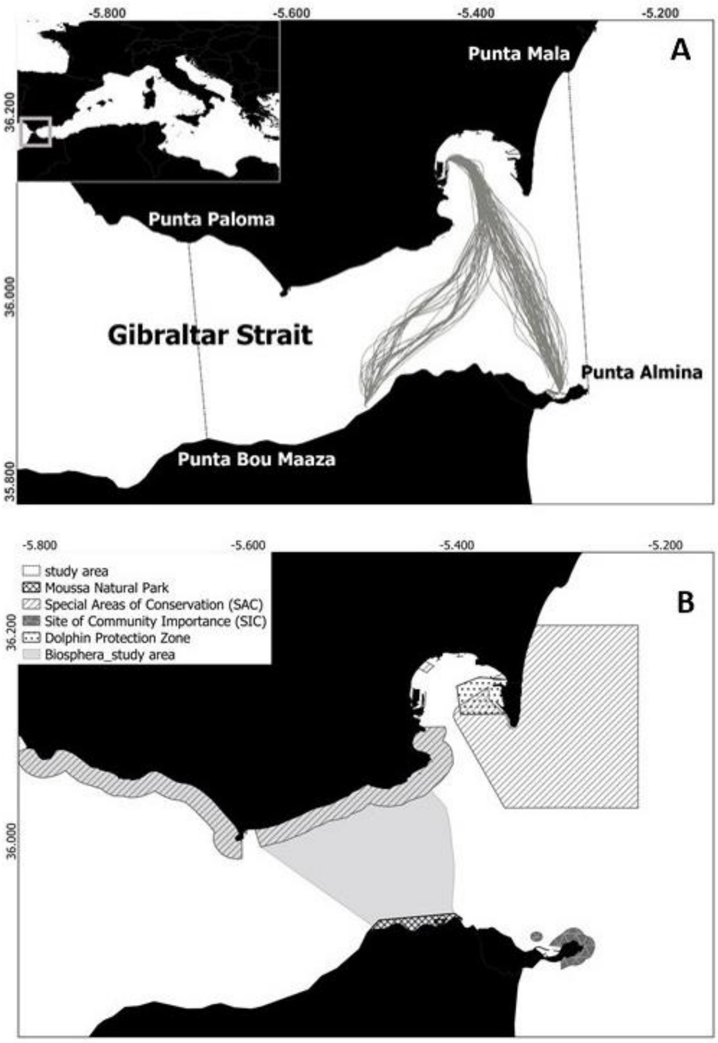

Figure 5.1 Maps of the area of study. (a) Map of the Strait of Gibraltar with highlighted transects Algeciras-Ceuta (Spain), and Algeciras - Tangier Med (Spain-Morocco) in grey. The sub-area of study includes from Punta Paloma (Spanish coast) and Punta Bou Maaza (Moroccan coast) for the western border, and Punta Mala (Spain) and Punta Almina (Morocco) for the eastern border. (b) Map of the Strait with georeferenced spatial management tools in force for the protection and conservation of the nature.

Method for data collection

Monitoring data were gathered thanks to the support of Foundation Baleària (http://fundaciobalearia.org), using the ferries Poeta López Anglada, Passió per Formentara and AMMAN as platforms of observation along the transects Algeciras-Ceuta (Spain, ALCE), and Algeciras - Tangier Med (Spain-Morocco, ALTA). Data collection followed the standard monitoring protocol of the Fixed Line Transect Mediterranean monitoring Network - FLT

Med Net[18], an international project coordinated by ISPRA since 2007, carried out systematically along 16 cross-border transects, using scheduled ferries as observation platforms[19].

During the monitoring surveys, a minimum of two expert Dedicated Observers (DOs) were located on the main bridge of the ferries, scanning both sides of the vessel (from 0° to 130°) to record data on cetaceans' sightings and maritime traffic. Binoculars and cameras were used by the DOs to optimize the monitoring. Data were collected under all weather conditions, notwithstanding only data collected in good conditions (Beaufort ≤ 3) were used for analysis. Whenever possible five surveys per summer (July-September), autumn (October-December), winter (January-March) and spring (April-June), were sampled for each transect all year-round except in August and keeping a minimum of one monthly survey per transect. Data collection depended on the sea state, weather conditions and availability of the ferry company. Surveys were carried out from January 2018 until December 2019.

Data collected on cetaceans include records about species, group composition and behaviour, the distance between the platform and species sighted. Also the speed and the route of the ferries were noted. Scan sampling to count all vessels visible by eyesight all around the ferry was performed each time a cetacean sighting occurred (presence dataset); additionally, scan sampling of vessels was conducted along the transect when animals were not sighted (absence or pseudo-absence dataset). Vessels were classified as small (smaller than 5 m), medium (between 5 and 20 m, distinguished in: motor, sailing, fishing) and big (longer than 20 m, such as cargos, tankers, passenger ships). Near Miss Events (NMEs) of collisions were also documented and qualitatively described. NMEs were defined when the animal is at 50 m in front of the bow or 25 m aside and it does not show approaching behaviour and/or a signal of evasion (David et al., 2022).

Methods for data analysis

Species composition and seasonal distribution

All cetacean records were firstly stratified per years and seasons. All records were investigated in a GIS software (the Free and Open Source QGIS 3.10 and 3.22, 2020) in order to calculate the relative length of the survey tracks within the study area, along with the number of cetacean sightings for each transect. Each survey transect was used as a replicate for temporal comparisons.

The diversity of cetacean species was investigated for each transect and season as species presence and as percentage composition (i.e. number of sightings of a species relative to the total number of sightings of all species). Relative abundance was expressed as Sightings

[18] https://www.isprambiente.gov.it/en/activities/biodiversity/technical-annex-i_monitoring-protocol_dec2020-1.pdf
[19] https://www.isprambiente.gov.it/en/activities/biodiversity/flt-mediterranean-monitoring-network-marine-species-and-threats

Per Unit of Effort (SPUE), calculated as the number of sightings per km travelled on effort in standard condition within each transect; SPUE was computed seasonally for all cetacean species and compared between the two monitored transects and the two investigated years with Mann Whitney (MW) test. Specific seasonal differences were instead tested with the Kruskall-Wallis test (KW) and the MW post-hoc comparison using PAST 2.17 software (Hammer et al., 2001).

For the spatial analysis, the study area was divided on a grid cell basis of 5 × 5 km to analyse and compare spatial distribution of all records in the four seasons. For each cell, we associated the total effort for cetacean monitoring and the number of cetacean sightings for each species, in order to calculate in each cell the SPUE (Sighting Per Unit of Effort) value as SPUE=(Number of sighting/Km in good weather conditions) x10. Only cells with more than 10 km covered on effort were considered to reduce outliers (Arcangeli et al., 2017; Zuur et al., 2010).

Important areas for bottlenose dolphin (habitat suitability model)

To identify the important areas for the priority species bottlenose dolphin, Species Distribution Modelling (SDM) was used to characterize suitable habitats and predict the core areas of distribution in the whole Strait of Gibraltar. The software MaxEnt was used, as it resulted particularly appropriate for species-only data when the number of presences used is low (Baldwin, 2009; Giannini et al., 2013). Four explanatory variables, selected between the factors already considered predictive of bottlenose dolphin habitat, were used in the model: bathymetry (m), bathymetric slope (degrees), distance from the nearest coast (m), and mean Sea Surface Temperature (SST, C°). Bathymetry values were obtained from the GEBCO raster file (GEBCO Compilation Group (2020) GEBCO 2020 Grid, doi:10.5285/a29c5465-b138-234d-e053-6c86abc040b9), while SST raster file were downloaded from NASA Ocean Colour (http://oceancolor.gsfc.nasa.gov) and averaged for the entire period (2018-2019). For the habitat modelling, N=22 sightings of bottlenose dolphins were used, pooling together the seasons in order to obtain a better predictive result. Maxent setting was: "Autofeatures" for the feature types, and rm=1. No correlation was found among variables, therefore none has been removed. Starting from the species occurrences and the predictive variables, the R package "ENMeval" was used to obtain the bias file, a function that permits to correct irregular distribution of the sampling effort (Phillips et al., 2006).

Maritime traffic and cetaceans

Salvamento Maritimo (SM) contributes to increasing the safety of maritime traffic by monitoring and facilitating traffic in the Traffic Separation Devices of Tarifa. *Tarifa Tráfico VTS* of SM has provided data on the vessels identified crossing the Strait of Gibraltar or the entrance/exit of the Spanish ports in the years 2018 and 2019. A preliminary analysis was performed to compare the seasonal pattern of total maritime traffic of the two investigated years obtained from SM using the two samples Kolmogorov-Smirnov (KS) and Mann-Whitney (MW) tests. Then, information on vessel types sampled along the monitored transects was used to characterise seasonal composition in maritime traffic and used as indicator of real-time vessel abundance, to be compared with seasonal pattern obtained from SM

To verify the influence of year, season and transect on the traffic intensity, comparisons were performed with non-parametric statistics of two-way PERMANOVA with Bray-Curtis dissimilarities, and results allowed to group the data and keep the separation only on a seasonal basis. Differences were tested with the Kruskall-Wallis test (KW) with the Bonferroni correction for multiple comparisons and the MW post-hoc comparison between two groups.

To study the relationship between maritime traffic and cetacean sightings, all records of the presence and absence datasets were compared to test the null hypothesis that the number of ships does not differ between them. The two datasets (with at least 10 records) were statistically compared using the KS test and the mean percentage difference between the number of vessels recorded in the sighting locations (Npres) and those recorded randomly in the absence of sightings (Nabs) was reported as: [(Npres − Nabs) / Nabs] * 100 (Campana et al., 2017). The analysis was performed on the whole maritime traffic and single vessel categories, pooling all seasons and sightings of all species together, then sorting by season. Finally, investigation at the species level was made for the most sighted species: common dolphin, striped dolphin, bottlenose dolphin and pilot whale. To study distribution and intensity of maritime traffic in the area, the total number of vessels counted in the presence and absence of cetacean sightings was linked to the grid cells and the mean value was calculated for each season; the same was done for the five categories of vessels. To identify the overlapping of cetaceans' hotspot and higher intensity of maritime traffic (3.1), the Kernel density estimate was used to identify areas of higher intensity of maritime traffic, by weighting the analysis on the mean number of vessels and considering a radius of 10 km. The 70% isopleths were used to define areas of major density of vessels (Campana et al., 2022), to be compared with the cells of higher SPUE in this way we could highlight the potential risk areas for cetacean species, first considering total traffic and all the species together, than specifying the overlap for each species in each season. The NMEs of collision (3.2) were qualitatively described and georeferenced.

Spatial protection measures

The marine spatial protection measures in force in the Strait of Gibraltar were mapped using GIS software (QGIS 3.22, 2020), and then overlapped with cetacean hot spots and the marine traffic high risk zones.

Of the spatial management tools, presence or absence of a management plan was highlighted and, when possible, practical measures to protect cetaceans were extrapolated by the respective plans (table 5.1).

Table 5.1 List of the different management spatial tools in force in the Strait of Gibraltar and of the related management plans. Mapping of the spatial management tools is available at the figure 5.1.

Strait of Gibraltar areas and national jurisdiction	Spatial tools in force	Management plan	Practical measures to protect cetaceans
Northwest and central areas **SPAIN**	Special Area of Conservation (SAC) ES0000337 Estrecho	*Plan de Ordenación de los Recursos Naturales (PORN) Frente Litoral Algeciras-Tarifa,* that includes *Paraje Natural Playa de Los Lances, and Planes Rectores de Uso y Gestión (PRUG) Parque Natural del Estrecho*	PORN – no specific measures PRUG - Requires authorization from the council for any activity of observation of cetaceans and the respect of the Royal Decree 1727/2007 during the sightings.
Northwest and central areas **SPAIN**	Estrecho Natural Park (in ES0000337 Estrecho)	PORN *Frente Litoral Algeciras-Tarifa* and PRUG *Parque Natural del Estrecho*	Same of the above
Northeast area **SPAIN and GIBRALTAR**	SAC-ES6120033 Fondos Marinos Marismas del Rio Palmones	PORN *Fondos Marinos Marismas del Río Palmones* Management Plan (MP) of the SAC ES6120033	PORN - no specific measures MP – To follow a selection of the measures more specific: Promotion of the inclusion in the nautical charts of the SAC limits (Measure code: A.1.3.1) Environmental education actions direct to the actors of the nautical (C.1.3.2) It will urge a participative process among authorities, fisherman's guilds and shell-fishers for a sustainable use of the resources (C.1.4.1)
Northeast **SPAIN and GIBRALTAR**	SAC-ES6120032 Estrecho oriental	*Real Decreto 1620/2012, de 30 de noviembre, por el que se declara Zona Especial de Conservación el Lugar de Importancia Comunitaria ES6120032 Estrecho Oriental de la región biogeográfica mediterránea de la*	It is recommended to navigate with extreme vigilance. Recommendation proposed to International Maritime Organization In case of collision mandatory call the

		Red Natura 2000 y se aprueban sus correspondientes medidas de conservación.	Emergency number 112 Whale watching activity has to follow the Royal Decree 1727/2007 Marine Mammal Observers on board are mandatory for survey with high acoustic contamination On species *T.truncatus*, *D.delphis* and *S.Coeruleoalba* the development of scientific studies and of monitoring programs
Northeast **GIBRALTAR**	Dolphin Protection Zone Regulation 2018	Gibraltar Marine Reserve Management Plan	Under the Marine Protection Regulations 2014: -Cetacean Protocol to apply during an encounter with cetaceans -No anchoring zones -Designation of Marine Conservation Zones including Micro-Marine Reserves -Designation of No-fishing Zones Under the Dolphin Protection Zone Regulations 2018: -Strict conditions on recreational and sports fishing by creating an exclusion zone -Enforcement to respect the Cetacean Protocol -Studies and monitoring programs and educational activities on cetaceans. Prohibition of some activities.
Eastern **SPAIN**	SIC-ES6310002 Zona marítimo-terrestre del Monte Hacho	Preliminary plan included analysis	None
Central area **MOROCCO and SPAIN**	Intercontinental Mediterranean Biosphere Reserve. Andalusia (SP) – Morocco	No plan on our knowledge.	None

5.1.3 Results

Effort data, including both transects, was analysed as a total time of 115 hours and 24 minutes spent and/or distance travelled of 2,927.17 Km on effort in good weather conditions (Beaufort ≤ 3). A total of 264 cetacean sightings were recorded, of seven identified species (table 5.2).

Table 5.2. Number of sightings per species in both transects Algeciras-Ceuta (ALCE) and Algeciras-Tanger Med (ALTA), total time spent and km travelled on effort (from January 2018 to December 2019).

No. Transects	33 ALCE	26 ALTA	59 ALCE-ALTA
Species sighted			
D.delphis	53	25	78
S.coeruleoalba	25	15	43
T.truncatus	11	11	22
G.melas	6	13	19
B.physalus	4	4	8
P.macrocephalus	1	5	6
O.orca	0	2	2
U.S.Small	40	46	86
U.S. Medium	0	2	2
U.S.Large	0	1	1
Tot. of sightings	140	124	264
Time on effort (hh:mm)	57:44	57:40	115:24
Km on effort	1,548.66	1,378.51	2,927.17

Species composition, seasonal distribution and habitat use

Species composition coincides between the two monitored fixed transects, including the six species: striped, common and bottlenose dolphins, pilot, sperm and fin whales, except for orcas sighted only on two occasions along the ALTA route. The most common species in both transects were common dolphin, followed by striped, bottlenose dolphin and pilot whale. Other less frequent species were fin and sperm whale.

For all the species, no significant differences in SPUE values were detected among the two investigated transects (MW ALTA-ALCE p>0.05). So, pooling data together, cetaceans sighting rates were compared among the two investigated years and no differences emerged, except for the fin whale, significantly more frequent during 2019 (MW 2018-2019 p=0,0007573). For the majority of the species, there were no significant differences in the seasonal sighting rates, except for the striped and common dolphins for which the summer sighting rate was the highest (KW p≤0.016). Species distribution also presented seasonal differences for these two species (figures 5.2 and 5.3): striped dolphin showed central southern distribution during winter and spring, but also the presence in the Bay between Gibraltar and Algeciras during summer and autumn, while common dolphin was concentrated in the Bay from spring to autumn.

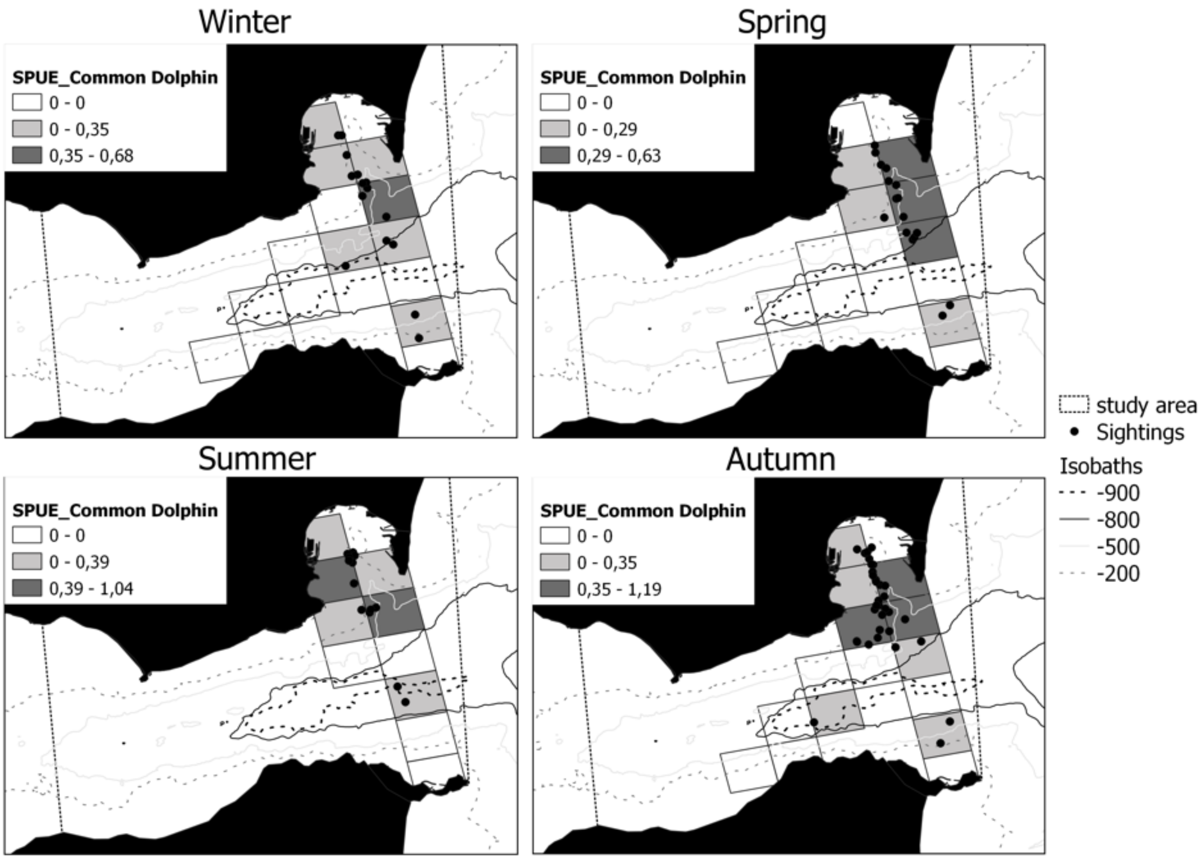

Figure 5.2 Maps of relative abundance of short-beaked common dolphin expressed as Sightings Per Unit of Effort (SPUE), per summer (July-September), autumn (October-December), winter (January-March) and spring (April-June).

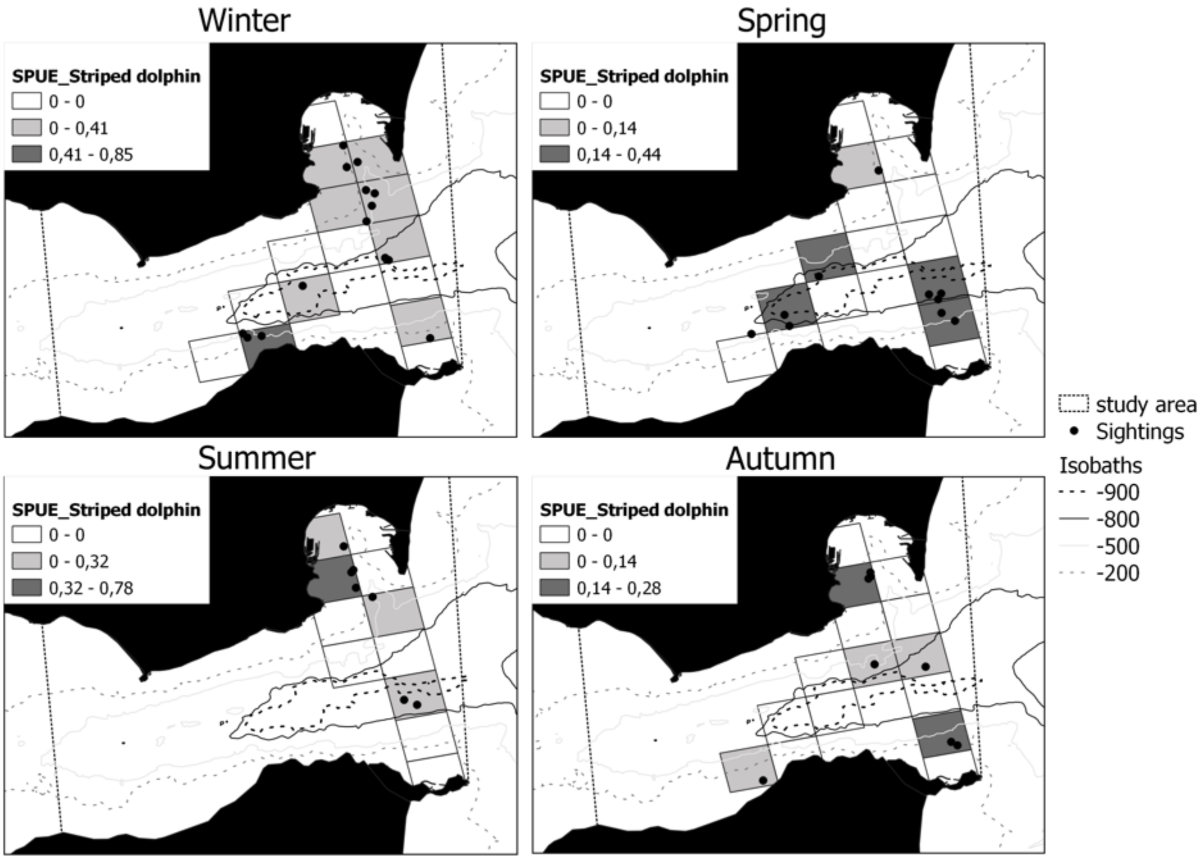

Figure 5.3 Maps of relative abundance of striped dolphin expressed as Sightings Per Unit of Effort (SPUE), per summer (July-September), autumn (October-December), winter (January-March) and spring (April-June).

The bottlenose dolphin was seen in the Strait from summer to winter, while during spring a high presence of this species was evidenced in the Bay (figure 5.4). Pilot whale was instead mainly observed in the central part of the study area in all seasons (figure 5.5), as well as fin and sperm whale (supplementary materials 5.1, I and II).

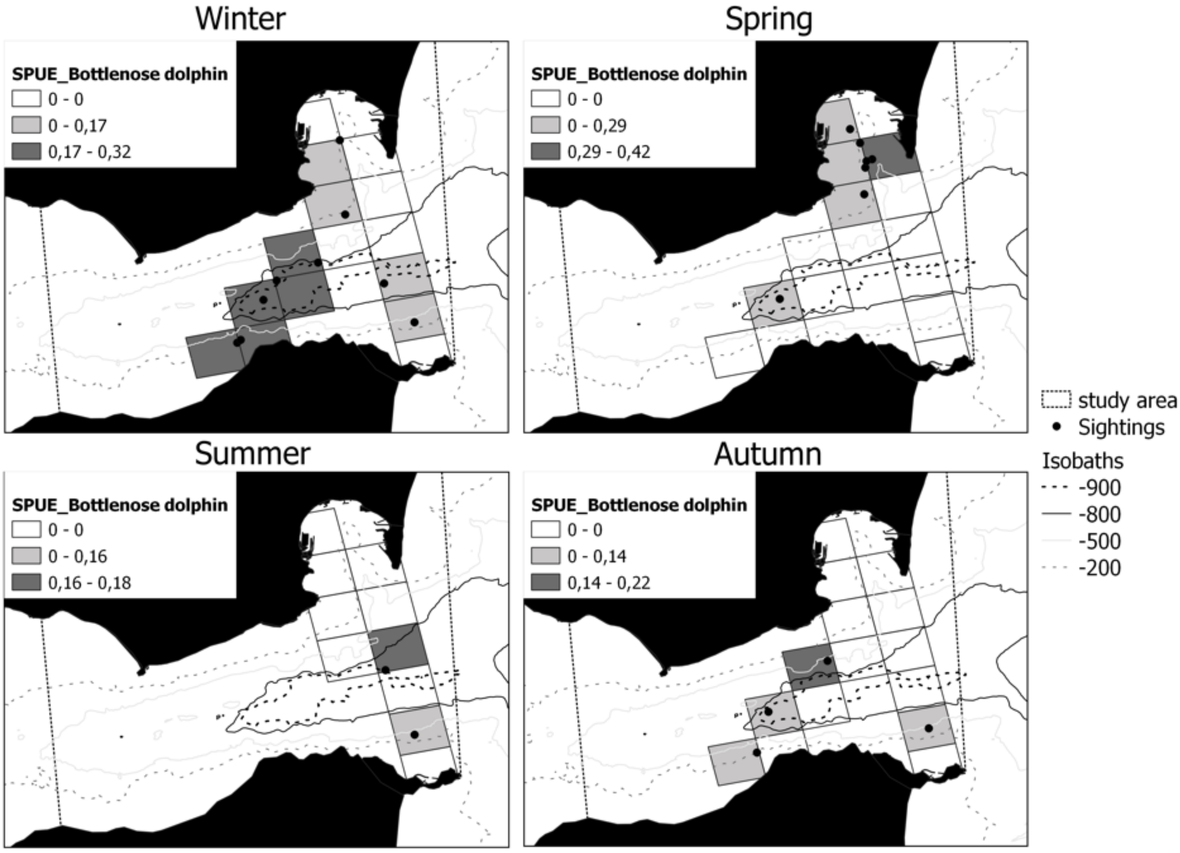

Figure 5.4 Maps of relative abundance of bottlenose dolphin expressed as Sightings Per Unit of Effort (SPUE), per summer (July-September), autumn (October-December), winter (January-March) and spring (April-June).

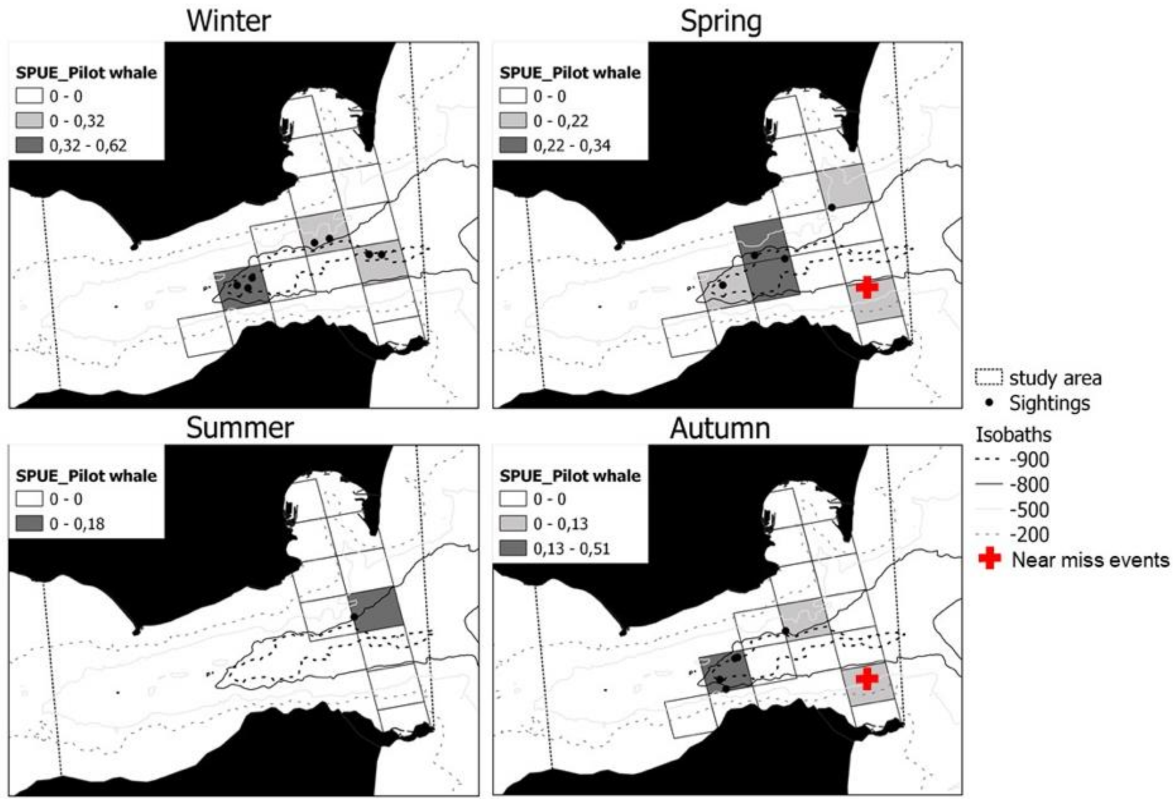

Figure 5.5 Maps of relative abundance of long-finned pilot whale expressed as Sightings Per Unit of Effort (SPUE), per summer (July-September), autumn (October-December), winter (January-March) and spring (April-June).

The SDM performed on bottlenose dolphin proved to perform well, with a final AUC value of 0.82. The most important variable determining the species habitat was bathymetry (65.3%), followed by minimum distance from the coast (19.7%) and bathymetric slope (14.8%). In general, bottlenose potential preferred habitat extended over the outer limit of the continental shelf, excluding the southern areas where the continental slope is close to the coast, and in the very central part of the study area in correspondence with the western steep limit of the deepest part of the Strait (figure 5.6).

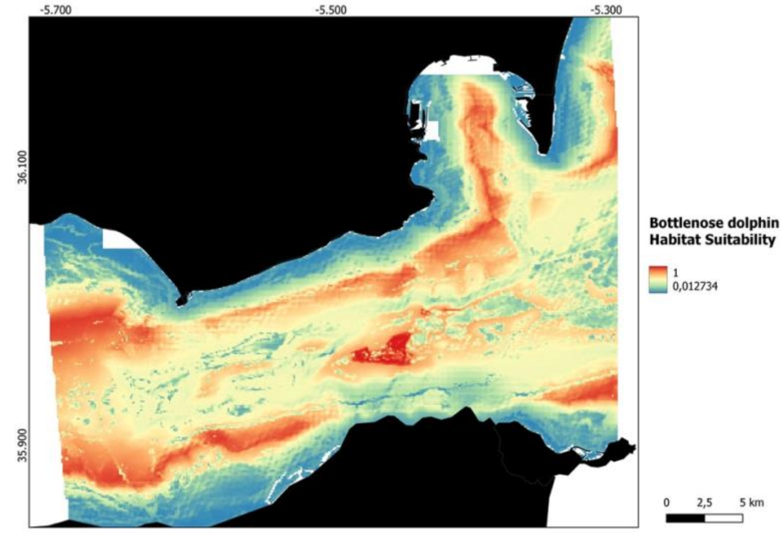

Figure 5.6 Map of the suitability of habitat for the bottlenose in the Strait of Gibraltar.

Maritime traffic and cetaceans

No differences were observed between 2018 and 2019 among the monthly total amount of vessels reported by **Tarifa Tráfico** (KS and MW, $p>0.05$), whereas there was a significant difference among seasons (KW $p<0.001$), where the mean maritime traffic reported during the summer was significantly higher than during spring and winter (MW $p=0.03$).

Using the data on vessel recorded along the monitored transect (i.e. **presence and absence datasets)**, the total number of vessels observed in ALTA did not show significant seasonal variations (KW $p>0.05$), but no summer data were available for this transect; and 80% of all traffic in all the seasons was represented by big ships (>20m).

In the ALCE transect, instead, a significant difference among seasons was found, with fewer vessels during the summer than in the other seasons (KW $p=0.000$). No differences were observed between the two transects when comparing maritime traffic intensity during spring and winter, while it resulted higher in ALTA than in ALCE during autumn (MW $p=0.034$). PERMANOVA analysis revealed in fact no variation in the traffic intensity in relation to year and transect ($p>0.05$) but a significant effect of season ($p<0.02$); therefore all the subsequent analyses were performed pooling together all data, and keeping the separation on a seasonal basis. The presence of big ships (>20 m) prevailed on the other vessel types in all seasons, representing more than 75% of all traffic only decreasing to 63% during summer (ALCE only). The medium-sized categories of sailing and motor boats were also characterising elements of maritime traffic by approximately 20% in all seasons, with an increase during summer, when fishing boats were never seen instead (figure 5.7). Also small boats reached the highest proportion during summer (5%), while fishing boats during winter (4%) (figure 5.7).

The different vessels categories showed uneven distribution in the study area, with big, sailing and fishing boats presenting high densities on wider areas compared to the other types. These categories were generally distributed in the central part of the Strait during winter and spring, while more dispersed from north to south during the other seasons. During summer all categories showed high densities inside the Bay.

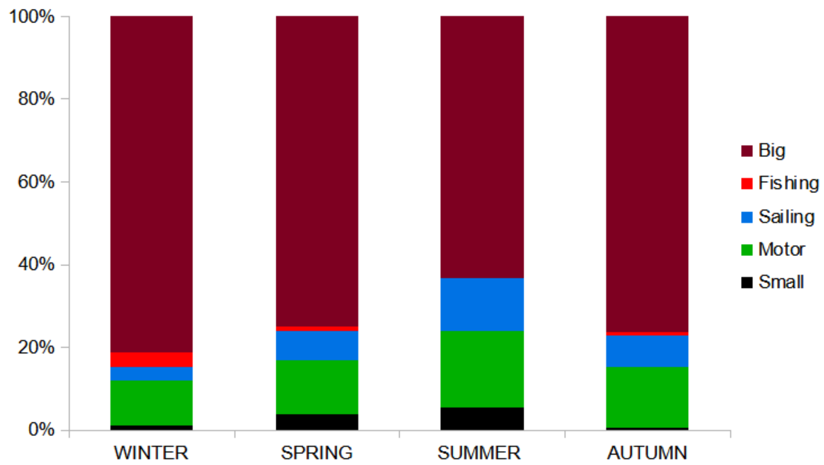

Figure 5.7 Seasonal composition of maritime traffic in the investigated area (ALCE-ALTA joined transects).

Considering all seasons and all cetaceans encountered, a similar number of vessels was observed in the **presence and absence of cetaceans** (KS $p>0.05$). Looking at the different vessels types, in the presence of cetacean sightings there were significant differences compared to the absence (KS $p<0.03$), with a higher number of small, motor and fishing boats (77%, 76% and 371% respectively), and a lower number of sailing and big ships (table 5.3, a).

During autumn and winter, a significantly higher number of small and fishing vessels were recorded in the presence of cetacean sightings (KS $p<0.01$), with the first only seen in locations of cetacean sightings; during winter, a greater number of sailing vessels was also recorded when cetaceans were sighted (KS $p=0.008$). During spring instead, a decrease of 29% on the number of total vessels in the presence of cetacean sightings compared to the absence was observed, driven by the categories sailing and big ships (KS $p<0.01$, see table 5.3, a). On the contrary, fishing boats were only observed when cetaceans sightings occurred, and during summer no significant differences were detected (KS $p>0.05$, table 5.3, a).

For the investigated species, common, striped and bottlenose dolphins showed a higher presence of small and fishing boats and a minor presence of big ships in the location of sightings (KS $p<0.05$, table 5.3, b). For the common dolphin also the number of motor boats was 80% higher than the records in the absence of sightings (table 5.3, b). The pilot whale instead was observed in locations with less presence of small, motor and sailing boats, and significantly higher presence of fishing vessels (KS $p<0.05$, table 5.3, b).

Table 5.3 Differences in the number of vessels (total and single categories) counted in the presence and absence of all cetacean species sightings (a) and most common species (b) in the surveyed transects: percentage difference and Kolmogorov-Smirnov test results (*p < 0.05; **p ≤ 0.01; ***p ≤ 0.001; NA = all zero absence data).

a

			Seasons			
All Species	**Vessel type**	**All seasons**	Autumn	Winter	Spring	Summer
presence		135	46	42	35	12
absence		67	21	18	20	8
% difference	Total	-2%**	-7%	22%	-29%**	1%
	Small	77%***	37%***	NA***	9%	500%
	Motor	76%*	69%	135%	57%	28%
	Sailing	-14%*	3%	20%**	34%*	-44%
	Fishing	371%***	357%***	226%**	NA**	NA
	Big	-12%**	-18%	8%	-40%**	-4%

b

		Common dolphins	**Striped dolphin**	**Bottlenose dolphin**	**Pilot whale**
presence		38	23	14	17
absence		67	67	67	67
% difference	Total	2%	-8%	-2%	15%
	Small	316%**	4%***	3%***	-72%***
	Motor	82%*	86%	211%	-25%*
	Sailing	-1%	-20%	2%	-16%*

Fishing	47%***	143%***	1,017%***	1,214%***
Big	-11%	-18%*	-31%*	15%

Overlapping cetaceans' hot spots and traffic areas

By overlapping the cells with higher SPUEs with the seasonal isopleths of all vessels categories we were able to highlight the areas for potential risk for cetacean species. We grouped the species according to the similar size or potential risk of interaction with ships: common and striped dolphins, more frequent in the Bay (Elejabeitia et al., 2012; Olaya-Ponzone et al., 2022); pilot whales and bottlenose dolphins, often associated in the Strait waters (Andréu et al., 2009); fin, sperm and killer whales for their large size, vulnerability to collisions (David et al., 2022; Di-Méglio et al., 2018; Gauffier et al., 2018; Williams & O'Hara, 2010) and low number of sightings.

Keeping all the species together we observed as cetacean risk area the Bay and the central eastern part of the sub-are studied for sailing and motor boats; the central-south area for fishing boat and the edge of and the whole Bay for small boats; instead the risk zone for big cover almost the all area of sighting (supplementary material 5.1, III).

Common and striped dolphins showed an important presence during spring, summer and autumn close to the Bay resulting in a high overlap with all vessels categories, while during winter their occurrence was limited to areas with lower traffic density (figure 5.8).

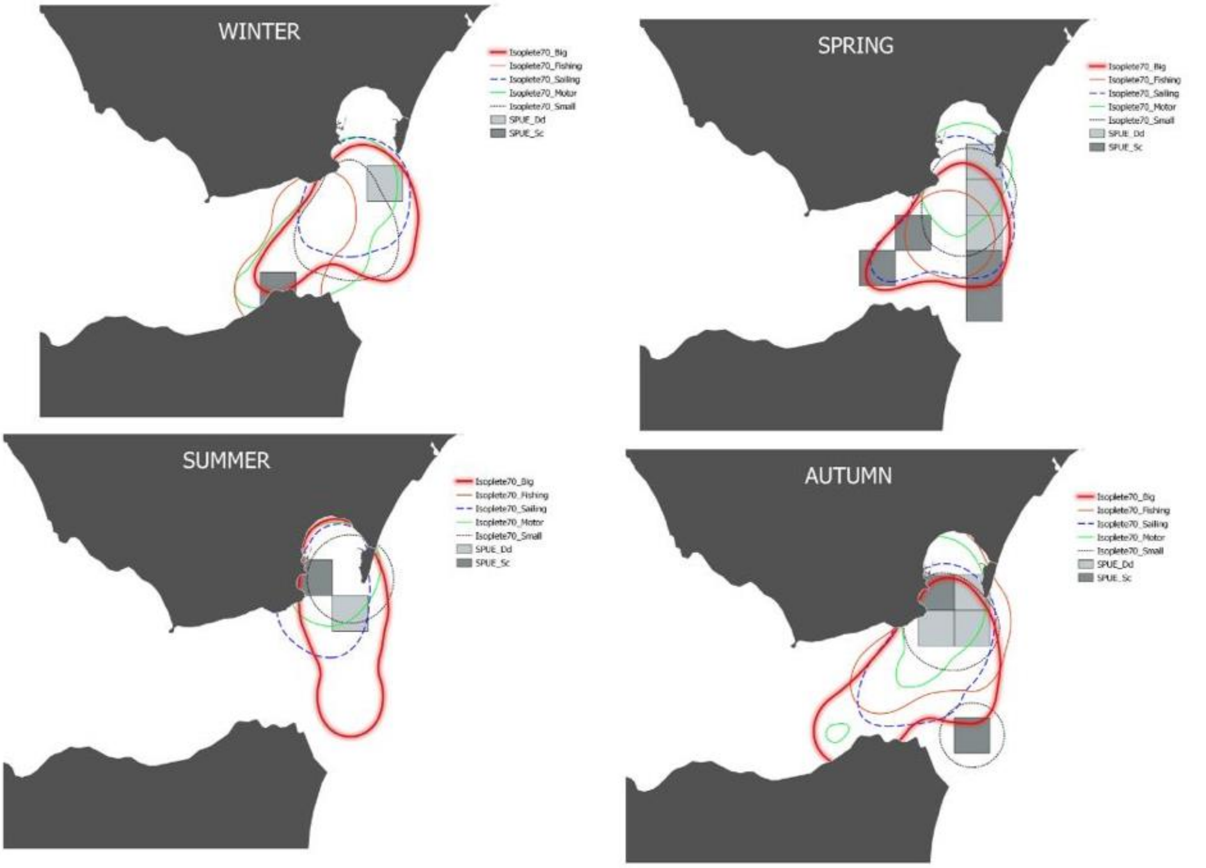

Figure 5.8 Maps of the Strait of Gibraltar highlighted the relative abundance of common (Dd) and striped (Sc) dolphins expressed as Sightings Per Unit of Effort (SPUE) and with marked isopleths of the different types of vessels. Red isopleths represent big ships (>20m), orange for the fishing boats, dashed blue lines the sailing boats, green for the motor boat (these last three categories between 5 and 20 m), and dotted black lines represent small vessels (<20m).

Pilot whale and bottlenose dolphin instead presented major overlap during winter and autumn in the central part of the Strait, where all vessels categories showed high densities; while during summer the overlap was mainly with big ships (figure 5.9).

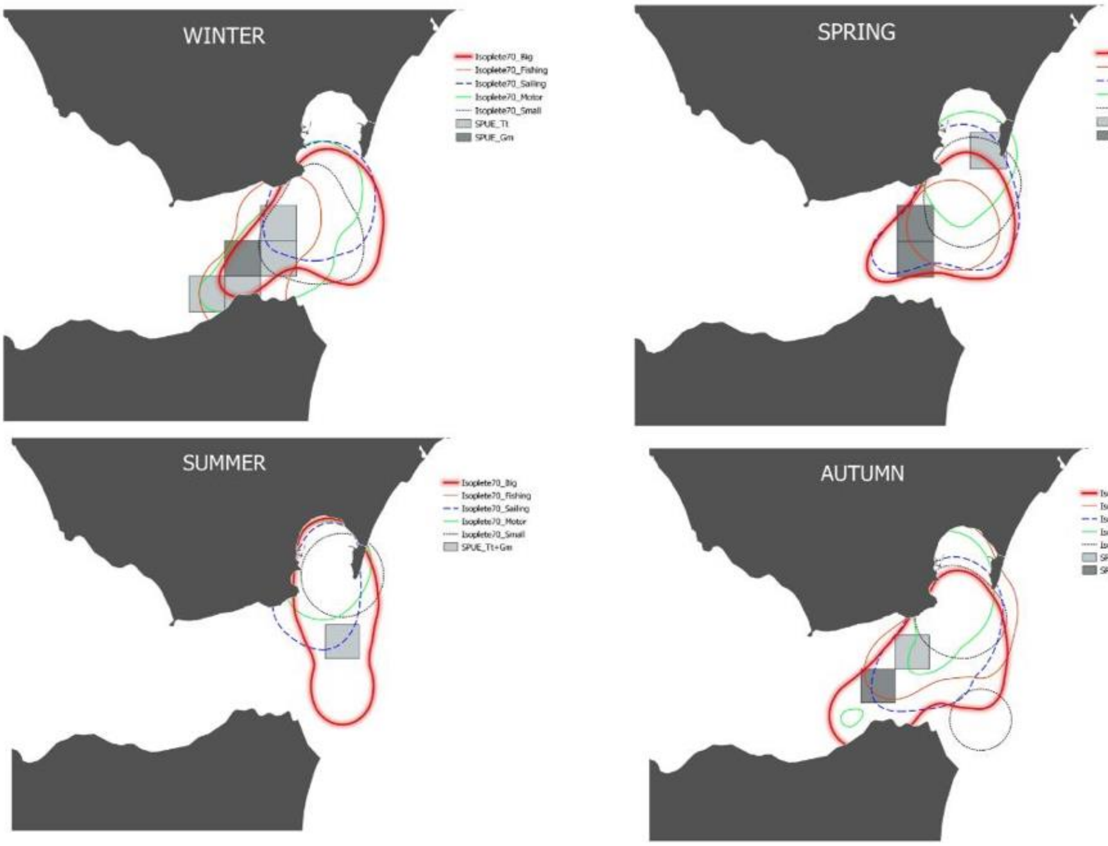

Figure 5.9 Maps of the Strait of Gibraltar highlighted the relative abundance of bottlenose dolphin (Tt) and pilot whale (Gm) expressed as Sightings Per Unit of Effort (SPUE) and with marked isopleths of the different types of vessels.

For large whales the areas of higher overlap were highlighted in the central part of the Strait during winter and spring with all types of vessels, and in the southern waters of the study area during autumn with big ships (figure 5.10).

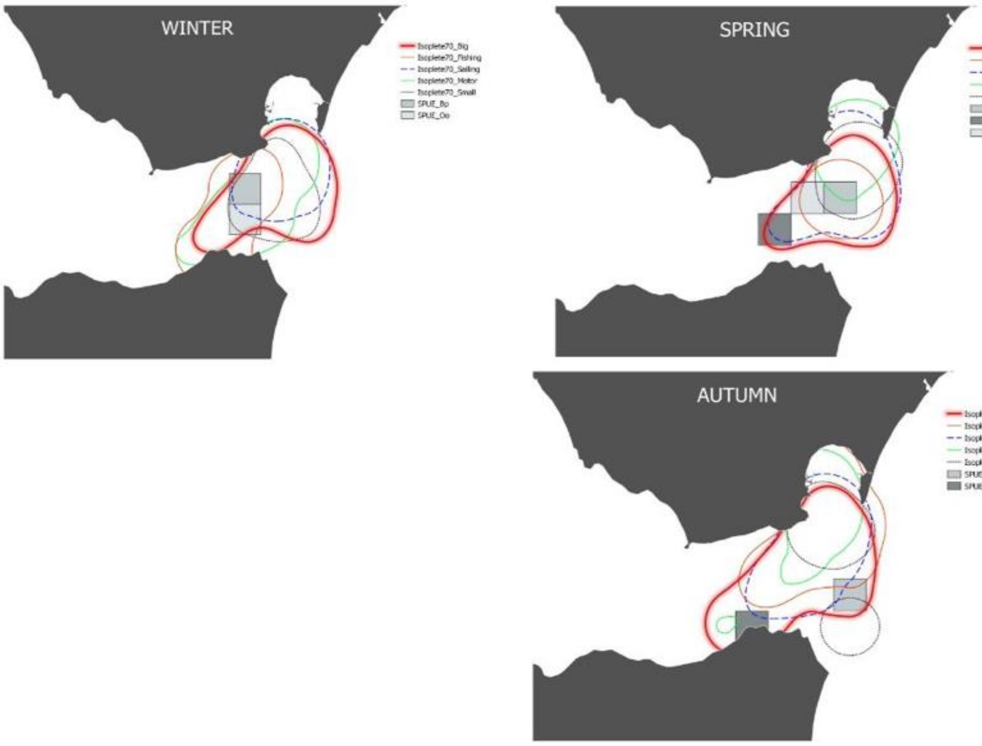

Figure 5.10 Maps of the Strait of Gibraltar highlighted the relative abundance of fin (Bp), sperm (Pm) and killer (Oo) whales expressed as Sightings Per Unit of Effort (SPUE) and with marked isopleths of the different types of vessels.

Near Miss Events of collision

Pilot, sperm and fin whales were the species involved in NMEs of collision, three of which happened in the transect ALCE and one in ALTA. The visibility state during the sightings was mean except for the sperm whale which was good, the sea state was mainly 2 (3 cases of 4) and it never rained (figure 5.5 and supplementary material 5.1, I and II).

Pilot whale NMEs occurred twice in 2019, codes: GmNME1 and GmNME2 (figure 5.5). GmNME1 happened in June and involved a pod of 18 individuals with two juveniles, that were at 60 meters and at 0°(in front of the bow) from the ferry and were travelling west. Ferry navigated at 17.10kn heading 342.1°, there were another 12 more vessels in the area, and the sea state was 3. GmNME2 was in October, where three adults of pilot whales and one juvenile were slowly travelling northwest, they were spotted at 500m and at 0° from the platform. The ferry kept a speed of 19.60kn and a route of 161.3°(southeast). At the moment of the NME, there were 22 other vessels in the area, of which 20 were bigger than 20 m. (NME positions of Gm1 latitude 35° 58,102 and longitude -5° 19,068; of Gm2 35° 57,152 and -5° 19,471).

On the 8th of June 2018, during the NME an individual sperm whale was spotted at 400m and at 70° to starboard from the ferry travelling to west, the ferry maintained a speed of

16.10kn and a route of 164°. There were only two other big ships in 2 nm radius from the ferry (NME position: latitude 35° 58,009; longitude -5° 19,878).

The last NME was reported along the ALTA transect and involved an adult and a juvenile fin whale travelling southeast. Fin whales were at 1,900m and 30° to port from the platform. The ferry headed to 55° (NE) with a speed of 14.7kn, and 13 other vessels were in the area (NME position: latitude 36° 0,848; -5° 24,157).

The highest percentage of NMEs per species was 16.6 % for sperm whales, followed by 12.5% and 10.52% for fin and pilot whales respectively.

Overlapping cetaceans' risk areas and spatial protection measures

The most important area for common, striped and bottlenose dolphins inside the Bay was identified in the central part and just partially overlapping with the spatial management measures of the Dolphin Protection Zone and the SAC-ES6120032 Estrecho oriental (further details in table 5.1).

The central- south and east parts of the sub-area of study resulted important for bottlenose dolphin, pilot, fin and sperm whales. These areas partially overlay only with the Intercontinental Mediterranean Biosphere Reserve and the Cetacean Critical Navigation Zone (figure 5.11, b).

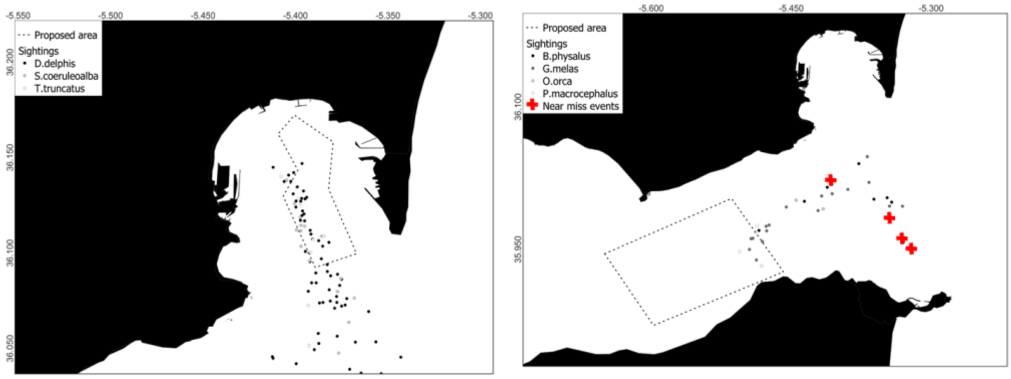

Figure 5.11 Maps of the Bay between Algeciras and Gibraltar (on the right) and of the subarea of study in the Strait of Gibraltar (on the left), in which are marked the international micro-sanctuary and the Cetacean Critical Navigation Zone respectively.

5.1.4 Discussions on cetacean distribution, maritime traffic, and spatial management tools

The **use of a non-dedicated platform to monitor large marine areas** is a cost-effective method that allows a long-term investigation of cetacean species and pressures, such as maritime traffic (Campana et al., 2017). In the present study data collected from the ferries travelling across the Strait of Gibraltar provided useful insights into the seasonal presence of the species along with the characterization of maritime traffic. This information is generally grounded in ship tracking or port monitoring systems, while relationships with different vessel types were provided here. The whole data obtained by the monitoring program using ferries as a platform of observation gave critical information for an effective evaluation of the spatial management tools.

This study corroborates the **presence of the seven cetaceans species** inhabiting the Strait's waters (Cañadas et al., 2005; de Stephanis, Cornulier, et al., 2008), all showing a constant presence over the investigated period. Only fin whale presented an increase in the second year may be due to its highly dynamic seasonal behaviour (Geijer et al., 2016). Furthermore, the number of fin whale sightings per year in the Strait has shown a high degree of variability in the past (among 7 and 29, data from 1999 to 2014), (Gauffier et al., 2018). For the most sighted species common and striped dolphin, seasonal variations in abundance were also documented by this study, as well as reported by Espada Ruíz *et al.* (2018).

Maritime traffic intensity resulted quite high throughout the year, with an increase during summer and with variations in composition, according to other areas (Campana et al., 2017; Coomber et al., 2016) (marinetraffic.com). Sampling data resulted in accordance with the general information obtained from Tarifa Trafico, but added specifications about the smaller types of vessels and their activity, confirming the reliability of the visual sampling protocol (Campana et al., 2017). On this basis, it was possible to describe the specific relationships with the different sectors of maritime traffic.

The spatial analysis of **cetaceans and maritime traffic** allowed us to highlight the main areas of overlap, where interaction is most likely to occur (figure 5.8, 5.9, 5.10 and supplementary materials 5.1, III). The study area is dominated by high maritime traffic, especially in the central part of the Strait due to large ships transiting along the Traffic Separation Scheme of the Strait of Gibraltar, while areas with a higher frequency of cetacean sightings were identified in the Bay and the central-southern part of the Strait, close to the main ports. The investigation of different vessel types, which can differentially affect species (Grossi et al., 2021; Herr et al., 2020; Tenan et al., 2020), is therefore important for planning effective management measures.

Considering all cetaceans, the difference in vessel abundance was positive for small, motor and fishing boats, probably indicating a real overlap between traffic and cetacean hotspots, that could be also driven by a possible positive/approaching behaviour between human activities and some species, such as fishing during autumn and winter (sometimes also represented by small boats) or whale watching (motor boats, table 5.3, a). These differences were confirmed in autumn, winter and spring when fishing vessels were even observed only in the presence of cetaceans. A negative difference in vessel abundance instead, can be related to the effect of traffic towards the animal's avoidance behaviour or to independent spatial segregation of cetacean and vessel observations (Campana et al., 2017). This was found considering all data for sailing and big vessels, even if on a seasonal basis more variable and no significant results were obtained (table 5.3, a). For example, during winter and spring, a higher number of sailing boats resulted in the presence of sightings, probably due to the approach of vessels to the dolphins during sailing boat trainings (Espada Ruíz et al., 2018). During summer instead, no relationship was found between maritime traffic and cetacean presence, although few data were collected during this season. This result is probably a consequence of the actual co-presence of species and vessels in the season of major abundance of both, and it was also reported in other studies, where potential areas of increased risk were identified (Campana et al., 2015; Pennino et al., 2017).

The central part of the Bay is here confirmed as an important area for the **common dolphins** (Olaya-Ponzone et al., 2022), especially from April to December and with a pick of presence during summer (Espada Ruíz et al., 2018). In spite of the Dolphin Protection Zone (Government of Gibraltar, 2018) partially covering the hot spot of the Endangered *Delphinus delphis* (Bearzi et al., 2021), we found a higher presence of small boats and fishing boats, as well as motor boats during the sightings, which is consistent with existing literature (Espada Ruíz et al., 2018; Olaya-Ponzone et al., 2020, 2022). Espada Ruíz and colleagues described in fact a co-presence of different types of vessels during sightings of common dolphin, 43% of which were whale watching boats, 29% recreational boats (that could encompass motor and small boats) and 22% of Atlantic bluefin tuna fishing boats (Espada Ruíz et al., 2018). In particular, taking into account the presence of fishing boats during the sightings, the fishing activity must be regulated as dolphins are frequently used as signs to find the aggregations of bluefin tuna, and the 'popping' technique should be controlled by penalizing fishermen who cast on dolphin–tuna feeding aggregation groups (Espada Ruíz et al., 2018; Olaya-Ponzone et al., 2020). Moreover, there are documented injuries inflicted on common dolphins by human activities, including fishing interactions and propeller strikes, probably as a result of the high level of fishing, recreational and whale-watching activities in the area (Olaya-Ponzone et al., 2020). Therefore findings of this study strongly support the request to design a specific micro-sanctuary in the central part of the Bay (figure 5.11) preventing or restricting navigation, prohibiting bluefin tuna fishing (Olaya-Ponzone et al., 2022) to protect the local Endangered population of common dolphins, also given the peak of the presence of mothers with calves pods during the summer season (Espada Ruíz et al., 2018) that are more vulnerable and prone to change behavior (Castro et al., 2022).

Even though **striped dolphins** were spotted in mixed groups with the common dolphins (Olaya-Ponzone et al., 2022), we observed that striped dolphins have a wider distribution throughout the Strait. This result could be in line with the spatial separation of the core areas of distribution of the two species (Giménez et al., 2017). Both species showed signs of injuries produced by anthropogenic causes (Herr et al., 2020; Olaya-Ponzone et al., 2020) and in our study, a higher presence of small and fishing boats was observed during their sightings. A positive association with these types of vessels was also reported in the Sardinian waters by Pennino and colleagues (Pennino et al., 2016). Accordingly, the previously proposed micro-sanctuary (figure 5.11), together with the enforcement of the surveillance and with a coordinated effort among Gibraltarian and Spanish patrolling forces, could also improve the conservation of the striped dolphin.

The **bottlenose dolphins** were sighted from July to March in the Strait and using the central part of the Bay from April to June as the common dolphin, albeit spatial segregation among species was observed in the Bay (whale watching operators' personal communication) and in another area (Methion & Díaz López, 2021). *Tursiops truncatus* is listed in the EU Habitat Directive (its transpositions Spanish R.D. 1997/1995 and British Conservation Natural Habitats &c. Regulations 1994) as a species of special interest whose conservation requires the designation of SAC, and it is also included in Annex IV as a species of community interest and that requires strict protection. The Strait includes three SAC and one SIC. Even so, it is notable to observe that all of our bottlenose sightings and those of other studies (de Stephanis, Cornulier, et al., 2008), just partially overlap with some areas of protections in force in the Strait (figure 5.1, b). The Intercontinental Mediterranean Biosphere Reserve, which unfortunately does not have cetaceans protection measures and a management plan either, covers the high suitable habitat in the central part of the Strait; the SAC - ES6120032 and the Dolphin Protection Zone, which establish measures directed to the protection of dolphins, moderately include an important area for bottlenose dolphin identified in spring (figure 5.4 and 5.6). A possible measure to mitigate impact could be the improvement of surveillance during the spring (April-June) in the Bay to optimize conservation efforts for the species. Moreover, the bottlenose population of the Strait seems to be spatially segregated from the adjacent population in the Gulf of Cádiz (Giménez, Louis, et al., 2018), their apparent annual survival probability was negatively correlated with ferry traffic (Tenan et al., 2020) and showed evidence of anthropogenic injuries (Herr et al., 2020), so it is needed to adjust the conservation management tools applied in the Strait. As observed for striped and common dolphins, during the sightings of bottlenose dolphins the presence of small and fishing boats was high. Considering the similarity of these results for the three dolphin species, we assume that in addition to the common dolphin (Espada Ruíz et al., 2018), also the other two species could be used as indicators of fish aggregation by fishermen. Conversely, all three species reflected the negative effect of big ships, as in other high-traffic areas (Pennino et al., 2016), despite David (2002) reported that in the Strait dolphin species do not seem to perceive big vessels as a danger. These results strongly support the need to improve protection measures for these species, especially during summers when a higher presence of all types of vessels was observed in the Bay during their sightings, and higher traffic is reported in the whole Strait.

We here endorsed the presence in the central part of the Strait of the Critically Endangered **long-finned pilot whale** (Verborgh & Gauffier, 2021), a resident species that is reported using the central and eastern parts of the Strait (Cañadas, 2008; Cañadas et al., 2005; de Stephanis et al., 2014; de Stephanis, Cornulier, et al., 2008; de Stephanis, García-Tíscar, et al., 2008; de Stephanis, Verborgh, et al., 2008), and that is afflicted by difference injuries of anthropogenic origin (e.g. effects of collisions, entanglement in fishing line or hook, etc.) (Herr et al., 2020; Verborgh et al., 2016). This agrees with the association observed with fishing boats

(+1,214%), while a general avoidance of other vessel types was shown by the species. The study also reported two NMEs of collision in the southern part of the Strait, where traffic of big ships is heavy and where no specific spatial management measures (such as speed reduction) have been implemented.

The reduced number of sightings of **fin, sperm and killer whales** did not allow us to describe their distribution and seasonal presence. Nevertheless, all these species were sighted in the central-southern part of the Strait, overlapping the Traffic Separation Scheme of the Strait of Gibraltar and inside the area of major presence of big ships (e.g. containers, bulk cargos, cruise, etc.). It has been reported that a portion of this area deemed important for these species was designated as a precaution zone called 'Cetacean Critical Navigation Zone', in which speed must be restricted to 13 knots in order to avoid collisions with whales, and a good lookout should be maintained between April and August (National Geospatial Intelligence Agency, 2022), and specifically for the sperm whale (Silber et al., 2012). Indeed the percentages of NMEs of the fin (12.5%) and sperm (16.6%) whales are quite high compared to the low number of sightings.

The presence of Dedicated Observers on board and the training of the crew members (Gende et al., 2019) could be applied as effective measures for reducing the risk of collision. Considering what previously discussed for pilot, sperm and killer whales, we suggested in addition that the "Cetacean Critical Navigation Zone" (as named in the Marine Spatial Planning of the Strait and of Alborán Sea by the Spanish Environmental Ministry[20]) should be extended to the west and should be changed from recommendation to mandatory in reducing the speed of all vessels to 13kn (figure 5.11).

All three states that line the Strait (i.e. Morocco, Spain and Gibraltar) are signatories to the conventions ICRW, CITES, BCCEW and CMS that aim to conserve and protect endangered species as well as their habitats, which also includes cetaceans. On the other hand, to the best of our knowledge there is currently no **common management plan** for the water of the Strait that focuses on conserving cetaceans. The importance of the Strait for cetaceans is confirmed by the designation of several IMMAs crossing it and the criticality of the area was highlighted by naming it as CCH. The presence of the SAC and SIC, being important management tools, may not be sufficient to conserve species at high mobility as cetaceans (Dwyer et al., 2020). We have to consider the temporal and variable cetaceans' presence when managing the spatial (Wilson et al., 2004). For instance, seasonal and dynamic regional shipping plans including mandatory reduction of speed and/or rerouting, have been adopted in portions of the Salish Sea[21] and the North Atlantic[22] to protect southern resident killer whales and North Atlantic right whales (NARW). In the case of NARW, the effectiveness of this approach was proved with a reduction of mortality due to ship strike events (Laist et al.,

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[20] https://www.miteco.gob.es/es/costas/temas/proteccion-medio-marino/estrategias-marinas/demarcacion-estrecho-alboran/

[21] https://www.pac.dfo-mpo.gc.ca/fm-gp/mammals-mammiferes/whales-baleines/srkw-measures-mesures-ers-eng.html#maps

[22] https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales

2014). Recently, in the Strait a temporal spatial management tool was used to reduce negative interaction among orcas and vessels. Navigation limitations from the Gulf of Cádiz to Tarifa were in full force to increase vessels' safety between 8th of August and the 22nd of September 2021 (Ministerio de Transporte Movilidad y Agenda Urbana, 2021a, 2021b)[23]. This supports the idea that a temporal plan could be designed to protect the cetaceans of the Strait, including speed restrictions and a no-take zone inside a micro-sanctuary.

5.1.5 Conclusions

Monitoring cetaceans using ferries as platform allows for providing significatively insights on cetacean distribution and maritime traffic, essential knowledge for improving the management cost-effectiveness of the marine areas. In the Strait of Gibraltar, the presence of the cetaceans' Dedicated Observers on board should be supported by the local administrations beyond the private nautical company and environmental NGO, as well the monitoring should cover equally all seasons, including the summer, to improve understanding of the high mobile cetaceans' distribution patterns. Further, mandatory training for bridge officers and other ferry crew members, together with the presence of DOs on board, would reduce collision risks significantly.

In the Strait, despite being widely recognized as an important area for the diversity of highly protected and mobile species, the spatial management tools in force are covering just partially the cetaceans hot spots and are static tools. In addition, the transboundary area of the Strait of Gibraltar does not have a respective transboundary management effort. It is time for the Spanish, Gibraltarian and Moroccan States to move from the conservation intentions (i.e. international agreements and conventions) to the actions (e.g. transboundary zone with a mandatory reduction of vessels' speed).

An international temporal, or in some zone, permanent speed reduction area (i.e. Nautical Critical Zone for the Presence of Cetaceans) and a micro-sanctuary (in the Bay between Algeciras and Gibraltar), could be effective management measures harmonizing maritime activities and cetacean conservation.

Finally, seeing the presence of this long-term monitoring program carried out throughout the Mediterranean Sea, the method employed in this study, which combined cetaceans' SPUE, maritime traffic, and spatial management tools analysis, may apply to other sensitive areas.

[23] https://www.orcaiberica.org

5.2 Fixed line transect Mediterranean monitoring network (FLT MED Net), an international collaboration for long term monitoring of macro-mega fauna and main threats

Red Mediterránea de Seguimiento por Transectos Fijos (FLT MED Net), una colaboración internacional para el seguimiento a largo plazo de la macro-mega fauna y las principales amenazas

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CRediT: Investigation, Resources, Data curation, Writing - Review & Editing, Project administration.

Abstract The monitoring of highly mobile species such cetaceans and sea turtle is challenging, and long term dataset based on seasonal repeated surveys can deliver primary information for understanding the main drivers of species movements and detecting early sign of changes. The synoptic monitoring of main threats is also a powerful method for a risk assessment based on real situation. Since 2007, a stable and growing collaboration among international research institutions in Mediterranean is delivering long term continuous information at large scale and on a seasonal basis, with the aim to contributing to improve the understanding of species ecology conservation status and prioritize effective mitigation measures.

Resumen *El seguimiento de especies altamente móviles como los cetáceos y las tortugas marinas es un reto, y el conjunto de datos a largo plazo basado en estudios repetidos estacionalmente puede proporcionar información primaria para entender los principales impulsores de los movimientos de las especies y detectar los primeros signos de cambios. El seguimiento sinóptico de las principales amenazas es también un método poderoso para una evaluación de riesgos basada en la situación real. Desde 2007, una colaboración estable y creciente entre instituciones internacionales de investigación en el Mediterráneo está proporcionando información continua a largo plazo a gran escala y sobre una base estacional, con el objetivo de contribuir a mejorar la comprensión del estado de conservación de la ecología de las especies y priorizar las medidas de mitigación eficaces.*

Key-words: cetaceans, sea turtle, long term monitoring, Mediterranean Sea.

5.2.1 Introduction

The Fixed Line Transect Mediterranean monitoring Network (FLT MED Net) is a network of research bodies using ferries as platform of observation to perform systematic surveys along several trans-boundary transects in the Mediterranean Sea. The network is coordinated by ISPRA and is run in collaboration with research bodies from Italy, France, Spain, Tunisia and Greece. More than 20 scientific partners are involved in the data collection, protocol definition, and data analysis. Aim of the Network is the long term monitoring of key marine species and the main threats to detect early signs of changes in species abundance, distribution and habitat use, and link these to main environmental and anthropogenic drivers.

5.2.2 Materials and methods

All the partners share the same protocol for the systematic survey of the marine species listed in the Habitat Directive 92/43/EEC (e.g. cetaceans, marine turtles and seabirds) and their main threats (i.e. maritime traffic, marine litter). Researchers and university students are involved in the data collection. Five surveys per season are undertaken all year round along each transect. Transects cross high sea and national waters among Italy, France, Spain, Greece, Tunisia, and, since January 2018, Morocco. Five ferries companies collaborate to the project. Data on marine fauna are collected using the distance sampling method, while marine litter data are collected using the strip transect protocol (Supplementary Material 5.2). Since 1989, the cetacean protocol was improved in order to strengthen the systematic approach of survey and the trans-boundary nature of transects. The marine litter protocol was specifically designed for large vessels (item >20 cm), and was perfected within the Interreg MEDSEALITTER project, in line with the revision of the Guidance for monitoring floating marine litter within the MSFD.

5.2.3 Results

In ten years of monitoring, the network surveyed more than 300,000 km in 10 routes, totalizing almost 7,500 cetacean records. The most sighted species were *Balaenoptera physalus* (N=2162) and *Stenella coeruleoalba* (4158), followed by *Tursiops truncatus* (546), *Physeter macrocephalus* (277), *Ziphius cavirostris* (152), *Globicephala melas* (47), *Delphinus delphis* (96), *Grampus griseus* (50) and *Orcinus orca* (1). Seasonal and yearly variations in abundance and distribution were recorded in all the studied areas. Almost 1,700 records of sea turtles were also recorded, allowing seasonal comparison of species distribution within different basins. To date the network produced 26 scientific papers published in ISI indexed journals, 73 conference papers, 37 University theses (Bachelor, Master, PhD) and 5 reports. The articles investigated seasonal presence and distribution for conservation purposes, long term trends, habitat use, correlation with environmental features, and influence of the main threats.

5.2.4 Conclusions

The synoptic collection of species and main threats data, allowed to assess risky areas/seasons were species are most exposed to threats, highlighting a complex situation in which the type and level of risk are determined by a combined effects of species diversity, abundance, juveniles presence, and differentiate primary biological needs. Results underlying thus the need for an adaptive conservation and the important contribution of continuous high sea monitoring across seasons to gather robust long-term datasets. The high number of repeated surveys allowed also to deliver interesting insights for the monitoring and modelling of rarer pelagic species.

5.3 Testing indicators for trend assessment of range and habitat of low density cetacean species in the Mediterranean Sea

Comprobación de indicadores para la evaluación de tendencias del área de distribución y del hábitat de especies de cetáceos de baja densidad en el Mar Mediterráneo

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CRediT of the PhD candidate: Data Curation, Writing - Review & Editing.

Through this study, we aim to contribute to the understanding of changes in distribution, such as contraction or expansion, of the three low-density species of cetaceans *G.griseus, G.melas* and *Z.cavirostris*. Four potential indicators (i.e. Observed Distributional Range, Ecological Potential Range, Range Partners and Observed vs Ecological Potential Range) are tested to assess range and habitat short-term trends of the low-density species along Habitat Directive 6-years periods (2013-2019/2008-2012) and to contribute to the evaluation of potential approaches to support legislative requirements.

Abstract Conservation of cetaceans is challenging, due to their large-range, highly-dynamic nature. The EU Habitats Directive (HD) reports 78% of species in 'unknown' conservation status, and information on low-density/elusive species such as *G.griseus, G.melas, Z.cavirostris* is the most scattered. The FLT-Net programme regularly collected year-round data along trans-border fixed-transects in the Mediterranean Sea since 2007. Nearly 7,500 cetacean sightings were recorded over 500,000 km of effort, with 296 less common species. Comparing data across two HD 6-years periods (2013-2019/2008-2012), this study aimed at testing four potential indicators to assess range and habitat short-term trends of *G.griseus, G.melas, Z.cavirostris*: 1) change in Observed Distributional Range based on known occurrence, calculated through the Kernel smoother within the effort area; 2) change in Ecological Potential Range extent, predicted through Spatial Distribution Models; 3) Range Pattern, assessed as overlap and shift of core areas between periods; 4) changes in Observed vs Ecological Potential Range. Most Observed and Ecological Potential areas confirmed the persistence of known important sites, especially in Western Mediterranean. All species, however, exhibit changes in distribution extent (contraction or expansion) and an offshore shift, indicating exploitation of new areas or operating pressures. Results confirmed that the Observed Distributional Range could underestimate the real occupied range, as referring to the effort area only; it can be used to detect trends providing that the spatio-temporal effort scale is representative of the species range. The Ecological Potential Range allows generalising species distribution outside the effort area, defining species' habitat and the proportion of Occupied/Potential Range. If used for investigating range trends, it needs to be adjusted based also on the Occupied/Potential Range proportion since it could be larger than the occupied

range in presence of limiting factors, or smaller, if pressures force the species outside the ecological niche. Using complementary indicators proved valuable to disclose the significance of changes. The concurrent analysis of more species with similar ecology too was critical to assess whether the detected changes are species-specific or representative of global trends. The FLT-Net sampling design proved adequate for trend assessment in Western-Mediterranean and Adriatic, while more transects are needed to intercept the central-Mediterranean and Levantine ecological variability.

Resumen *La conservación de los cetáceos, animales altamente dinámicos y de amplia distribución, es un reto. La Directiva de Hábitats (HD) de la UE informa de que el 78% de las especies se encuentran en un estado de conservación "desconocido", y la información sobre especies a baja densidad/escurridizas como G.griseus, G.melas, Z.cavirostris es la más escasa. El programa FLT-Net recoge regularmente datos durante todo el año a lo largo de transectos fijos transfronterizos en el Mar Mediterráneo desde 2007. Se registraron casi 7.500 avistamientos de cetáceos a lo largo de 500.000 km de esfuerzo, con 296 avistamientos de especies menos comunes. Comparando datos a lo largo de dos periodos de 6 años HD (2013-2019/2008-2012), este estudio tiene como objetivo testar cuatro indicadores potenciales para evaluar las tendencias a corto plazo del área de distribución y del hábitat de las especies G.griseus, G.melas, Z.cavirostris: Se estudia 1) el cambio en el área de distribución observada basada en la presencia conocida, calculada a través del suavizador de Kernel dentro del área de esfuerzo; 2) el cambio en la extensión del área de distribución potencial ecológica, predicha a través de modelos de distribución espacial; 3) el patrón de distribución, evaluado como superposición y cambio de áreas centrales entre periodos; 4) el cambios en el área de distribución observada frente al área de distribución potencial ecológica. La mayoría de las áreas de distribución observadas y de potencial ecológico confirmaron la persistencia de lugares importantes ya conocidos, especialmente en el Mediterráneo occidental. Sin embargo, todas las especies muestran cambios en la extensión de su distribución (por contracción o por expansión) y un desplazamiento mar adentro, lo que indica la explotación de nuevas zonas o una consecuencia de las presiones. Los resultados confirmaron que el área de distribución observada podría subestimar el área de ocupación real, ya que se refiere únicamente al área de esfuerzo; que puede utilizarse para detectar tendencias siempre que la escala de esfuerzo espaciotemporal sea representativa del área de distribución de las especies. El área de distribución ecológica potencial permite generalizar la distribución de las especies fuera de la zona de esfuerzo, definiendo el hábitat de las especies y la proporción de área de distribución ocupada/potencial. Si se utiliza para investigar las tendencias del área de distribución, debe ajustarse también en función de la proporción de área de distribución ocupada/potencial, ya que podría ser mayor que el área de distribución ocupada en presencia de factores limitantes, o menor, si las presiones obligan a la especie a salir del nicho ecológico. El uso de indicadores complementarios resultó valioso para revelar la importancia de los cambios. El análisis simultáneo de más especies con una ecología similar también fue fundamental para evaluar si los cambios detectados son específicos de una especie o representativos de tendencias globales. El diseño de muestreo de la red FLT resultó adecuado para la evaluación de tendencias en el Mediterráneo occidental y el Adriático, mientras se necesitan más transectos para interceptar la variabilidad ecológica en el Mediterráneo central y el Levantino.*

Keywords: conservation, habitat modelling, monitoring, Risso's dolphin, long-finned pilot whale, Cuvier's beaked whale, Habitat Directive, MSFD Descriptor.

5.3.1 Introduction

The conservation of cetacean species is extremely challenging due to the large extent of their range and their highly dynamic nature. The European Environmental Agency (EEA) Report (No 10/2020) states that "marine mammals (including cetaceans) are among the species with the highest proportion of unknown assessments (over 78%)". Data deficiency is mainly due to the fact that most cetacean species spend the majority of their life in remote offshore areas, which are more difficult to monitor due to logistical reasons, linked to the organisation of surveys, and political reasons, such as coordinating the effort in areas overcoming socio-political borders requires functional international cooperation. Moreover, the high costs generally required for carrying out regular large-scale surveys prevent the possibility to gather sufficient information, especially on rare species.

Low-density cetacean species conservation status in the Mediterranean Sea

In the Mediterranean Sea, Risso's dolphin (*Grampus griseus*, Gg), long-finned pilot whale (*Globicephala melas*, Gm), and Cuvier' beaked whale (*Ziphius cavirostris*, Zc), are considered low-density elusive species. Their assessment status under the IUCN Red list of threatened species recently changed from 'Data Deficient' to, respectively, 'Endangered' (Gg, Lanfredi et al., 2021), and 'Vulnerable' (Gm, Gauffier and Verborgh, 2021; Zc, Cañadas and Notarbartolo di Sciara, 2018). A distinct subpopulation of long-finned pilot whales, limited to the Strait of Gibraltar area, and listed as 'Critically Endangered', was also identified during the last assessment (Verborgh & Gauffier, 2021). The three species are listed in Annex IV of the EU Habitats Directive (HD, Directive 92/43/EEC) requiring a special protection regime across their natural range, both within and outside the Natura 2000 sites, to enable their Favourable Conservation Status (FCS) to be maintained or, where appropriate, restored, in their natural range. The core areas of their habitat must be identified, designated as Sites of Community Importance, included in the Natura 2000 network, and managed in accordance with their ecological needs. Moreover, Member States must regularly report to the EU on their conservation status. Cetaceans are also a target species of Descriptor 1 (Biodiversity) of the Marine Strategy Framework Directive (MSFD, Directive 2008/56/EC), which aims at achieving a Good Environmental Status (GES) of EU marine waters by establishing a common approach and objectives for the prevention, protection and conservation of the marine environment. Thus, information about the preferred habitats of cetacean species and the early detection of potential changes in their distribution is essential to identify needed conservation measures.

Overview of approaches for assessing range and habitat trends

Despite the fact that the HD focuses on the conservation status of the species (i.e., the effects), and the MSFD on eliminating the causes (i.e., the threats) through mitigation measures that will restore the GES (Palialexis et al., 2019), the HD and MSFD have strong synergies. Under the MSFD, Member States are required to establish threshold values for each species through regional or sub-regional cooperation and, for species covered by the HD, these values shall be consistent with the Favourable Reference Values (FRV) established under the HD. Both HD and MSFD directives require reporting every six years equivalent parameters/criteria for the assessment of the species conservation status, such as 'Range' (i.e., HD 'The natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future'; MSFD D1C4 'the species distributional range and, where relevant, the pattern, is in line with prevailing physiographic, geographic and climatic conditions'), and 'Habitat' (i.e., HD 'There is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis'; MSFD D1C5 'The habitat for the species has the necessary extent and condition to support the different stages in the life history of the species'). Similarly, the EO1 assessment within the Barcelona Regional Sea Convention (UNEP-MAP, EO1) is based on the Common Indicators (CI) 3 ('Species distributional range') and 1 ('Habitat distributional range'). The IUCN Guidelines for the assessment of the conservation status of threatened species also foresee the assessment based on the criteria A2c ('A decline in Area Of Occupancy-AOO, Extent Of Occurrence-EOO and/or habitat quality') and B ('Geographic range'). Specifically, the AOO is defined as 'the area contained within the shortest continuous imaginary boundary that can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy' (IUCN, 2011), where 'Projected sites' are considered as the sites spatially predicted on the basis of habitat maps or models (area of potential habitat, also called Extent of Suitable Habitat, ESH). A suspected decline in the AOO could consequently be estimated based on the reduction of suitable habitat. Beside this, also the Reporting Guidelines of the Habitats Directive (2017) suggest to evaluate the FRV as the AOO, or as the potential range in relation to available suitable habitat ('Ecological potential', the potential extent of range considering physical and ecological conditions). Within such legal requirements, Spatial Distribution Modelling (SDM) is a promising approach to support the assessment of cetacean species. Indeed, SDM can be used to support regulatory decision-making for conservation, i.e., by informing on spatial prioritisation through the identification of biodiversity hotspots, important areas for vulnerable species, or valuable habitats, overcoming the problems related to coarse or incomplete knowledge (Franklin, 2010; Maiorano et al., 2019). Time series of comparable data with sufficient statistical power, coupled with standardized SDM analyses, can help identify changes from a reference period, trends in a data series or shifts in the species range. A significant reduction in the extent or a shift of species' geographical distribution can then be related to a modification in the environmental drivers and/or in the conditions of the habitat or population, or to the effect of anthropogenic pressures. Moreover, the comparison of the suitable habitat predicted through SMD with the distributional range observed may provide an indication of potentially suitable areas that are not used by the species due to the influence of anthropogenic pressures or other limiting factors. However, at this date, no relevant indicators or threshold values have been developed yet (Palialexis et al., 2019), and some recommendations were only recently provided through international scientific cooperation to define indicators, assessment methods, and data requirements for the assessment of marine turtles under the MSFD (Girard et al., 2022). Moreover, despite an increasing research effort, a limited number of studies attempted so far to infer temporal changes in cetacean distributional range or habitat use, and the 'trend' criterion for these parameters/criteria is still considered 'unknown' for almost all cetacean species in the Mediterranean Sea (last HD report 2013-2018), likely due to the lack of comparable data and standard methodological approaches.

Aim of the study

The Fixed Line Transect monitoring Network (FLT Net) has been operating in the Mediterranean basin since 2007, collecting cetacean data along fixed trans-border transects regularly surveyed throughout the years. Using the dataset gathered across twelve years, this study aims to improve the knowledge on three low-density cetacean species of the Mediterranean basin Risso's dolphin (*Grampus griseus*, Gg), long-finned pilot whale (*Globicephala melas*, Gm), and Cuvier's beaked whale (*Ziphius cavirostris*, Zc), and contribute to the evaluation of potential approaches to support legislative requirements. In particular, using the dataset collected during the third HD six-years reporting cycle (2007-2012) as baseline, the study aims to assess potential changes in the range and habitat of the three species over the subsequent periods (short-term trend) testing four potential indicators: 1) **Observed Distributional Range, ODR**: changes in the extent of ODR detected within the area covered by monitoring effort; 2) **Ecological Potential Range, EPR**: change in the Extent of Ecological Potential Range predicted by means of SDM; 3) **Range Pattern**: percentage of overlap, and shifts of ODR and EPR between the two time periods; 4) **ODR vs EPR**: changes in the proportion of observed distributional range vs the ecological potential range between the two periods. Overall, the study aims to test and evaluate such methodological approaches and indicators to contribute to the species assessment under the requirements of the main European nature legislative framework.

5.3.2 Material and methods

Study Area

Cetacean monitoring was carried out from passenger ferries travelling along 11 trans-border transects, covering the Mediterranean Sea within the latitudes 43.6° N - 35.8° S and longitudes -5.5° E - 20.8° E, and connecting Italy, France, Spain, Greece, Tunisia and Morocco. These transects are included in the Fixed Line Transect Mediterranean Network (FLT Med Net, Arcangeli et al., 2019), and are representative of a large proportion of the Western-Mediterranean, and the Adriatic sub-regions, and the Eastern Ionian Sea in the Central Mediterranean Subregion. Transects considered for the baseline period (2008-2012) covered the effort area shown in dark grey in figure 5.12. In the second period (2013-2019) monitoring was also extended to the area in light grey.

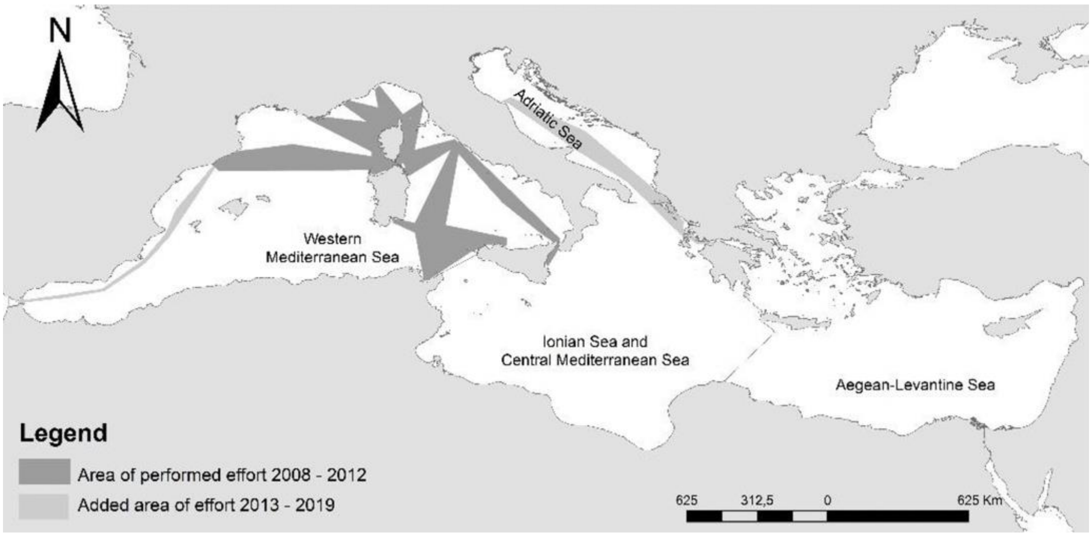


Figure 5.12 Study Area with the survey effort performed by the FLT Med Net during 2008-2012 (I baseline period, dark grey) and 2013-2019 (II period, dark and light grey). The four Mediterranean MSFD Subregions are shown in the figure: Western-Mediterranean (WMED), central-Mediterranean (Central MED), Adriatic, Aegean-Levantine Sea (downloaded from the European Environment Agency www.eea.europa.eu).

Data collection

The monitoring activity was performed on a seasonal basis with at least three surveys per season along each sampling transect. Seasons were defined as winter (January to March), spring (April to June), summer (July to September) and autumn (October to December). Data on cetacean species were systematically collected following a standard protocol applied from large vessels, ISPRA 2015 (supplementary material 5.2). Ferries provided an observation point at 20−29 m above sea level and travelled at a mean speed in the range of 19−25 knots. Two experienced observers were positioned on the two sides of the command deck scanning both sides of the ship within an angle of 130° ahead in order to avoid re-counting the animals; observations were performed by naked eye and binoculars; binoculars and cameras were used to correctly identify the species and the number of animals. A dedicated GPS was used for automatically recording the survey track at the finest resolution, marking the beginning/ending points and the locations of cetacean sightings. Monitoring was carried out during daylight hours only in optimum weather conditions (<4 on the Beaufort scale).

Data analysis

All the analyses performed for this study considered the sighting as a statistical unit, regardless of the number of animals. However, the mean group size was preliminarily reported to verify potential differences over the two periods. Data were analysed considering the different Mediterranean sub-regions of the MSFD: Western-Mediterranean (WMED), central-Mediterranean (Central MED), Adriatic, and Aegean-Levantine Sea (figure 5.12).

Observed Distributional Range, ODR

As suggested by the HD Guidelines (DG ENV, 2017), the Kernel Density estimator (KDE) was used to spatially generalize the distribution of the species occurrence, identifying the extent and the core areas of species within the area covered by effort. After initial testing, the KDE analysis was set with a resolution cell of 500 m, and a search radius of 50,000 m. The 95% isopleth was used to define the extent of the Observed Distributional Range (ODR), calculated in km2. After calculating the area covered by the effort for each time-period (EffortArea), the proportion of species ODR inside the effort area was calculated per each sub-region and time-period. Then, the ODRs of the two periods were displayed and overlapped, and the temporal trend in the ODR extent was estimated as: Δ distribution = [(ODR/EffortArea(2nd period) – ODR/EffortArea(1st period)) x 100]. Following the OSPAR indicators for seals (Palialexis et al. 2019), threshold values were defined as: if index > 10% = increase, if index < -10% = decrease, otherwise = no change.

Ecological Potential Range, EPR

The changes in the Ecological Potential Range (EPR) between the two periods were assessed based on projected sites of species occurrence, using spatially predicted sites based on the habitat maps models (also called Extent of Suitable Habitat) (IUCN Guidelines 2011, 2022). The following criteria were preserved: i) use of adequate spatial resolution for the species knowing their range in the Mediterranean Sea, key variables, and appropriate model validation; ii) validation of suitable maps with independent datasets not used to build models; iii) estimate of the proportion of suitable habitat likely occupied by the species (within the area of effort).

Maximum Entropy (MaxEnt version 3.3.3, http://www.cs.princeton.edu/~schapire/maxent/) was applied to model the relationships between environmental predictors and the occurrence records, and to build the Suitable Habitat Maps for each of species over the two periods. MaxEnt was chosen as it provided more consistent results than the most common modelling approaches (Arcangeli and Orasi, in prep), and is generally more adequate for low presence records and deep divers or elusive species, for which absence data cannot be sure. MaxEnt is a machine learning method commonly used in systems with restricted information based on a probability distribution with maximum entropy (the most spread out, closest to uniform), subject to known constraints (Phillips et al., 2006): MaxEnt generates a probability distribution of suitable habitats over pixels in the grid, starting from a uniform distribution and repeatedly improving the fit to the data. Since MaxEnt accounts for sampling biases via correction features that consider area of sampling effort used to generate pseudo-absences points (‘background points’), a bias file of effort was built using the Minimum Convex Polygon (MCP) around the surveyed sites (figure 5.12). The spatial resolution of the dataset used for modelling was adequate for the species distribution and their known ranges in the Mediterranean Sea: the model was indeed built based on heterogeneously distributed effort in the Western-Mediterranean Sea and Adriatic-eastern Ionian Region, largely representing the variability of the environmental parameters in these areas, while the projection was performed at Mediterranean basin wide scale and the outputs successively tested for reliability. Two dataset were used: 1) the dataset obtained from the systematic long-term monitoring along the FLT routes, including the effort track lines to build the background file and sightings as presence points; 2) sighting data gathered by ORCA NGO during cruises in the Mediterranean basin (2016-2018), ACCOBAMS Survey Initiative at Mediterranean scale (2018), and local scale data from Ketos-Mare Camp organizations (Catania Gulf – east Sicilian Ionian coast) as independent dataset for the validation of the model results. The preparation of data for modelling included: 1) a Bias file (background file) built as Minimum Convex Polygon (MCP) around the track lines of effort; 2) presence data per each species prepared as .csv file with information on Species, Longitudes, and Latitudes; 3) environmental variables prepared as raster files with same scale, extension and resolution. Nine key predictor variables, known to be relevant for the biology of the species (e.g. Fullard et al., 2000, Moors-Murphy 2014, Breen et al., 2020, Dede et al., 2022) were included in the model (i.e., Depth, Standard Deviation of Depth, Distance from the coast, Distance from seamount, Distance from Canyon, Slope, Aspect North, Aspect South, Chl mean, SST mean) and used as proxies of the factors that could affect species presence and distribution. After a preliminary test to verify correlation among variables, Standard Deviation of Depth was excluded as correlated with Slope.

MaxEnt was run splitting the dataset into two periods, using 2008-2012 as a reference baseline for being compared with the more recent 2013-2019 period (almost corresponding to the third and fourth HD reporting cycles). The effort area was consistent between the two periods, except for the Adriatic-eastern Ionian Region, the Barcelona-Tanger and the Strait of Gibraltar routes, which were only surveyed during the second period (light grey area in figure 5.12). Thus, two bias files were used to define the area from which to extract the background points. For each period, distinct MaxEnt models were run, using the same settings and set of variables. After preliminary runs with different setting parameters, the default recommended feature classes (hinge, linear, quadratic) and regularization parameters (i.e., =1) were used, with 10,000 background points and maximum iterations up to 500 to reach convergence at a threshold of 0.00001. Duplicates were removed to reduce problems of pseudo-replication and spatial autocorrelation of samples. Random seeds bootstrap replication type over 34% test samples (Efron and Tibshirani, 1997) and 100 iterations were used to obtain a summary output and response curves with statistical indication on standard deviation and error bars. A Jackknife test was conducted to obtain alternative estimates of the variable contribution to the MaxEnt run. The logistic format was used to improve model calibration, displaying output maps that better highlight the continuum of differences in the suitable maps produced, so that large differences in output values correspond better to large differences in suitability (Phillips and Dudík, 2008). As suggested by Pearson et al. (2007), more than 15 presence points were used for each model: 86 presence points were used for Gg (N1st period = 27; N2nd period

= 59), 68 for Gm (N1st period = 16; N2nd period = 52), 142 for Zc (N1st period = 27; N2nd period = 115). The descriptive power of each model was evaluated by the Area Under the receiver operating characteristic Curve, a threshold-independent metric of overall accuracy (AUC; Thorne et al., 2012), and by the 'omission rate', i.e., the proportion of test localities falling outside the prediction. The AUC metric determines model discriminatory power by comparing model sensitivity (i.e., true positives) against model specificity (i.e., false positives). The AUC values rangefrom 0 to 1, with values below 0.5 indicating worse model predictions than random, and values over 0.5 indicating improved model precision. The output maps were visually inspected by expert judgement to check for overfitting problems and the general reliability of results. The suitable output maps of the whole study period were first visualized as a continuous colour scheme of suitable-unsuitable prediction and then reclassified in binary suitable-unsuitable predictions under three threshold scenarios (i.e., Minimum training presence logistic threshold, Equal training sensitivity and specificity logistic threshold, Maximum training sensitivity plus specificity logistic threshold). The three thresholds were chosen among the most commonly used available by MaxEnt (e.g., Merrow et al., 2013), considering the balance between the proportional predicted area (proportion of pixels that are predicted as suitable for the species) and the extrinsic omission rate (proportion of test localities that fall into pixels not predicted as suitable for the species). The best threshold method was then chosen based on expert considerations, after visual inspection of the suitable maps, in order to include the area that likely reflects the range of the species, knowing the biology and ecology of the species, the confirmed sites of occurrence, and the species dispersal capability. An independent dataset was also used to assess the power of the resulting binary maps.

To calculate the extent of suitable area (Ecological Potential Range, EPR), the output binary suitable-unsuitable predictions rasters were converted into polygon layers including the highest suitable class for each species and period, and were then used to measure the EPR in km2. Then, the percentage difference in the EPR between periods was calculated for each species as: [(EPR(2^{nd} period) - EPR(1^{st} period)) / EPR(1^{st} period))].

Range Pattern

The trend in distributional pattern was calculated in terms of shift either in the surface or in the centre of gravity (centroid) of range areas (ODR, EPR), assessing the: a) overlapping area between the two periods; b) percentage of overlapping area compared to the first period, and c) direction and magnitude of shift in the centroids of the range area between the two periods (calculated through the geometric spatial zonal statistic in GIS).

Observed Distributional Range vs Ecological Potential Range, ODR/EPR

The proportion of the suitable habitat effectively occupied by the species (ODR vs EPR) was calculated for each period considering only the areas covered by the effort, identified by the MaxEnt bias files. Within these areas, the extent of suitable habitats (Ecological Potential Range, EPR) was estimated in km2. The percentage proportion of the predicted EPR occupied by the species (ODR) was calculated as: [(ODR / EPR) * 100], and differences between periods were computed as: [(%(2nd period) - %(1st period)) / %(1st period))].

5.3.3 Results

During the twelve years between 2008 and 2019, the FLT Med Net covered almost 500,000 km of effort and recorded 296 sightings of Gg (86), Gm (68) and Zc (142). Group sizes of the species were not significantly different between the two periods, but they differed among species: Gg groups were composed by a mean of 5 individuals (5.7 ± 5.1 SD1st period / 4.7 ± 4.3 SD2nd period), while Gm groups were generally larger (7.0 ± 9.5 SD1st period / 7.0 ± 6 SD2nd period), and Zc smaller (mean group size of 1.67 ± 1.0 SD 1st period /1.87 ± 1.2 SD2nd period).

Observed Distributional Range, ODR

Table 5.4 Distribution and extent (in km^2) of the area of effort per each Mediterranean sub-region, the extent of observed species range calculated within the 95% KDE isopleth, and percentage of overlap between observed species range and effort area.

		WMED	Central MED	Adriatic	Aegean-Levantine Sea
Effort Area	**1 period**	191,658	1,579	NoEffort	NoEffort
	2 period	208,088	9,126	19,165	NoEffort
Observed Distributional Range (KDE, Km2)	**Gg_1**	38,415	1,568	NoEffort	NoEffort
	Gg_2	77,173	0,0	2,595	NoEffort
	Gm_1	19,664	0,0	NoEffort	NoEffort
	Gm_2	32,818	0,0	0,0	NoEffort
	Zc_1	29,169	0,0	NoEffort	NoEffort
	Zc_2	37,496	632	0,0	NoEffort
Observed Distributional Range vs Extent of Effort area (Km2)	**Gg_1**	20%	99%	NA	NA
	Gg_2	37%	0%	7%	NA
	Gm_1	10%	0%	NA	NA
	Gm_2	16%	0%	0%	NA
	Zc_1	15%	0%	NA	NA
	Zc_2	18%	2%	0%	NA

The area covered by the effort was the largest in the WMED sub-region, while very limited in the central MED during the first period (i.e., eastern Sicily), and increased during the second thanks to the inclusion of new Adriatic routes covering also the Northern Hellenic Trench. No effort was performed in the Aegean-Levantine sub-region (table 5.4).

Between 10 to 37% of the effort area overlapped with the species observed range (ODR) in the WMED. In the central MED instead, 99% of the effort area overlapped with Gg ODR during the first period (i.e., in eastern Sicily), and a limited percentage with the ODR of Zc (2%) during the second period (i.e., in the Northern Hellenic Trench). In the Adriatic, 7% of the effort area intercepted the Gg ODR in the southern part.

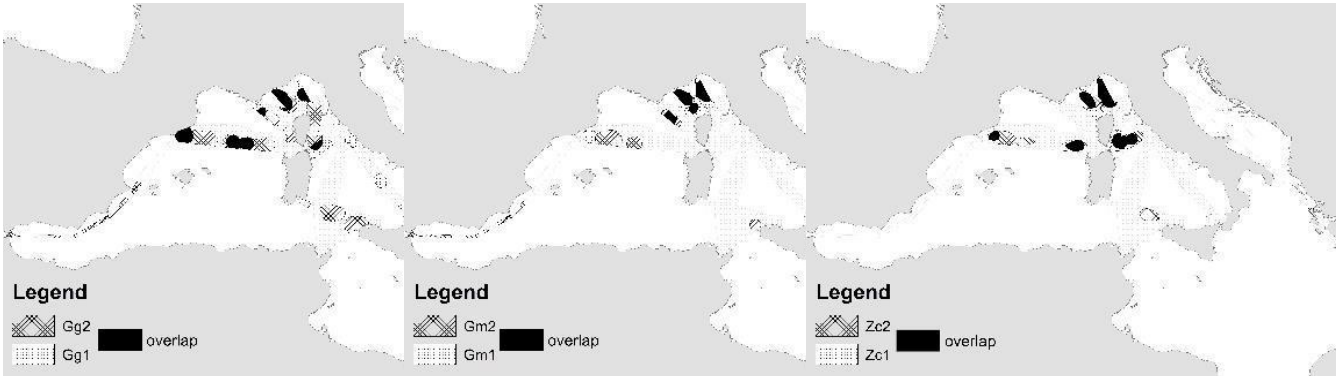


Figure 5.13 Core areas highlighted by the 95% KDE isopleth within the area covered on effort during the two periods, used to define the Observer Distributional Range, ODR (Gg left, Gm centre, Zc right).

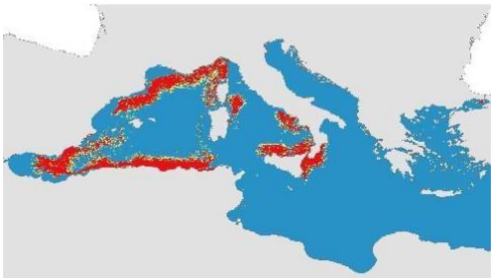
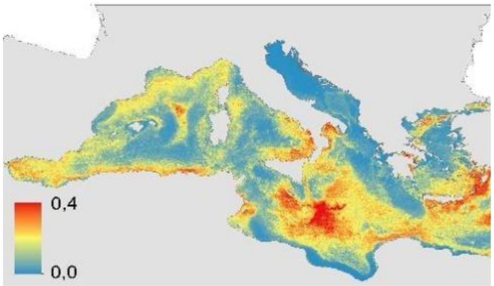
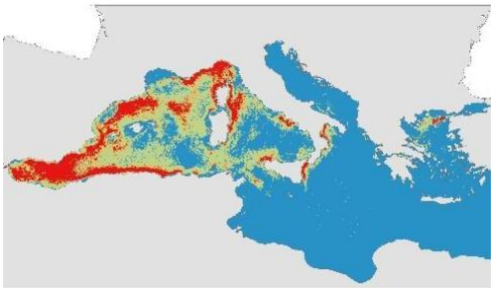
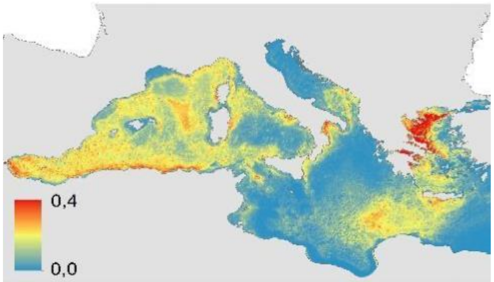
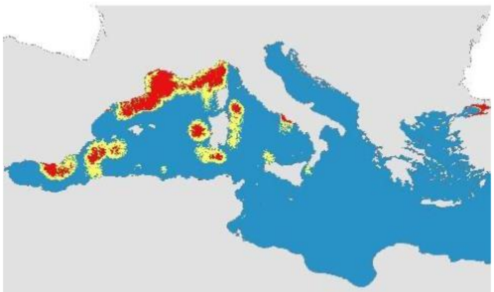
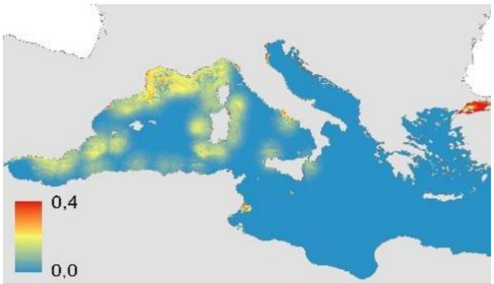
ODR areas were mostly located in the northern part of the WMED Subregion for all the species (figure 5.13) with ODR for Gg also located in the westernmost MED, the Tyrrhenian-Sardinian channel and the southern Adriatic, Gm in the westernmost MED, and Zc in the Eastern Ionian (i.e., Northern Hellenic Trench). In the northern area, the ODR generally overlapped between the two periods, with a tendency to shift towards offshore in the Sardinian-Balearic basin for all three species, and in the Ligurian Sea for Gg (Fig. 2, left). In general, the trend calculated over the WMED revealed an increase in the ODR of all three species, with a significant delta index >10% for Gg (+17%).

Ecological Potential Range, EPR

Table 5.5. MaxEnt Results for the first and second periods considered.

Species	#Training samples	#Test samples	AUC Train	AUC Test	AUC SD	*overfitting*	Minimum training presence logistic threshold	Equal training sensitivity and specificity logistic threshold	Maximum training sensitivity plus specificity logistic threshold
Gg_1	18	9	0.95	0.86	0.06	0.10	0.19	0.26	0.19
Gm_1	11	5	0.94	0.90	0.04	0.04	0.18	0.42	0.42
Zc_1	18	9	0.97	0.92	0.03	0.05	0.06	0.27	0.30
Gg_2	39	19	0.90	0.81	0.05	0.09	0.08	0.38	0.29
Gm_2	32	15	0.96	0.92	0.03	0.04	0.06	0.17	0.14
Zc_2	75	38	0.95	0.91	0.02	0.04	0.01	0.16	0.16

Based on AUCs, validation data, and well-known sites of species presence, model outputs showed high performance at the basin wide scale. The ROC plots exhibited high average AUCs for both training and test datasets, and small Standard Deviation and overfitting values for all models (table 5.5), which indicates consistency and reliability.

Gg_1		
Gg_2		
Gm_1		

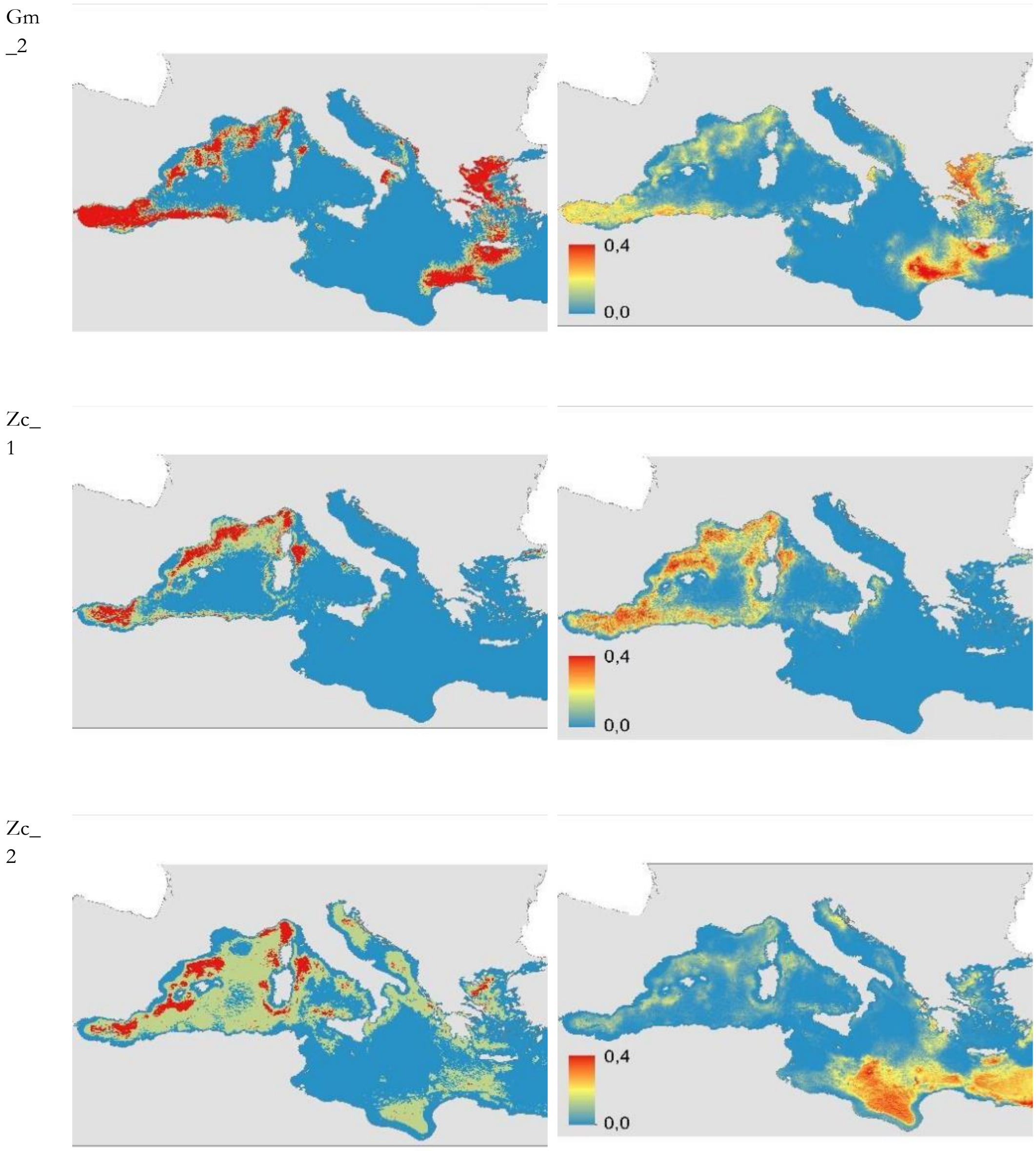


Figure 5.14 Output of the Suitable Habitats predicted based on 2008-2012 (Gg_1, Gm_1, Zc_1) and 2013-2019 (Gg_2, Gm_2, Zc_2) FLT Med Net data (left) with the relative Standard Deviation (right). The partition of suitable habitat is shown under three threshold scenarios defined by: 'Equal training sensitivity and specificity logistic threshold' (red), 'Minimum training presence logistic' and 'Maximum training sensitivity plus specificity logistic threshold' (values in table 5.5). Blue colour displays the predicted unsuitable habitat.

In general, performance of the prediction maps of the second period was higher compared to those of the first period when validated by the independent dataset collected during the same period. Performance was also higher for prediction maps for Gm2 (over 90%

of correct prediction), while performance of Gg and Zc maps was fair-good in the WMED sub-region only (over 70% of correctly predicted sites). In general, the areas of suitable habitats highlighted by the MaxEnt output maps resulted in line with previous knowledge on the species (figure 5.14), with the highest incongruence noted for the Gm_2 prediction in the Levantine Subregion. Standard Deviations were generally low (<0.4), especially for the unsuitable areas.

However, higher uncertainties were revealed in general in the Levantine Subregion, and in the central and southern areas of the Central-Ionian Subregion for the Gg_1 and Zc_2 outputs.

As the threshold values identified through the 'Equal training sensitivity and specificity' and 'Maximum training sensitivity plus specificity' approaches resulted roughly the same (table 5.5), the first were chosen, as being more conservatives than the 'Maximum training sensitivity' but more balanced than the 'Minimum training presence', and used to define the EPR.

Table 5.6 Extent area of potential range (EPR, Km^2), based on Equal sensitivity plus sensitivity logistic 820 thresholds and percentage of change in the extent of suitable area (2008-2012: Gg_1, Gm_1, Zc_1; 2013-2019: Gg_2, Gm_2, Zc_2). In Italic are indicates the very small extension of predicted suitable 822 habitat (less than 3,000 km^2); ° not reliable results as based on very limited predicted area in one or both periods.

		WMED	**Central MED**	**Adriatic**	**Aegean-Levantine Sea**
Extent of Ecological Potential Range (Km2)	**Gg_1**	182,910	12,859	*0*	87,212
	Gg_2	170,028	4,581	*50*	*1,785*
	Gm_1	101,305	*20*	*0*	*1,275*
	Gm_2	159,226	48,888	4,724	88,960
	Zc_1	92,218	*591*	*0*	*0*
	Zc_2	96,136	*1,781*	*2,310*	5,879
% change	**Gg_2/ Gg_1**	-7%	-64%	°	°
	Gm_2/Gm_1	57%	°	°	°
	Zc_2/Zc_1	4%	°	°	°

Some differences in the EPRs were found between the two periods (table 5.6). The EPR of Gg decreased by almost -40% at the basin scale, with a reliable small reduction of -7% in the WMED and a much higher (-64%) in the central MED. The EPR of Gm increased by 57% in the WMED Subregion, while results for the other Subregions were not reliable as based on very small probability of presence in those areas (<3000 km2). The EPR of Zc was more stable, high in both periods in the WMED, and limited in the other Subregions.

Table 5.7 Measures of environmental variables contribution to the ecological models for the target species. Percentage contribution (% cont) and permutation importance (Perm) derived from Maximum Entropy models. In dark and light grey respectively the first and second contributing variable.

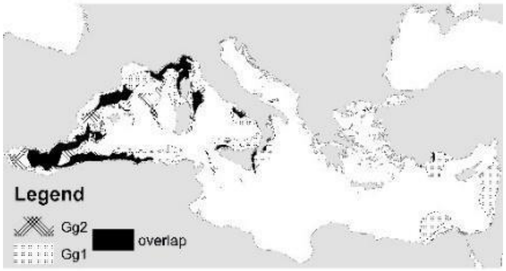
	Gg_1		Gg_2		Gm_1		Gm_2		Zc_1		Zc_2	
	% cont.	Perm.	% cont.	Perm.	% cont.	Perm.	% cont.	Perm.	% cont.	Perm.	% cont.	Perm.
Aspect-E	8.6	6	11.3	3.9	3.2	0.9	3.6	1.6	8.5	1.9	2.9	3.3
Aspect-N	9.6	9.2	6.6	5.4	16.9	7.5	4.9	1.8	6.9	7.9	4.7	3.6
Canyon dist.	**23.1**	**20**	12.5	10.5	**45.9**	**73.6**	4.5	5.3	***20.8***	**43.9**	15.2	8.6
Chl-a	*17.4*	*29.5*	**24.1**	*25.8*	1.6	4	**38.4**	**43.5**	**25.7**	20.1	15.1	7.4
Dist. coast	6.1	3.3	7.2	7.1	2.7	6.4	11.1	4.2	4.6	4.6	3.7	6.2
Depth	13.5	7.8	*18.2*	**26.8**	2.8	1.2	13.4	15.2	*20.7*	8	**23.4**	**36.3**
Slope	11.1	3.4	6.1	3.3	2.7	0.9	3.3	2.2	7.6	6.3	3.3	1.6
Seamount dist.	4.8	10.3	9.7	13.4	1.8	2.2	*19.9*	*25.3*	4.8	6.5	*17.3*	11.7
SST	5.8	10.3	4.4	3.7	*22.4*	3.3	0.8	1	0.4	0.7	14.5	*21.3*

In general, canyon distance, chlorophyll concentration (Chl), and depth were the most important predictors for all three species, followed by seamount distance and Sea Surface Temperature (SST), but only for Gm and Zc (table 5.7). Chl was the most important parameter for the definition of Gg habitats, either as percent contribution or permutation importance, in both periods, followed by canyon distance during the first period and depth during the second. Distance from the canyon was the most relevant parameter for Gm during the first period, while Chl strongly contributed during the second period, followed by the distance from seamounts. Chl and distance from the canyon were the most significant parameters also for Zc during the first period, while depth and distance from seamounts were the parameters that most affected the distribution of the species during the second period.

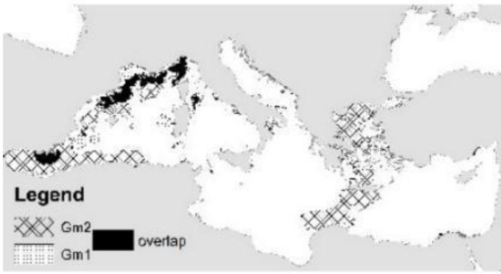
Range Pattern

In addition to the investigated changes in the extent of range areas, the analysis of spatial pattern revealed some shifts in the location of the main range areas: indeed, the percentage of overlapping spanned 40-70% for ODR for the three species, reaching the maximum overlap for Zc, and 30-50% for EDR. The location of overlapping areas for ODR (figure 5.13) and EPR (figure 5.15) showed the permanence over the time of some well-known areas for the three species.

Gg



Gm



Zc

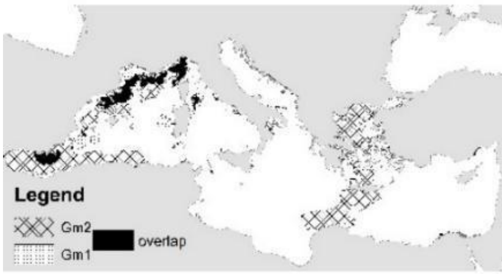


Figure 5.15 Overlap of EPRs over the two periods. Points EPR of the first period, strips EPR second period, and in black the overlapping areas.

In particular for Gg, some well-known areas were predicted in both periods (e.g., Albóran Sea, Balearic Sea, Corso-Ligurian-Provençal basin, Tyrrhenian Sea east of the Bonifacio Strait, Pontine Archipelago, Egadi Islands and Gulf of Catania). The offshore waters of the Gulf of Lion were no longer identified as the most suitable during recent years, while three new areas were highlighted, in the centre of the Sardinian-Balearic basin, along eastern Corsica, and around the Pantelleria Island (figure 5.15). In the eastern Mediterranean basin, the northern Greek Aegean waters were identified as suitable during the more recent period, while the waters along the coasts of Lebanon-Israel-Palestine and Egypt were identified during the first period only. A general reduction of suitable habitat was identified in the Pontine Archipelago, around the Sicilian coasts and offshore the southern Türkish coasts. Apart from the better-defined sites of suitable habitat, widespread spots of potential suitable habitat appeared dispersed in the WMED from the recent model.

Suitable Gm habitats were predicted mostly in the WMED Subregion, in the Albóran Sea and along the continental shelf of Balearic, Gulf of Lion and the Corso-Ligurian-Provençal basin. A small area was highlighted in the Pontine Archipelago, and other patch areas were predicted around Sardinia Island. During the second period, a reliable enlargement of suitable habitat was predicted over the Alborán Sea and the Strait of Gibraltar, while the large prediction stretching from the Aegean to Libya seems unreliable given the current knowledge on the species distribution.

Some well-known suitable areas were highlighted in both periods for Zc, especially in the WMED, such as the Alborán Sea, Ligurian Sea, northern Tyrrhenian Sea, and Balearic Sea. In the central Mediterranean and Adriatic Subregions, the Hellenic Trench, northern Ionian Sea, and southern Adriatic Sea were predicted during the second period only.

A shift of centroids' core areas between the two periods was detected for the ODR, and the EPR predicted over the WMED sub-region (figure 5.16). The shift on EPR for the other Subregions or at all MED scale was not considered as based on a very limited predicted area in one or both periods (table 5.6).

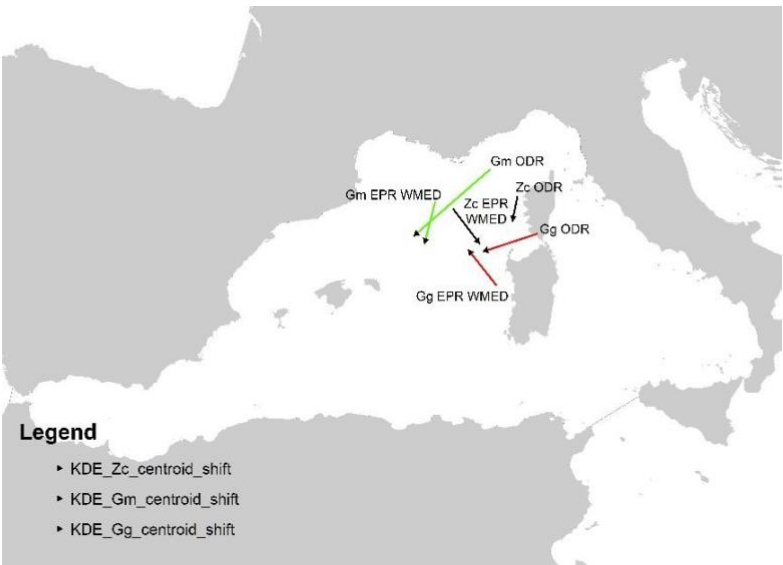


Figure 5.16 Direction and magnitude shift of the centroids of the distributional area respectively of ODR, and EPR WMED. Gg red, Gm green, Zc black lines.

Observed distribution range vs Ecological Potential Range, ODR/EPR

Results showed that all the species used almost the same areas or a smaller proportion of their ecological potential habitat during both periods, with the only exception of Gg, whose distribution in the second period was larger than the ecological potential extent (table 5.8).

In the WMED, the proportion of suitable habitat effectively occupied by the species ranged between 62% for Gm_1 and 158% of Gg_2. No significant changes were detected here in the proportion of occupied habitat over the two periods for the Zc (-1%), while the areas occupied by Gg and Gm increased by 59% and 46% respectively. Limited area was predicted for Gg and Zc in the central MED, effectively occupied by the Zc by 50%, while the Gg was recorded largely outside the predicted potential area. Gm was never detected either in the central MED and in the Adriatic and Central Mediterranean (North-Eastern Ionian) Subregions.

Table 5.8 Percentage of the extent of Real Distribution (Km2, 95% KDE isopleth) over the Ecological Potential Range (Km2, based on Equal sensitivity plus sensitivity logistic threshold) calculated within the area performed on effort. 2008-2012: Gg_1, Gm_1, Zc_1; 2013-2019: Gg_2, Gm_2, Zc_2. ° not reliable results as based on very limited predicted area in one or both periods.

	WMED	**Central MED**	**Adriatic**	**Aegean -Levantine Sea**
Gg_1	99%	114%	NoEffort	NoEffort
Gg_2	158%	°	°	NoEffort
Gm_1	62%	°	NoEffort	NoEffort
Gm_2	90%	°	°	NoEffort
Zc_1	115%	°	NoEffort	NoEffort
Zc_2	112%	°	°	NoEffort

The spatial pattern of observed and predicted potential areas showed large overlap, but with some local differences. Both the areas of observed and predicted range of Gg in the

WMED expanded mainly towards offshore waters of north WMED and stretched in patchy suitable areas in the centre, while the shift in the species observed range detected in the more recent years in the Corso-Ligurian-Provençal basin brought Gg outside predicted suitable areas in the western portion; all along the eastern Corsica coast new areas of both, observed and predicted range emerged recently, connecting the permanent structure revealed in the central Tyrrhenian sea. A contraction in suitable areas was instead detected in the south Tyrrhenian, where the species was no longer present, while new areas emerged in the Sardinian channel. A permanent suitable area was confirmed in eastern of Sicily. Gm observed range was almost similar across periods in the northern WMED, except for an enlargement towards offshore waters in the Sardinia-Balearic basin, which almost corresponded with the predicted potential range, despite the latter being more scattered and fragmented during the more recent years. No noteworthy changes in observed and predicted range were detected for Zc in the northern part of WMED, while a new area emerged in the Sardinian channel both for the observed and predicted range.

5.3.4 Discussion

Sampling strategy

The sampling strategy of the FLT Med Net was set in order to homogeneously cover large portions of the Mediterranean basin, with regular continuous monitoring of the sampled areas during all the seasons (Arcangeli et al., 2019). The FLT Med Net dataset used for this study confirmed to be adequate for the trend assessment over time periods even for rare or elusive cetacean species such as Risso's dolphin, long-finned pilot whale and Cuvier's beaked whale, in particular for the WMED Subregion, and especially during the more recent years when new monitored transects concurred to cover also the westernmost portion of the basin, the Alborán sea and the Strait of Gibraltar area (roughly 80% of WMED covered by the effort). Also, in the Adriatic Subregion, the effort strategy allowed covering almost the whole region, although with still some uncertainty in the northernmost area, as also assessed by Zampollo et al. (2022). The central MED was instead only represented by the effort in the eastern Sicilian coast and the Greek Ionian portion, and no effort was performed in the Levantine Subregion, which leaves open opportunities for improvement. However, an adequate proportion of the effort area intercepted the main distributional range and suitable habitats of Gg, Gm and Zc in the WMED Subregion (between 10-37% for the observed distributional range, over 46% of the predicted ecological range), and a more limited proportion in the central MED and Adriatic Subregions, in correspondence with some known important areas for Gg (i.e., eastern Sicily) and Zc (i.e., Northern Hellenic Trench). Therefore, the sampling design of FLT Net proved to be adequate to produce reliable results also outside the area of effort, especially in the WMED, where the fixed transect resulted adequately distributed to intercept the ecological variability of the area; whereas more transects are instead required to improve reliability in understudied sub-region (e.g., central and Levantine sub-regions). Moreover, as the distributional range and habitat use of species varies seasonally, the temporal resolution of surveys allowed including seasonal-related displacements into the assessment. The approach was also efficient in terms of monitoring costs vs. acquired information, and proved to have a high level of repeatability and confidence.

Main findings on species distributional range and habitat

Most of the Observed Distributional Range (ODR) of the species highlighted by the Kernel analysis and the Ecological Potential Range (EPR) predicted on the basis of suitable habitats modelling where consistent with previous knowledge on the species, especially for the WMED Subregion, further confirming the importance of the north-western Mediterranean for Gg, Gm and Zc (ACCOBAMS, 2021). Consistency in these areas was also found across periods, with a general enlargement in the areas of distribution, and a shift towards more offshore areas in the Sardinian-Balearic basin for the three species, and in the Ligurian Sea for Gg. Some unreliable areas were however predicted, such as for Gm_2 prediction in the Levantine Subregion, while other known areas did not emerge, such as for the Southern Adriatic Sea, the Ionian Sea and the deep Hellenic Trench for Zc. These areas however were predicted, even if for a limited extent, during the second period only, when monitoring effort was added in the Adriatic-eastern Ionian region. Higher uncertainties were revealed, as expected, in the Levantine Subregion, where no effort was performed.

Findings of this study on both ODR and EPR of **Risso's dolphin** (Gg), confirmed the permanence across the two investigated periods of some well-known important areas for the species, mostly in the WMED Subregion. The species is mostly found in the Western-Mediterranean Sea, from the Alborán Sea, including deep offshore waters (Cañadas et al., 2002, 2005), to the south of the Provençal Basin, with high values along the Algerian coast and the Balearic Islands (Verborgh et al., 2016, ACCOBAMS, 2021). However, findings of this study no longer identified the offshore areas of the Gulf of Lion as most suitable during recent years, while highlighting new distributional areas in the offshore waters of the Sardinian-Balearic basin and Ligurian sea. The species was considered favoured by the proximity of the continental slope, primarily in the north-western Basin (Bearzi et al., 2011), with a very specialized niche and a habitat spatially restricted on the upper part of the continental slope (Praca and Gannier, 2008). A high fidelity for the Provencal continental slope, without strong seasonal pattern in abundance (Laran et al., 2010, 2017), and a transient use of the offshore area was also confirmed on a long-term basis between 1989-2012 by Labach et al. (2015). Nonetheless, in accordance with the result of this study, during recent years Gg was sighted in more offshore environments than previously reported in literature (ACCOBAMS, 2021); this is also in line with the trend observed by Azzellino et al. (2016), who reported a significant decrease in Gg abundance between the early '90s and 2014 in coastal and continental slope areas of the Ligurian Sea, with stable occurrence in pelagic areas. The result was assumed as a loss of coastal group or a shift in animal distribution (Azzellino et al., 2016). Moreover, apart from the more defined sites, widespread spots of potential suitable habitats appeared dispersed in the WMED from the recent model of this study. A general reduction of suitable areas was also detected in the Pontine Archipelago, and around the Sicilian coasts and Ionian Sea, where only a portion of suitable habitat persisted inshore the

Catania and Taranto Gulfs where strong side fidelity was found by other studies (e.g., Monaco et al., 2016, Carlucci et al., 2020a, Cipriano et al., 2022). More eastern, relatively large groups of Risso's dolphins were reported in the Southern Adriatic and Ionian Seas and the deep Hellenic Trench from ASI visual surveys, but none from acoustic surveys (ACCOBAMS, 2021), in line with the uneven prediction produced by this study. During the first period, some suitable areas emerged in correspondence of the Türkish Mediterranean, Palestinian and Israeli coasts, consistent with the few contemporary reports (Öztürk et al., 2011, Karem et al., 2012). The absence of effort in this area however, prevents any conclusion on whether or not the predicted reduction reflects a true species negative trend. The few encounters of Gg in mixed-species groups with striped dolphins and short-beaked common dolphins in the deep waters of the semi-closed Gulf of Corinth (e.g., Frantzis and Herzing, 2002; Frantzis et al., 2003), as for the unique stranding record in the 2012 in the Marmara Sea (Dede et al., 2013), appear to confirm the minor prediction in these areas.

Findings of this study confirmed some of the existing knowledge on the **long-finned pilot whale** (Gm). The species is known to be found almost exclusively in the WMED (Verborgh et al. 2016, ACCOBAMS 2021), with a strong preference for deep pelagic waters. Relative higher densities were reported in the Strait of Gibraltar and Albóran Sea (Cañadas et al., 2005; de Stephanis et al., 2008a) and lower in Balearic and Corso-Ligurian-Provençal Seas (Gomez de Segura et al., 2006, Raga and Pantoja 2004, Azzellino et al., 2008, Praca and Gannier, 2008). In accordance, the ACCOBAMS survey of 2018 (ACCOBAMS 2021) observed larger groups of Gm in the Alborán Sea, along the coast of Morocco and in the Gulf Lion, and relatively smaller pods in the Ligurian Sea. The species was never recorded in the central Tyrrhenian sea (Arcangeli et al., 2013, Arcangeli et al., 2017), while a stable pod has been recurrently sighted in the Pontine Archipelago since 1995 (Mussi et al., 2000). In accordance with the literature, the Distribution Observed in this study for Gm was exclusive of the WMED, but with a tendency to shift towards offshore waters during recent years, especially in the Sardinian-Balearic basin. Suitable habitats were also mostly predicted in the Albóran sea, and along the continental shelf of the Balearic archipelago, Gulf of Lion and the Corso-Ligurian-Provençal basin, with a similar shifting trend towards offshore as the Observed Range. Smaller areas were predicted in the Pontine Archipelago, supporting the stable presence reported by Mussi et al. (2000), and around Sardinia Island. During the second period, a reliable enlargement of suitable habitat was predicted in the WMED Subregion, especially over the Albóran Sea and the Strait of Gibraltar, probably as a result of the new added monitored transects representative of the westernmost part of the basin and intercepting the Gibraltar sub-population (Verborgh and Gauffier, in press). A large Ecological Potential area stretching from Gibraltar towards the northern African coast was indeed predicted by this study in the second period, confirmed by the ACCOBAMS (2021) sightings of large pods, and by some reported strandings in Morocco (Bayed, 1996; Masski and de Stephanis, 2015), Algeria (Bouslah, 2012; Boutiba, 1994) and Northern Tunisia (Attia El Hili et al., 2010; Karaa et al., 2012). The species was never detected either in the central MED and in the Adriatic sub-regions, and no EPR was predicted here, while the large prediction stretching from the Aegean to Libya seems unreliable given the current knowledge on the species distribution.

Known habitats of **Cuvier's beaked whale** (Zc) were highlighted by the study in the WMED sub-region, while the south Adriatic and Hellenic trench of the Eastern Ionian Sea were only predicted during the second period, likely thanks to the effort performed in those areas that allowed including some environmental features not considered by the environmental variability of the WMED effort area only. Zc is considered to inhabit both the western and eastern basins of the Mediterranean Sea (Podestà et al., 2016), and is mostly found in canyon areas in the Ionian Sea, the Hellenic Trench, the deep southern Adriatic Sea (Carlucci et al., 2020b; Frantzis et al., 2003), the Central Tyrrhenian Sea (Arcangeli et al., 2015, Gannier 2015), the Balearic and the Alborán Seas (Cañadas and Vázquez, 2014, Cañadas et al., 2018), and the Ligurian Sea (Moulins et al., 2007, Azzellino et al., 2008, Tepsich et al., 2014). The ACCOBAMS survey of 2018 confirmed the existing knowledge on the basin wide presence of the species and at the same time showed how Zc occur in relatively small patches at low densities (ACCOBAMS 2021). In accordance with literature, this study highlighted the importance of the WMED and in particular of the Albóran Sea, the central Tyrrhenian Sea and Ligurian Sea, but also a permanent area of suitable habitat in correspondence with the Spanish-French continental slope coast and stretching offshore. However, despite being recognised by some studies (Raga and Pantoja 2004, Praca and Gannier 2008, Gannier and Epinat 2008, Podestà 2016, Arcangeli et al., 2017) and the records of the ACCOBAMS survey (ACCOBAMS 2021), this latter area was not considered among the important areas for the species. This discrepancy could indicate either an underrepresentation of scientific literature, or a minor occupancy of Ecological Potential habitat for the species.

Interpretation of trends

In general, the WMED was confirmed as the most important Subregion for Gg, Gm and Zc, whose presence and suitable habitats endure over time. However, the changes in the extent (whichever a contraction or expansion) and the shift highlighted on both the observed distribution and the suitable areas, likely indicate a different displacement of the species (table 5.9). This could be the result of exploitation of new potential suitable areas or an adaptation forced by existing pressures. Indeed, despite the differences recorded in the suitable areas of the WMED, the extent remained almost similar over time for Gm and Zc, while Gg enlarged the proportion of occupied area over the ecological potential by almost 50%, distributing outside the predicted suitable areas. This was the case for the Corso-Ligurian-Provençal basin, but also the new areas emerged in the centre of the Sardinian Balearic basin or eastern Corsica coast, together with the contraction of the areas in the south Tyrrhenian Sea and around the Sicilian coasts, revealed changes that need further investigation. Moreover, the concurrent enlargement of the area of distribution of Gm and Zc, even if with a minor evidence, was not reported by literature but pointed out a general tendency towards a wider distribution of animals that surely deserve attention.

Table 5.9 Summary results on assessed trends for the WMED Subregion.

	Gg	Gm	Zc	
ODR Extent	↑	(↑)	(↑)	() not significant
EPR Extent	↔	↑	↔	↑ Positive
ODR Shift	↘	↘	↘	↘ Attention
EPR Shift	↘	↘	↘	↓ Negative
ODR/EPR	↑	↑	↔	↔ Stable
ODR > EPR	↘	↔	↔	

Methodological approach and indicators

The indicators here tested mostly contributed to describe the main consistencies and differences on short-term range trends between periods, highlighting the advantages and weaknesses of the tested approaches.

The **Observed Distributional Range (ODR)** indicator has the advantage of preventing difference biases due to the manipulation of data, analysis settings or approximations, being closely related to the real observed distribution of the species. On the other hand, results are only representative of the area where the effort is performed, introducing the need for considerations on the sampling design of the data collection if used as representation of species distributional range. Spatial extensive large-scale surveys covering the whole range of species would deliver a spatially adequate base-data for detecting ODR, but are cost-expensive and susceptible to lose the temporal resolution needed to detect the natural species variability avoiding output linked to occasional or seasonal fluctuations. Continuous local scale surveys would allow the inclusion of the needed temporal dynamic, and could be merged to increase the spatial representation of outputs, however they could be too coarse, and caution must be taken when matching data collected with different methodologies. Time extensive large-scale monitoring data collected in sampled areas spatially representative of regional ecological conditions could represent a suitable balance, and can be used as an index of the real species range. A prior assessment of the ecological variability representativeness of monitored transects is however needed to avoid bias in underrepresented regions.

With regard to the methods to represent the distributional range, if compared to the species occurrence mapped in a 10x10 Km2 grid (suggested by HD and MSFD), the Kernel density smoother proved to be a feasible tool to spatially generalize the distribution of species, able to define the area where the species is found. It is adaptable to the spatial scale (grain) and resolution of data through the adjustment of search radius and cell size resolution, still remaining relatively simple to apply. Moreover, when using high quality spatial data as those of this study, the KDE proved to be more appropriate and accurate than other coarse methods. Other approaches such as the Kriging could also apply to the same purpose, and are worth exploring.

The **Ecological Predicted Range (EPR)** based on sites of present occurrences and extrapolated through habitat maps models proved to be able to generalize the spatial distribution of the species also outside the area of effort, providing meaningful outputs. Results of this study indicate a general correspondence of trends detected in the Observed and Predicted Range, both in terms of extent of areas (e.g., enlargement recorded for all the species in both ODR and EPR), and shifts (e.g., towards offshore areas in the Western-Mediterranean sub-region). This result confirms the potential for using the EPR to indirectly determine the AOO (IUCN, 2011) and so, the range of the species. However, some differences were also detected, such as the new areas detected by the ODR in the Sardinia channel for Gg that were not recognised by the EPR in the corresponding period. Thus, careful consideration is needed to correctly discriminate the meaning of the Range predicted on the basis of SDM to investigate the species conservation status, as the Potential Range does not always correspond to the actual distributional range of the species.

On the other hand, Suitable Habitat Maps can directly be used to define the extent, trend and pattern of the suitable habitats to answer the parameter/criteria 'Habitat' for the species (e.g., for HD and MSFD), adding also information on the main ecological factors that drive their distribution; they also have the potential to be used to investigate the 'Habitat conditions' requirement, if parameters linked to the pressures are added to the models.

EPR can also be used to compare the Observed versus the Potential Range (IUCN 2011, 2022), as they provide indications on the area and quality of occupied habitat and on the available area of unoccupied habitat of suitable quality allowing the long-term survival of the species (DG ENV, 2017). Including data on pressures, the comparison between the Observed and the Potential Range can also help to identify potential suitable areas that are not used by the species due to the influence of anthropogenic pressures or other limiting factors, or, at the opposite, assess if the species is pushed outside the preferred suitable habitat as a consequence of a pressure or as the effect of exploitation of new resources. The trend on the ratio between Observed vs Potential range could then be used to correlate the detected changes with other environmental or anthropogenic parameters, and/or assess the effectiveness of mitigation measures.

In summary, the Observed Distributional Range based on known occurrence can underestimate the real occupied range and needs to be referred to the area of effort, but can still be used as an index to detect trends. Conversely, the Ecological Potential Range could be larger than the occupied range in presence of limiting factors, either environmental or anthropological, or even smaller in the case of pressures that force the species outside the ecological niche, and needs to be adjusted (e.g., using the estimated proportion of ODR/EPR, IUCN 2011). Thus, in general, the parallel use of complementary indicators, such as the Observed and Ecological Potential Range, proved valuable to disclose the significance of a change. As well, the contemporary investigation of trends in extent (surface range) and shifts (range pattern) is suggested: in this study, for example, the enlargement of the Observed surface Range could have been interpreted as positive, but it was associated with a shift towards offshore less suitable or unsuitable areas, which deserve attention. Finally, synoptic analyses performed on more species with similar ecology can help to assess whether a detected modification refers to just a single species or is likely representative of a more global change.

Data availability statement

The data analysed in this study were collected by several organizations participating in the FLT Med Net coordinated by ISPRA. Each organization owns the data collected. Requests to access these datasets should be directed to the data owners.

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CHAPTER 6 - COVID-19 LOCKDOWNS, ANIMAL COMMUNICATION AND NATURE CONSERVATION

The lock COVID-19 pandemic led to lockdowns that banned all non-essential services and travel both on land and sea in several parts of the world. Overnight, the Hauraki Gulf Marine Park became devoid of almost all recreational and non-essential commercial vessels resulting in changes in the marine soundscape. In response to this sudden drop in noise pollution, the communication ranges of fish and dolphins immediately increased by up to 65%, demonstrating the impact that small vessels can have on underwater soundscapes.

Results obtained in the Haruaki Gulf were shared with the international scientific community in a global effort to monitor the immediate impacts of changes in human activities on wildlife and environmental threats during the early lockdown months of 2020. The pandemic lockdown had both positive and negative effects on nature, all of which can result in a cascade of implications for wildlife and nature conservation. These first qualitative and quantitative results demonstrate how humans are both threatening and protecting ecosystems and species. It is possible to favourably tilt this delicate balance by reducing impacts and increasing conservation effectiveness

6.1 A Gulf in Lockdown: how an enforced ban on recreational vessels increased dolphin and fish communication ranges

Un Golfo en confinamiento: cómo la prohibición impuesta a las embarcaciones de recreo aumentó el alcance de las comunicaciones entre delfines y entre peces

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Here, we quantified and analysed the effects of the lockdown on the underwater soundscape within the Hauraki Gulf Marine Park (HGMP), New Zealand. This includes effects on the sound pressure level, on the vessel activity and on dolphin and fish communication range.

Abstract From midnight of 26 March 2020, New Zealand became one of the first countries to enter a strict lockdown to combat the spread of COVID- 19. The lockdown banned all non-essential services and travel both on land and sea. Overnight, the country's busiest coastal waterway, the Hauraki Gulf Marine Park, became devoid of almost all recreational and non-essential commercial vessels. An almost instant change in the marine soundscape ensued, with ambient sound levels in busy channels dropping nearly threefold the first 12 h. This sudden drop led fish and dolphins to experience an immediate increase in their communication ranges by up to an estimated 65%. Very low vessel activity during the lockdown (indicated by the presence of vessel noise over the day) revealed new insights into cumulative noise effects from vessels on auditory masking. For example, at sites nearer Auckland City, communication ranges increased approximately 18 m (22%) or 50 m (11%) for every 10% decrease in vessel activity for fish and dolphins, respectively. However, further from the city and in deeper water, these communication ranges were increased by approximately 13 m (31%) or 510 m (20%). These new data demonstrate how noise from small vessels can impact underwater soundscapes and how marine animals will have to adapt to ever- growing noise pollution.

Resumen *A partir de la medianoche del 26 de marzo de 2020, Nueva Zelanda se convirtió en uno de los primeros países en entrar en un estricto confinamiento para combatir la propagación del COVID- 19. El confinamiento prohibió todos los servicios no esenciales y los viajes tanto por tierra como por mar. De la noche a la mañana, la vía fluvial costera más transitada del país, el Parque Marino del Golfo de Hauraki, quedó desprovista de casi todas las embarcaciones de recreo y comerciales no esenciales. Se produjo un cambio casi instantáneo en el paisaje sonoro marino, ya que los niveles de sonido ambiental en los canales más concurridos se redujeron casi tres veces en las primeras 12 horas. Este descenso repentino hizo que los peces y los delfines experimentaran un aumento inmediato de sus rangos de comunicación de hasta un 65%. Una actividad muy baja de los buques durante el confinamiento (indicada por la presencia de ruido de los buques durante el día) reveló nuevos conocimientos sobre los efectos acumulativos del ruido de los buques en el enmascaramiento* *auditivo. Por ejemplo, en los sitios más cercanos a la ciudad de Auckland, los rangos de comunicación aumentaron aproximadamente 18 m (22%) o 50 m (11%) por cada 10% de disminución de la actividad de los buques para los peces y los delfines, respectivamente. Sin embargo, más lejos de la ciudad y en aguas más profundas, estos rangos de comunicación aumentaron aproximadamente 13 m (31%) o 510 m (20%). Estos nuevos datos demuestran cómo el ruido de las pequeñas embarcaciones puede afectar a los paisajes sonoros submarinos y cómo los animales marinos tendrán que adaptarse a la creciente contaminación acústica.*

Key words: acoustics, anthropogenic noise, communication range, COVID- 19, dolphins, marine mammals, masking, vessels

6.1.1 Introduction

Because of the COVID- 19 pandemic, many countries around the world entered into various forms of 'lockdowns' to combat the spread of the novel coronavirus. Borders were closed, freedom of movement and commerce was heavily restricted and international trade substantially reduced within months (Bates et al., 2020), bringing about the 'Anthropause' (Rutz et al., 2020). This presented re- searchers around the world an unprecedented setting to quantify the effects of human activity on wildlife (Bennett et al., 2020; Patrício Silva et al., 2020; Rutz et al., 2020). Although the socio- economic impacts were severe and widely felt, urban wildlife responded to the sudden cessation of human activities (Bates et al., 2021). News reports of wildlife invading urban areas quickly ensued: pumas spotted in downtown Santiago; jackals on the streets of Tel Aviv; goats along deserted highways in Istanbul; fallow deer in London; grey langurs in Ahmedabad, India, and many others (Rutz et al., 2020). Perhaps more hidden from view, but still noticed, was the response of coastal marine organisms to this new, relative calm (Rutz et al., 2020). One potential key factor in explaining this observed change in wildlife behaviour during the 'lockdown' is the reduction of anthropogenic noise in the environment. Noise pollution is the most pervasive by- product of urbanisation, transport and industry, that changes the acoustic environment which many animals are acutely tuned to (Shannon et al., 2016). On land, the 'quiet' brought about by COVID- 19 pandemic management measures led to an immediate drop in urban noise pollution (Mandal & Pal, 2020) and 50% drop in seismic noise (Lecocq et al., 2020). There was also a 1.5 dB re 1 μPa drop in underwater noise levels off Vancouver Island, Canada, due to reduced shipping (Thomson & Barclay, 2020).

Marine mammals, fish and invertebrates depend on sound for critical life history processes, such as mate selection and predator avoidance (Peng et al., 2015). Anthropogenic underwater noise has been increasing around the world for decades (Andrew et al., 2011; Frisk, 2012). Rising underwater noise levels in coastal environments due to small boats has become of substantial concern due to growing evidence of both lethal and sublethal impacts on marine life (Hawkins & Popper, 2014; Hermannsen et al., 2019; Jones, 2019; Popper & Hawkins, 2019). This is particularly relevant in highly productive waters that are near major port- cities, such as the Salish Sea near Vancouver (Cominelli et al., 2018; Joy et al., 2019), the Pearl River

Estuary near Hong Kong (Pine et al., 2017; Sims et al., 2012) and the Hauraki Gulf near Auckland (Pine et al., 2016; Putland et al., 2018). A common threat facing these productive waters is increasing levels of vessel noise from an increasing volume of commercial and recreational marine traffic (Dolman & Jasny, 2015; Farcas et al., 2020; Hildebrand, 2009; Luís et al., 2014; McWhinnie et al., 2017; Pine et al., 2016; Simmonds et al., 2014; Weilgart, 2007). For example, Auckland, which is New Zealand's largest city, is located within the centre of the Hauraki Gulf Marine Park (HGMP), an area of 4000 km2 with outstanding marine biodiversity including >700 species of marine intertidal invertebrates, >80 species of fish and 25 species of marine mammals, at least six of which are resident (Hauraki Gulf Forum, 2014). Auckland residents have the highest recreational vessel ownership per capita in the world, and in 2011, boat ownership was estimated to be 132,000, with numbers expected to reach 183,000 by 2041 (Beca, 2012).

Recent research has shown that increasing vessel noise reduces the ability of dolphins and fish to effectively perceive their acoustic environment (Erbe et al., 2016, 2019; Putland et al., 2018; Stanley et al., 2017). The primary mechanism for this is auditory masking (Erbe et al., 2016; Slabbekoorn et al., 2010). Vessel noise commonly masks natural sounds as the broad frequency range of vessel noise strongly overlaps many abiotic, such as rain and wind, and biotic sounds from animals, especially dolphins and fishes (Mooney et al., 2020; Slabbekoorn et al., 2010). Masking of dolphin whistles, buzzes and echolocation clicks, or grunts, pops, clicks and hums from fishes have all been linked to a range of impacts, as acoustic signalling is involved in navigation, for- aging, mating, socializing and avoiding dangers (Au & Hastings, 2008).

On 26 March 2020, New Zealand entered a strict lockdown of societal activity to combat the spread of COVID- 19, with the government placing a complete ban on all non-essential services on both land and sea. Vessel activity in the HGMP abruptly declined, with all recreational and non- essential commercial vessels banned from operating for 7 weeks. Shipping and related vessels continued to operate, but traffic was heavily reduced. For example, automated identification system records for vessels within a 10- km radius around the Noises Islands, showed an approximate 58% decrease during the 7- week lockdown period (L. Wilson, unpublished data). For the HGMP's marine animals that depend on underwater sound for critical life history processes, the reduction in vessel traffic resulted in significant changes to their acoustic habitat.

6.1.2 Materials and methods

Acoustic data - Acoustic data were gathered between February and May 2020 using seafloor-mounted acoustic recording stations (ST300HF, Ocean Instruments NZ) at five sites within the Hauraki Gulf, northern New Zealand (Figure 6.1).

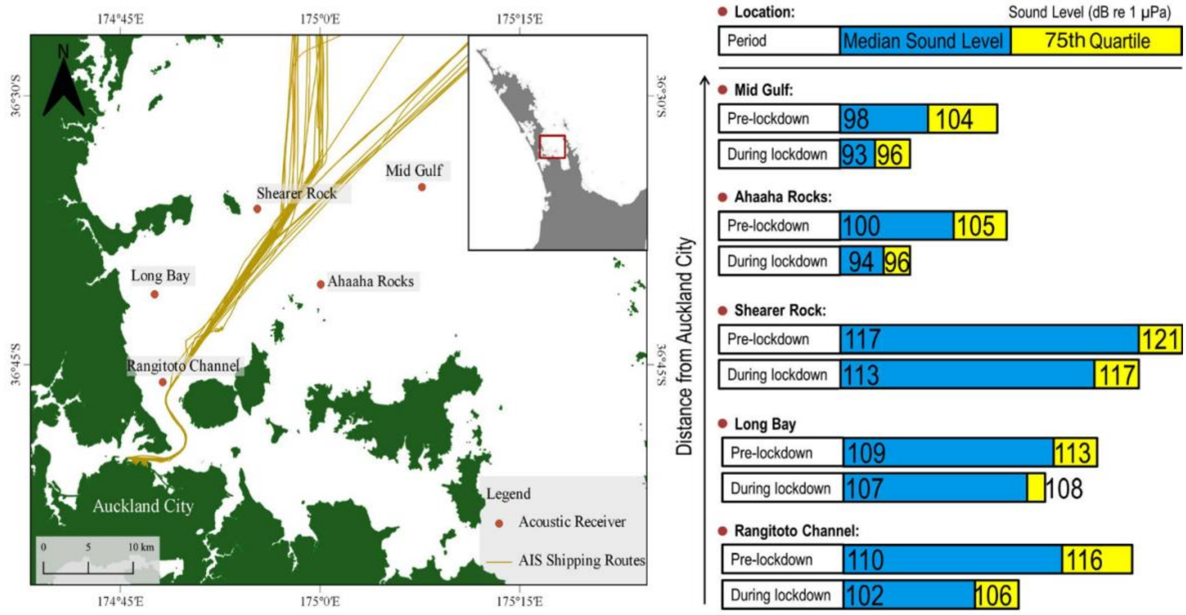

Figure 6.1 Map of the Hauraki Gulf Marine Park showing the location of the sea- mounted acoustic recording stations and corresponding median sound pressure levels (SPLs) measured before and during the lockdown (7 weeks for both periods). The blue bars represent the median SPL (dB re 1 μPa) measured during daylight hours, whereas the yellow bars represent the 75th quartile for the median.

Recorders captured a 2- min sample of ambient sound (digitized to a.WAV file) every 10 min at a 48- kHz sampling rate and high gain setting. Deployment was 2 months prior to community lockdown due to COVID- 19 that started at 23:59 h on 25 March 2020. The acoustic recorders were field- calibrated before and after deployment using a calibrated piston phone (G.R.A.S Type 42AA, 250 Hz @ 114 dB) and a sound level meter (Brüel & Kjaer 2250 Type 1 SLM with a Bruel & Kjaer ½ condenser microphone Type 4189 and calibrated with a Brüel & Kjaer Type 4231 sound calibrator). Each recorder was located in open water in frequented vessel routes that were of varying distances from Auckland City. The Rangitoto Channel site (Figure 6.1) was located in the Rangitoto Channel at a depth of 14– 17 m to capture the changes in vessel activity within a major thoroughfare for both recreational and commercial marine traffic. Three sites were located at varying distances offshore of Auckland City's northern suburbs, that is, Long Bay (silty- seafloor, 13– 17 m depth), Shearer Rock (rocky reef, 17– 20 m depth) and the Ahaaha Rocks (sandy seafloor, 34– 37 m depth). The fifth site was offshore in the centre of the Hauraki Gulf, approximately 45 km from the central business district of Auckland City, and named Mid- Gulf (sandy seafloor, 47– 50 m depth).

Weather data - Hourly wind speeds (km/h) and direction were continuously logged at a weather station (operated by the National Institute of Water and Atmosphere [NIWA]) located at 318 m above the central business district in Auckland City on the Sky Tower building (S 36.85004°S, 174.76242°E). This was selected in favour of other weather stations at sea level because it had omnidirectional exposure to the wind flow that was also present at the acoustic recording sites between ~9 and 44 km away.

Data analysis - Every 10 s of acoustic data was used to determine power spectral densities (PSDs). Broadband sound pressure levels (SPLs; 10 Hz– 24 kHz) were calculated as an average over each 2 min re- cording using 1 s Hamming windows and 50% overlap. This generated a single SPL value every 10 min (due to the 2 min recording for every 10- min duty cycle); 6 samples per hour and 144 samples per day. To control for increased ambient noise resulting from elevated wind speed, only acoustic data recorded during the hours of wind speed below 18.5 km/h, that is, 10 knots, were selected for statis- tical analyses, comprising 45% of the total data set. These missing data points occurred randomly across time. Daily median SPLs were extracted from this delimited data set for each sampling site and pooled into two periods, pre-lockdown (i.e. 1 February to 25 March 2020) and during the lockdown (i.e. 26 March– 8 May 2020), which were then compared with Mann– Whitney tests.

Vessel activity at each site was determined from the 2- min recordings over each 24 h period (from 00:00 to 23:59 h) using a vessel noise detector, which used a convoluted neural network (CNN) with nine neural layers. The CNN was trained on 10,000 PSD spectrograms of vessel noise from archived data in MATLAB, with a validation accuracy of 96% after 8 epochs. The validation was performed on a separate dataset containing 5,165 different spectrograms. The detector did not classify the type of vessel, instead identified predominately the presence of harmonic tones and Lloyd mirror patterns. Every detection was examined and confirmed by visually examining spectrograms. Over half of all recordings were also manually reviewed to confirm the reliability of the acoustic detection algorithms and to further ensure all vessel noise signatures were detected. The proportion of 2- min recordings that contained vessel noise over the total number of recordings in a single 24 h period was calculated to provide a measure of vessel activity in the vicinity of the recording site. The relationship between measured vessel activity per day and median SPL per day (the response variable) at each site were evaluated with generalized linear models (GLM), after confirming that the required assumptions were met, including independence.

Bottlenose dolphins (*Tursiops truncatus*) and bigeyes fish (herein called bigeyes, *Pempheris adspersa*) are both commonly found in the Hauraki Gulf, maintain social groupings via acoustic communication and have well documented acoustic source levels and hearing thresholds. This enabled the calculation of communication range. The communication range is the maximum distance from a vocalizing animal at which a conspecific listener could detect and perceive the source animal's signal (Clark et al., 2009). Whistles are an important component of the bottlenose dolphin vocal repertoire, playing an important role in dolphin communication and social dynamics (Au & Hastings, 2008; Frankel et al., 2014). Whistles are pervasive and omnidirectional signals, unlike the much higher frequency and highly directional echolocation clicks or burst pulses commonly used by many dolphin species (Au & Hastings, 2008). In contrast, the low- frequency pop sounds from bigeyes are considered a model acoustic signal for fish due to their limited frequency range and source levels (Putland et al., 2018; Radford et al., 2015). To calculate communication ranges for dolphin whistles and fish calls, a simplified sonar equation (Clark et al., 2009), that has previously been used within the Hauraki Gulf, was applied to the data (Putland et al., 2018). Key assumptions for the communication range calculations were as follows: (1) the signal was ambient noise limited (as determined by the audiogram values for bottlenose dolphins and bigeyes being lower than the ambient sound levels in the same critical bandwidths within the Hauraki Gulf); (2) no masking release mechanisms occurred and (3) both the dolphin's or fish's hearing and the propagation of their calls were omnidirectional. Masking release mechanisms are strategies used by animals to counteract naturally occurring maskers, such as waves or conspecific or heterospecific choruses (Pine et al., 2020). They can include increasing the amplitude of their calls (Lombard effect), changing the spectral characteristics of the call, reduce the spectral overlap with the masker or changing the timing of their calls (Erbe et al., 2016; Radford et al., 2014).

The signal excess equation used to calculate the communication range was

$$SE = SL - N\log10\ (R) - MSL - DT,$$

where signal excess, SE, equals zero at the limited range of detection, SL is the source level of the dolphin's whistle (set at the median level of 138.2 dB re 1 μPa @ 1 m, Frankel et al., 2014) or fish's call (116 dB re 1 μPa @ 1 m, Radford et al., 2015), N is the propagation coefficient over some distance R, MSL is the hourly mean ambient SPL and DT was the detection threshold (set at 10 dB, following recent research on dolphin communication space in the Hauraki Gulf, Putland et al., 2018). The bandwidth of a dolphin's whistle was set between 268 and 18,115 Hz (Frankel et al., 2014), whereas the bandwidth of fish calls was set between 90 and 700 Hz (Radford et al., 2015). The corresponding MSL for those same bandwidths were calculated, after adjusting for half a critical bandwidth either side of the whistle or call frequency limits. The frequency cut- offs for the MSL calculations were based on critical ratio curves (Erbe et al., 2016) for the dolphin whistles, but for the fish calls, the critical bandwidths were based on previous measures (Hawkins & Chapman, 1975). To investigate the relationships between the dolphin's or fish's communication ranges and daytime vessel activity, the MSL values were calculated for the daytime only when wind speeds were below 18.5 km/h. The propagation coefficient, N, determines the rate of acoustic attenuation of the source signal and was calculated by curve- fitting the modelled propagation loss of each third or full octave centre frequency (represented by the average of three frequencies within each octave band) within the dolphin whistle's (i.e. 268 and 18,115 Hz) or fish call's (i.e. 90 and 700 Hz) bandwidth, respectively. The propagation models used for this were a combination of the fully-range- dependent parabolic equation method (RAMGeo [for frequencies below 1.6 kHz]) and ray/Gaussian beam tracing (Bellhop [for frequencies above 1.6 kHz]), for 72 radials from the position of the hydrophone (Pine et al., 2019). Because Bellhop is based on Snell's law, it is applicable if a signal's wavelength is much shorter than the layer within which it is propagating. It was for this reason that the 1.6 kHz cut- off was used for the switch from PE to Bellhop models. Bathymetry data were obtained from NIWA, and the seafloor sediment was set as homogenous soft sediment of silt and sand. Sound speed profiles for the summer (January–February) and autumn (March– May) months were calculated from temperature and salinity data obtained from the Waikato Regional Council.

The communication ranges for bottlenose dolphins and big-eyes were calculated for each hour when wind speeds were below 18.5 km/h for two of the sites. The Rangitoto Channel is the main shipping channel into the Ports of Auckland City and was the shallowest sampling site at 15 m depth, whereas the Ahaaha Rocks is an important site for recreational and tourism activities, such as fishing and cruising with deeper water (35 m). The hourly communication ranges for each species were then averaged over each daytime period (sunrise to sunset, Beauducel, 2020) and the daily median communication ranges compared with corresponding measures of daily daytime SPLs (daily SPLs) and vessel activity using GLM, after con- firming that the required assumptions were met.

6.1.3 Results

Effects of the lockdown on the overall SPLs

The lockdown had an immediate and significant effect on the underwater soundscape at all sites within the HGMP, particularly at frequencies below 1 kHz (Figure 6.2). For example, daily SPLs below 100 Hz dropped from 100 to 88 dB re 1 μPa and for 100– 1000 Hz from 103 to 88 dB re 1 μPa. In the weeks leading up to lockdown, hourly SPLs below 100 Hz ranged between 83 and 155 dB re 1 μPa, which decreased to between 78 and 120 dB re 1 μPa during the lock- down. Between 100 and 1000 Hz, hourly SPLs ranged between 84 and 141 dB re 1 μPa pre- lockdown but between 80 and 122 dB re 1 μPa during the lockdown.

The most noticeable effects of the lockdown were as follows: (1) near- constant presence of vessel noise recorded before the lockdown (during daylight hours) suddenly dropped off and (2) variation in SPLs were substantially reduced, indicating markedly lower number of vessels passing by the hydrophones. As a result, median (±75% quartile) SPLs decreased by 8 dB (from 110 ± 6 dB to 102 ± 4 dB re 1 μPa ($p < .001$)) within the Rangitoto Channel (a busy thoroughfare); approximately 6 dB off the Ahaaha Rocks (from 100 ± 4 dB to 94 ± 2 dB re 1 μPa ($p < .001$)) and in the mid- Gulf (from 98 ± 6 dB to 92 ± 3 dB re 1 μPa ($p < .001$)); and 4 dB (from 117 ± 4 dB to 113 ± 3 dB re 1 μPa ($p < .001$)) off Shearer Rock (Figure 6.1). The decrease in noise levels were immediate, with median SPLs down by between 8 dB (Rangitoto Channel) and 10 dB (the mid- Gulf) on the first day of lockdown (26 March 2020).

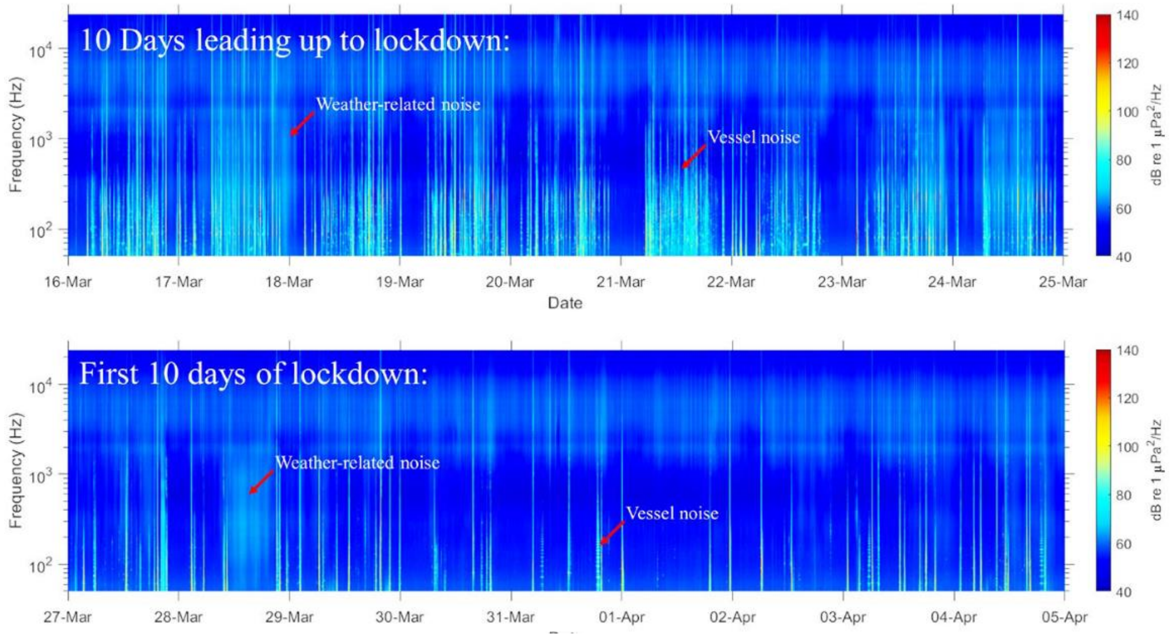

Figure 6.2 Spectrograms before and during the lockdown within the Rangitoto Channel. The diurnal presence of vessels is particularly noticeable below 1 kHz before the lockdown.

Effects of the lockdown on vessel activity

Due to New Zealand's strict lockdown measures for non- essential vessels, vessel activity significantly decreased. For example, on 25 March 2020, vessel noise within the Rangitoto Channel was recorded 63% of the time, decreasing to 34% on the first day of lockdown, and to just 8% after 5 days, at which point contributions were exclusively from essential commercial shipping activity. There was a statistically significant relationship identified between the decline in the presence of vessel noise per day and the median SPL per day, after controlling for wind speeds (GLM: Rangitoto Channel R2 = .75, p < .001; Ahaaha Rocks R2 = .71, p < .001; Figure 6.3). For example, for every 10% increase in vessel noise presence during the day, the daily SPLs increased by ap- proximately 2 dB within the Rangitoto Channel, and the Ahaaha Rocks (Figure 6.3).

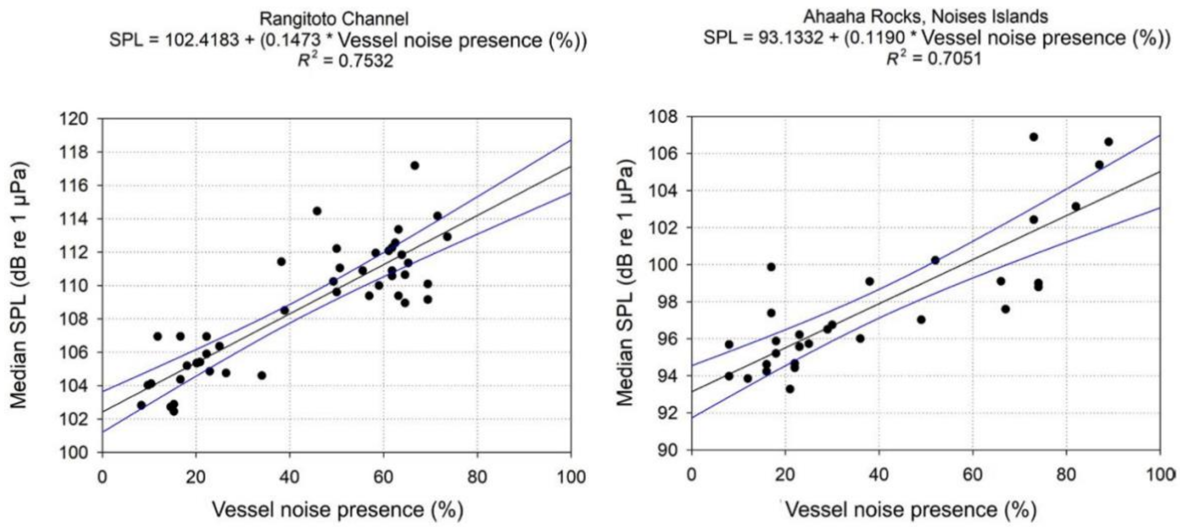

Figure 6.3 Relationships between median sound pressure level (SPL) per day and the daily presence of vessel noise in the ambient soundscape at the shallower Rangitoto Channel site and deeper site at the Ahaaha Rocks.

Effects of the lockdown on dolphin and fish communication range

The calculated communication range for dolphins and fish significantly increased during the lockdown (Figure 6.4), and this effect was greater at the sites furthest from the city. For example, the maxi- mum median range within which dolphins were estimated to be able to communicate was approximately 400 m within the Rangitoto Channel prior to lockdown, increasing to 565 m during the first week of lockdown. For fish, daily communication ranges increased from just a few meters to 155 m after the lockdown (Figure 6.4). At the Ahaaha Rocks, dolphin communication ranges increased from 2.9 km to nearly 4 km and for fish, from 4 to 70 m. Statistical analyses of the median communication ranges and vessel noise presence revealed a significant relationship for both dolphins (GLM: R2 = .77, $p < .001$ [Rangitoto Channel]; R2 = .71, $p < .001$ [Ahaaha Rocks]) and fish (GLM: R2 = .81, $p < .001$ [Rangitoto Channel]; R2 = .80, $p < .001$ [Ahaaha Rocks]). After controlling for wind speeds, every 10% in- crease in the daily presence of vessel noise equated to a 47 m loss in communication range for dolphins within the Rangitoto Channel and 519 m loss around the Ahaaha Rocks. Fish communication ranges decreased 18 or 13 m within the Rangitoto Channel or off the Ahaaha Rocks, respectively.

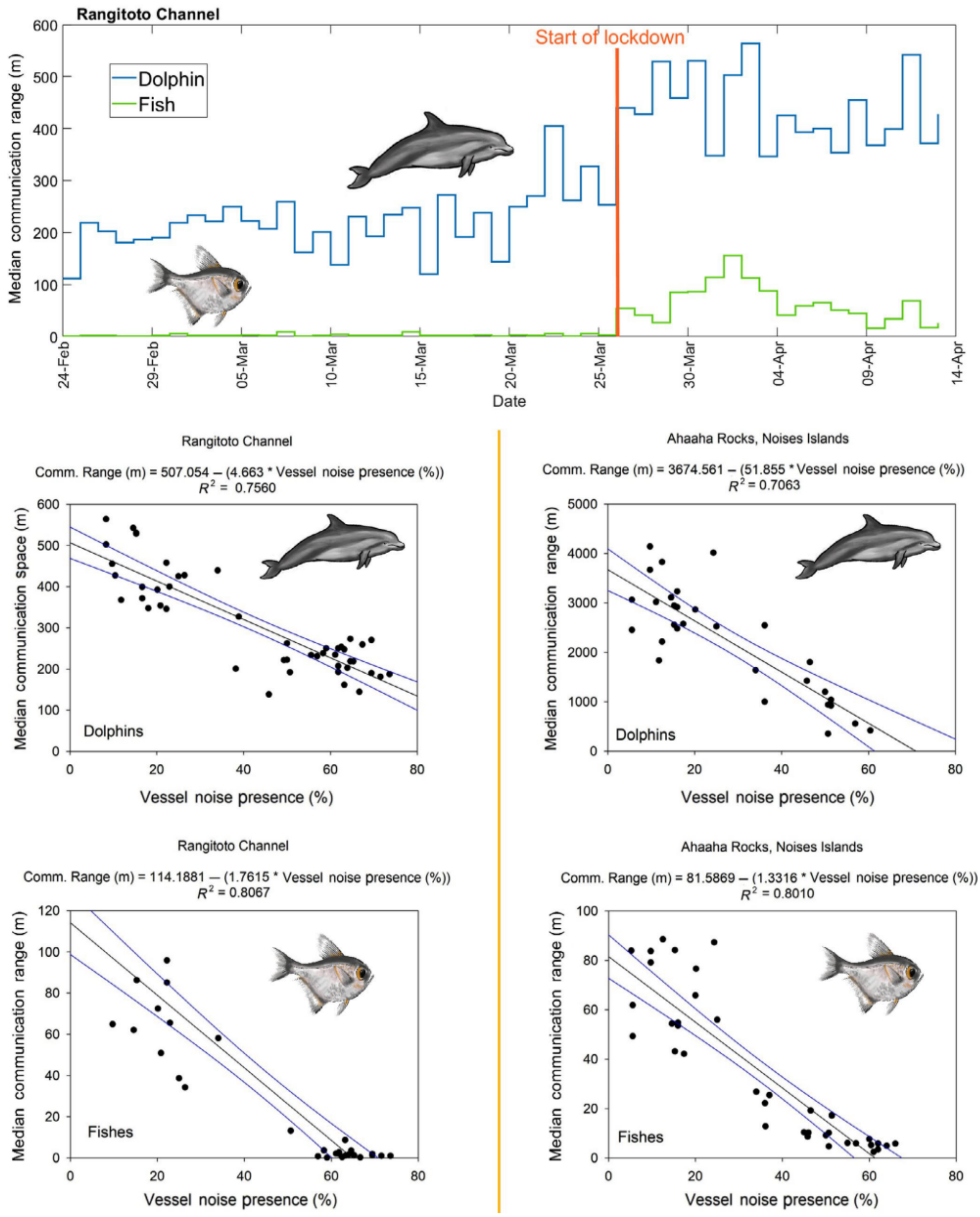

Figure 6.4 Plots showing the effects of vessel noise presence per day (%) on the estimated communication ranges (m) for dolphins and fishes. The stairs plot at the top shows the median communication ranges in dolphins and fishes in the days leading up to, and during, the lockdown. The scatter plots show the relationship between the vessel noise presence per day (%) and corresponding median communication ranges in dolphins and fishes.

6.1.4 Discussion

Although the effects of noise pollution and the role of auditory masking on animal behaviour have been well studied (Shannon et al., 2016), never has it been possible to investigate the reverse in the field. That is, what happens to ambient sound levels and communication ranges when vessel traffic decreases to exceptionally low volumes. The COVID- 19 lockdown in New Zealand provided a means to understand the effects of small boat traffic (because commercial shipping continued during the lockdown, although at a reduced level) on shallow water noise levels near a busy metropolitan centre through the collection of baseline data with very little anthropo- genic noise. These data showed that ambient noise levels dropped 2 dB for every 10% fall in daily vessel noise presence, equating to tens of meters in expected communication ranges being gained by fish and hundreds or thousands of meters for dolphins in shallow (<20 m) or deeper (<50 m) water, respectively. The data collected during the lockdown confirm that vessel noise is likely a key anthropogenic noise source contributing to ambient sound levels within the HGMP. After the lockdown, overall ambient sound levels fell up to 8 dB re 1 μPa over the first 12 h and up to 10 dB re 1 μPa over the entire lockdown period. The proportional presence of vessel noise per day was calculated as the proxy for vessel activity because (1) vessels operating in the area are directly related to the presence of vessel noise and (2) masking in marine animals is related to vessel noise emission rather than the number of vessels operating. The counting of multiple vessels at the same time (since overlapping noise signatures from two or more vessels were not differentiated) or distant/proximate vessels impacting the rate at which ambient sound levels changed in response to vessel activity were controlled for using multiple sites around the inner HGMP of differing depths and wind exposures. The resulting 2 dB change in ambient levels for every 10% rise/fall in vessel activity was seen at both the shallow and deeper sites. Direct translation of our findings to other areas should be carried out carefully, especially if no local data are available and particularly in narrower waterways than those in this study (such as fjords) where vessels would operate in closer proximity to each other and at consistently closer ranges to the hydrophones. The relationship between communication ranges and vessel activity levels, in contrast, did show some site- dependence, with the bigger gains in communication ranges occurring at the deeper and more exposed sites (i.e. further from Auckland City). Those deeper and more exposed sites experienced greater SPL decreases during the lockdown than the shallower sites due to more distant vessels being recorded at the hydrophone (because low-frequency vessel noise propagates further in deeper water). Therefore, the difference in vessel noise being detected at the deeper sites after the lockdown began was greater than at the shallower sites, meaning the overall drop in SPLs were higher. There is a mounting body of evidence showing vessel noise to be highly invasive and audible to nearly all marine mammals (Erbe et al., 2016) and fishes (Popper et al., 2014). Smaller vessels, particularly recreational boats, can present a substantial threat in the marine environment in some areas as an unregulated noise source with higher interaction rates with marine animals than any other source (Correa et al., 2019). Furthermore, the sheer volume of recreational boat traffic can dilute the mitigating effect of their transient nature (McWhinnie et al., 2017). Assessing the effects of these vessel movements on the marine environment has become a management challenge. The lockdown measures imposed in New Zealand during the busy summer/fall boating season provided the fundamental data needed to statistically test relationships between vessel traffic and noise levels, and the effects of cumulative vessel noise on the overall communication range of dolphins and fish. Furthermore, the extended period for which lockdown occurred (7 weeks) meant that an extensive data set was obtained, providing superior base- line values compared with previous recordings and estimates. This event provided an unprecedented chance to rigorously assess some key parameters, including relating the number of vessels passing through an area required to raise the ambient noise floor of that area by a single decibel (i.e. cumulative noise) and relating vessel noise exposure to impacts on the communication range in marine animals. The unprecedented low SPLs recorded during the lockdown were particularly interesting because of the known influence vessel noise can have on the ability of marine animals to communicate (Erbe et al., 2016; Hawkins & Picciulin, 2019). Masking of marine animals' acoustic communication signals by small vessel noise is a key research question after being somewhat neglected compared with the attention given to noise from commercial shipping (Erbe et al., 2019). For many coastal areas, small vessels are likely to be the most prevalent and ongoing source of masking noise in shallow waters. Previous studies have investigated reductions in animal communication ranges from individual commercial or small vessels, including within the HGMP, with small vessels raising ambient noise levels at least 47 dB re 1 μPa (Li et al., 2015) or as much as 75 dB re 1 μPa nearer the passing vessel (Pine et al., 2016). However, the cumulative effect of many individual vessels passing during daylight hours on the overall communication range has not been measured before, as vessel activity has not dropped low enough to obtain true baseline data. The New Zealand lockdown provided a unique opportunity to obtain these baseline data as the daily presence of general vessel noise decreased to 8%. During the lockdown, there was significant increase in dolphin and fish communication ranges, hundreds of meters to several kilometres for dolphins and tens of meters to hundreds of meters for fish. Overall, the daily communication range more than doubled after the lockdown began, and for every 10% decrease in daily vessel noise presence, the communication range increased by between 47 and 519 m for dolphins, or 13 and 18 m for fish, respectively. The expected benefits of the reduced interference by boat noise are an improved ability for marine animals to communicate and maintain social cohesion over longer distances, including when foraging, and improving their perception of their environment and associated threats— most likely resulting in lower stress levels (Rolland et al., 2012). Although the first two benefits are more intuitive, lower stress levels occur because anthropogenic noise (including continuous noise, such as small vessel noise) is a well- known stressor in marine mammals (Nowacek et al., 2007; Richardson et al., 1995; Rolland et al., 2012; Wright et al., 2007) and fishes (Hawkins et al., 2020; Hawkins & Popper, 2017; Popper & Hawkins, 2019; Slabbekoorn et al., 2010). For example, North Atlantic right whales (Eubalaena glacialis) showed lower baseline levels of glucocorticoids in faecal samples following a 6 dB reduction in ambient noise from reduced vessel activity after the 9/11 terrorist attacks in the United States of America (Rolland et al., 2012). Yangtze finless porpoises (*Neophocaena asiaeorientalis asiaeorientalis*) had higher serum cortisol levels in areas with high vessel activity than conspecifics in areas without vessels (Nabi et al., 2018). Noise-induced stress has also been seen in coral reef fish (Mills et al., 2020), temperate kelp fish (Nichols et al., 2015), European seabass (Spiga et al., 2017) and freshwater fishes (Smith et al., 2004). With sustained decreases in vessel activity due to various lockdowns around the world, the physiological changes in wild fishes and marine mammals (since much research, particularly on fishes, are in captive environments) in response to lower vessel presence would be of particular interest

6.1.5 Conclusions

The COVID- 19 lockdown measures in New Zealand put a stop to all non- essential vessels operating, bringing a high degree of masking relief for marine life. The dramatic cessation of human activity on the water provided new baseline data on ambient sound levels due to very low vessel activity, revealing the measured cumulative effect that vessel noise has on the ambient soundscape and masking in fish and dolphins. The key advantage of these new data is that they provide strong empirical evidence that small vessels, when in sufficient numbers/presence, directly influence ambient sound levels and are not an acute noise source with limited impact as sometimes believed by regulators. The data also, for the first time, demonstrate how small vessels are already contributing to ambient sound levels in ecologically important areas that are near busy metropolitan centres.

6.2 Global COVID-19 lockdown highlights humans as both threats and custodians of the environment

El confinamiento mundial por COVID-19 pone de manifiesto que los seres humanos son a la vez amenazas y guardianes del medio ambiente

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CRediT of the PhD candidate: Investigation, Data curation, Project administration.

Here, the global COVID-19 lockdown was considered a unique, quasi-experimental opportunity to test the role of human activities in both harming and benefiting nature.

Highlights

- The global COVID-19 lockdown has impacted nature and conservation programs.
- Immediate effects are documented across the world and in all ecosystems.
- Initial responses are biased towards established monitoring programs and networks.
- Complex positive and negative effects were detected, some with cascading impacts.
- Humans are important custodians of species and ecosystems.

Abstract The global lockdown to mitigate COVID-19 pandemic health risks has altered human interactions with nature. Here, we report immediate impacts of changes in human activities on wildlife and environmental threats during the early lockdown months of 2020, based on 877 qualitative reports and 332 quantitative assessments from 89 different studies. Hundreds of reports of unusual species observations from around the world suggest that animals quickly responded to the reductions in human presence. However, negative effects of lockdown on conservation also emerged, as confinement resulted in some park officials being unable to perform conservation, restoration and enforcement tasks, resulting in local increases in illegal activities such as hunting. Overall, there is a complex mixture of positive and negative effects of the pandemic lockdown on nature, all of which have the potential to lead to cascading responses which in turn impact wildlife and nature conservation. While the net effect of the lockdown will need to be assessed over years as data becomes available and persistent effects emerge, immediate responses were detected across the world. Thus, initial qualitative and quantitative data arising from this serendipitous global quasi-experimental perturbation highlights the dual role that humans play in threatening and protecting species and ecosystems. Pathways to favourably tilt this delicate balance include reducing impacts and increasing conservation effectiveness.

Resumen *El confinamiento mundial para mitigar los riesgos sanitarios de la pandemia de COVID-19 ha alterado las interacciones humanas con la naturaleza. Aquí informamos de los impactos inmediatos de los cambios en las actividades humanas sobre la vida silvestre y las amenazas ambientales durante los primeros meses de confinamiento de 2020, basándonos sobre 877 informes cualitativos y 332 evaluaciones cuantitativas de 89 estudios diferentes. Cientos de informes sobre observaciones de especies inusuales en todo el mundo sugieren que los animales respondieron rápidamente a la reducción de la presencia humana. Sin embargo, también surgieron efectos negativos en la conservación, ya que el confinamiento hizo que algunas/os funcionarias/os de los parques no pudieran realizar tareas de conservación, restauración y aplicación de la ley, lo que provocó un aumento local de actividades ilegales como la caza. En general, existe una compleja mezcla de efectos positivos y negativos del cierre de la pandemia en la naturaleza, todos los cuales pueden dar lugar a respuestas en cascada que, a su vez, repercuten en la conservación de la vida silvestre y la naturaleza. Aunque el efecto neto del confinamiento deberá evaluarse a lo largo de los años, a medida que se disponga de datos y surjan efectos persistentes, quepa destacar que se detectaron respuestas inmediatas en todo el mundo. Así pues, los primeros datos cualitativos y cuantitativos derivados de esta perturbación global cuasi experimental destacan el doble papel que desempeña el ser humano en la amenaza y la protección de las especies y los ecosistemas. Las vías para inclinar favorablemente este delicado equilibrio incluyen la reducción de los impactos y el aumento de la eficacia de la conservación.*

Keywords: pandemic, biodiversity, restoration, global monitoring.

6.2.1 Introduction

Human-driven alterations of atmospheric conditions, elemental cycles and biodiversity suggest that the Earth has entered a new epoch, the Anthropocene (Crutzen, 2002; Steffen et al., 2007). Negative impacts associated with human activities include a much warmer Earth state, marked expansion of urbanization, and accelerating species extinctions (Schipper et al., 2008). The perspective that the main role of humans is a source of threats on species and ecosystems leads to the prediction that the global human lockdown to mitigate COVID-19 health risks may alleviate human impacts, with resulting positive environmental responses (Derryberry et al., 2020; Rutz et al., 2020). Indeed, early reports indicate that restrictions led to immediate decreases in air, land, and water travel, with similar declines in industry, commercial exploitation of natural resources and manufacturing, and lower levels of PM10, NO2, CO2, SO2, and noise pollution (Bao and Zhang, 2020; March et al., 2021; Millefiori et al., 2021; Otmani et al., 2020; Santamaria et al., 2020; Thomson and Barclay, 2020; Terry et al., 2021; Ulloa et al., 2021).

Yet a more comprehensive consideration of the links between human activities, species and ecosystems also acknowledges the role of humans as custodians of nature, who engage in conservation research, biodiversity monitoring, restoration of damaged habitats, and enforcement activities associated with wildlife protection (Bates et al., 2020; Corlett et al., 2020; Evans et al., 2020; Manenti et al., 2020; Rondeau et al., 2020; Zambrano-Monserrate et al., 2020; Kishimoto and Kobori, 2021; Miller-Rushing et al., 2021; Vale et al., 2021; Sumasgutner et al., 2021). Indeed, the global COVID-19 human confinement has disrupted conservation enforcement, research activities and policy processes to improve the global environment and biodiversity (Corlett et al., 2020; Evans et al., 2020; Zambrano-Monserrate et al., 2020; Quesada-Rodriguez et al., 2021). The lockdown has also created economic insecurity in rural areas, which may pose biodiversity threats as humans seek to support themselves through unregulated and illegal hunting and fishing, and conservation spending is reduced. In particular, declines in ecotourism in and around national parks and other protected areas lowered local revenue, park staffing, and funding to enforce hunting restrictions and invasive species management programs (Spenceley et al., 2021; Waithaka et al., 2021). In many areas, restoration projects have been postponed or even cancelled (Bates et al., 2020; Corlett et al., 2020; Manenti et al., 2020).

Here, we consider the global COVID-19 lockdown to be a unique, quasi-experimental opportunity to test the role of human activities in both harming and benefiting nature (Bates et al., 2020). If the negative roles of humans on species and ecosystems predominate, we would expect overwhelmingly positive reports of responses of nature to human lockdown. We integrate 30 diverse observations from before and during the peak lockdown period to examine how shifts in human behaviour impact wildlife, biodiversity threats, and conservation. We first analyse the mobility of humans on land and waterways, and in the air, to quantify the change in human activities. Second, we compile qualitative reports from social media, news articles, scientists, and published manuscripts, describing seemingly lockdown-related responses of nature, encompassing 406 media reports and 471 observations from 67 countries. Third, we map the direction and magnitude of responses from wildlife, the environment and environmental programs, using data collected before and during lockdown provided by scientists, representing replicated observations across large geographic areas. We collated data from 84 research teams that maintained or accessed existing monitoring programs during the lockdown period, reporting 326 responses analysed using a standardized analytical framework. We accounted for factors including autocorrelation and observation bias using mixed-effects statistical models, and selected the most robust available baselines for each study to report lockdown-specific effect sizes (see methods). We empirically describe the type, magnitude, and direction of responses for those linked with confidence to the lockdown, and offer integrated outcomes supported by examples drawn from our results. Finally, we use these results to provide recommendations to increase the effectiveness of conservation strategies.

6.2.2 Materials and methods

Here we interpret data and qualitative observations that represent a non-random sample of available information comprising diverse response variables. Thus, we make inferences about the geographic scope of observations and focus on what integrated understanding can be gained from considering the evidence of both positive and negative effects of the lockdown and their linkages.

From diverse data sources and analyses, we compiled a high-level view of how the lockdown influenced four major categories of responses or shifts in (1) human mobility and activity, (2) biodiversity threats, (3) wildlife responses, and the (4) social structures and systems that influence nature and conservation (described in further detail in Appendix 1, Table A1). In brief, human mobility and activities included recreational activities such as park visits and boating, commuting, and activities related to industry, such as shipping. Biodiversity threats included categories which were linked directly to a possible negative wildlife response, such as hunting, fishing, mining, vehicle strikes, wildlife trade, environmental pollution, and deforestation. Wildlife responses represented observations related to biodiversity and species, such as community structure, animal performance (e.g., reproduction, health, foraging) and habitat use (i.e., abundance and distribution). Environmental monitoring, restoration programs, conservation, and enforcement enforcement were grouped as representing social systems and structures that influence and support conservation.

Human mobility data

Data on government responses to COVID-19 across countries and time were retrieved from the Oxford COVID-19 Government Response Tracker (Hale et al., 2021), which also reports where the restrictions on internal movement apply to the whole or part of the country. The global population under confinement of internal movement was calculated by adding up the population of countries where the restriction is general, and 20% of the population of countries where the restriction is targeted, as an estimate of the fraction of the population affected. Population data by country corresponding to year 2020 have been obtained from the Population Division of the Department of Economic and Social Affairs of the United Nations (United Nations, 2018). Note that the data about restrictions contain missing information for some countries and dates. Therefore, the calculated number of human confinement does not take into account the population of countries with missing information and may thus underestimate the actual number of humans under restriction.

Changes in human mobility data were recorded by a number of agencies globally, and combined, describe how the lockdown affected movements on land, at sea, and in the air. Data on the restriction of individuals in residential areas and to parks were derived from Google Community Mobility Reports (https://www.google.com/covid19/mo bility/). Data on driving were obtained from the Apple Maps Mobility Trends Report (https://www.apple.com/covid19/mobility). Marine traffic and air traffic data were derived from exactEarth Ltd. (http:// www.exactearth.com/), and OpenSky Network (https://openskynet work.org/) respectively. Google Community Mobility Report data are based on anonymized data representing how long users stay in different types of localities, and are aggregated to regional scales (usually country). Each regional mobility report reflects a percentage change over time compared to a 5-week baseline (Jan. 3 to Feb. 6, 2020). Similarly, Apple Maps Mobility Trends Reports are based on Apple maps user data and aggregated by region to reflect the percent change in time Apple maps users spent driving relative to a baseline (Jan. 12, 2020). The percent change in the responses of human mobility through time allows identification of extreme inflections related to human behaviour. For Google and Apple data, we extracted the overall mobility trends for each country until May 1st, which was selected from a sensitivity test and before relaxation of confinement measures were introduced in most countries. We further excluded within-country variations in mobility, and removed all countries with extensive data gaps and countries that did not show a response to lockdown.

The first step to quantifying the effect due to the lockdown on community mobility (residential and parks) and driving data was identifying the date of greatest change in each time-series (data and script files are here: https://github.com/rjcommand/PAN-Environmen t). Because each country had differing lockdown dates and multiple types of lockdown, we identified critical transition dates which best explained the change in mobility for each country. To do so, we used Generalized Additive Models (GAM (Wood, 2011)) on daily mobility levels in each country, using the Oxford Covid-19 Government Response Tracker database of country-level containment policies (C1-C7) to define a variable for the before and after lockdown periods, running up to 15 models per country depending on the number of different kinds of lockdown measures imposed. From these models, we selected the lock- down date that explained the greatest amount of change. We manually identified the confinement dates in cases where the models did not converge or when multiple unexplained inflection points were detected (N = 10 countries). Percent change was calculated as the mean per- centages after implementation of the confinement measure selected from the models.

For marine traffic mobility, satellite AIS (S-AIS) data for April 2019 and 2020 were obtained from exactEarth Ltd. (http://www.exactearth. a space-based data service provider which operates a constellation of 65 satellites to provide global AIS coverage at a high-frequency rate (< 5 min average update rate). The latest upgrade in the constellation entered into production in February 2019 and S-AIS coverage was equivalent for both periods (exactEarth Ltd., pers. comm.). Values rep- resented the monthly number of unique vessels within grid cells of 0.25 × 0.25 degrees. We calculated the vessel density as the number of vessels per unit area, considering the difference of cell size across the latitudinal gradient (March et al., 2021). Grid cells from the Caspian Sea and with <10% ocean area were removed from the analysis, based on the GADM Database of Global Administrative Areas (version 3.6, https://gadm. org/). Further quality control procedures were provided in more detail in a complementary publication. We calculated the percentage change in marine traffic density between April 2019 and April 2020 per country and Exclusive Economic Zones using a Generalized Linear Model (GLM (R Core Team, 2020; Pinheiro et al., 2021)).

For air traffic mobility, data were downloaded from the OpenSky network (https://openskynetwork.org). OpenSky uses open-source, community-based receivers to receive air traffic data from around the world and makes these data available in an online repository. The online database consists of latitude and longitude of departure and landing for all flights detected where receivers are available. Data are limited in some areas, including Africa and parts of Asia. We downloaded daily data for 129 countries where data were available in April 2019 (1,302,282 flights) and the same period in April 2020 (316,609 flights, when most countries included in the analysis had imposed international travel restrictions) to compare the total volume of traffic departing from, or arriving to, all countries where data were available for both years. We aggregated these flights by country, then ran a GLM on the daily number of flights in each country, accounting for the day of the week and comparing 2020 (countries in lockdown) to 2019. We used this model to calculate a t-statistic for the lockdown effect in each country, and then calculated a percentage change in flight volume based on numbers of flights per country in April 2019 versus the lockdown period in April 2020.

Qualitative observations

Observational evidence of the impact of the first four months of the COVID-19 lockdown on society, the environment and biodiversity was collected and collated through: (1) internet searches with the keywords nature, conservation, environment and COVID-19; (2) calls on social media for personal observations and for volunteers to contribute from our networks; (3) Web of Science general search for papers (terms: nature, conservation, environment, COVID-19) released between May to August 2020 that also used qualitative evidence to investigate the lockdown effect, and (4) through volunteer contributions from our global PAN-Environment working group of over 100 scientists. Each qualitative observation (N = 877 observations) was assigned a geographic location (latitude and longitude) and classified by observation type (described in Appendix 1, Table A1), including a description and details on the species impacted (where relevant). Reports that listed several impacts (e.g., independent observations, species, or locations) were entered as multiple lines. Following entry to our dataset, each observation was assigned an effect score from 0 to 10 (as described in Appendix 1, Table A2) to distinguish between observations with ephemeral effects with unknown impacts from those that will have widespread or persistent outcomes with strong effects in positive or negative directions. Qualitative data were recorded for all continents, except Antarctica, representing 67 countries. countries. Non country-specific observations were also included, representing 20% of all anecdotes. The majority of countries were represented by fewer than five observations (51 countries), while South Africa submitted approximately one third of the total observations (total = 297). This high representation in South Africa was a known bias due to the use of African birding forums to collect citizen science data which were organized to communicate and engage widely as lockdown measures were implemented. Similarly, other known biases included high relative representation of charismatic species and those that were easily observed during lockdown by humans (e.g., giant pandas and garden birds). Most reports were gathered from English sources, however, over 100 observations were translated from Italian, and another 50 and 10 were from Spanish and Afrikaans, respectively. We interpreted our results in this context by focusing on the inferences that can be made in spite of these biases, and in combi- nation with the empirical data. See Appendix 3 (Table S3) for the full dataset.

Empirical data

We further assembled a global network of scientists and managers to download, interpret, and analyze quantitative information investigating the negative, neutral, and positive effects resulting from the lockdown. We made use of ongoing monitoring programs for comparisons before, during, and after the lockdown confinement period, or in similar time windows in previous unaffected years. Seven example scripts were provided to represent different types of considerations for analyses for each team to match with the types of response data, biases, references, study durations, and complexity (covariates, spatial and temporal autocorrelation, and random effects) (available in Appendix 2). The core author team further consulted on the analysis of each dataset to ensure consistency across studies. The original authors reviewed and edited their data following transcription.

With this overall approach, we were able to provide insights on the immediate changes likely due to the lockdown (69 studies used a historical reference period including the lockdown months in previous years; studies compared the strict lockdown period to the same months in pre-lockdown years, described in detail for each study in Supplementary materials 6.2, Appendix 4, Table A4). In other cases, the reference was an area representing a reference state (i.e., remote areas or large, well-governed protected areas did not undergo a difference in human activities due to lockdown measures). If observations were unavailable prior to the start of the pandemic lockdown or for reference year(s), comparisons were made (if sensible) during and after the lockdown, i.e., the reference was the post-confinement period (8 studies). For instance, litter accumulation at two locations was measured from the strict lockdown in April 2020, and over two months as restrictions eased. Spatial comparisons between areas impacted by the lockdown with unaffected sites were also included to detect lockdown related effects. These unaffected sites were considered as reference areas after evaluation by the relevant research teams who contributed the data (2 studies). The rationale for each study design and selection of the baseline period is reported in Table A4 and A5 (Appendices 4 and 5), and was reviewed by the core analysis team to ensure the baseline period comprised a suitable reference for the given response of interest. Total percent changes were calculated as the difference between the response coefficient (attributed to the lockdown) relative to the reference coefficient. For instance, if we observed a 400% increase in a response during the lockdown, this translates to an effect which was 4 times greater. We used Generalized Linear, Additive Mixed (GAMM (Wood, 2004)) or Linear Mixed-Effects (LME (Pinheiro et al., 2021)) models, as best suited for each data type. Suitability was based on the distribution of the response data, fit of the statistical data, and the covariates that needed to be accounted for to estimate the appropriate coefficients. In brief, for each dataset, we quantified percentage change from expected or typical values, as well as an effect size in the form of a t-statistic standardized by sample size (Bradley et al., 2019). Datasets and results summary tables for each analysis of human mobility and empirical datasets are deposited in a GitHub repository, filed under each contributing author's name: https://github. com/rjcommand/PAN-Environment. The independent data availability statement for each study is reported in Table A5 (Appendix 5).

Different datasets were analysed using statistical models with parameters dependent on the type, duration and complexity of each response and study design. Table S5 (Appendix 5) provides a summary of the information that was collected from the authors who contributed each study, a description of the methods and relevant references, analysis type, spatial scale, details on the temporal or spatial baselines and how they were accounted for or interpreted, reports of any confounding factors (included as covariates), model results summary table links to GitHub, interpretation, and confidence score that the observed effect was indeed due to the lockdown (with a rationale for this selection). The relevant information for interpretation across studies was subsequently transcribed to Table S4 (Appendix 4).

6.2.3 Results

Human mobility on land, in the air and on water

The global peak of lockdown occurred on April 5th, 2020, at which time 4.4 billion people were impacted (figure 6.5), representing 57% of the world's population. In the weeks before and after this lockdown peak, residents of most countries spent much more time at home (figure 6.6). Country-specific critical transition dates (which occurred primarily in late March leading up to the April peak) were used to assess the total change in mobility until May 1st. During this period, driving decreased by 41%, there was a 20% overall reduction in park visits, particularly in Central and South American countries, although Nordic countries were an exception (figures S1 & S2). The April 2020 period also saw major disruptions in community, food transport, and supply chains, with a 9% decrease in marine traffic globally and a 75% total reduction in air traffic (both relative to April 2019, figures A3-A5). Thus, the COVID-19 lockdown has led to a significant global reduction in human mobility, notably travel, causing an "anthropause" (Rutz et al., 2020).

Effects on wildlife around the world As humans retreated, animals quickly moved to fill vacated spaces

As humans retreated, animals quickly moved to fill vacated spaces (figure 6.7) (Derryberry et al., 2020; Zellmer et al., 2020). In our dataset, approximately half of the qualitative observations and more than one third of all measured quantitative species responses that were linked with some confidence to the lockdown related to unusual animal sightings in urban areas (both land and waterways), and to species occurring in different abundances compared to pre-perturbation base- line estimates (figures 6.8 and 6.9). Many initial observations painted a rosy picture of wildlife "rebounding"; indeed, our qualitative observations of wildlife responses are predominantly positive, likely reflecting reporting biases (figure 6.8). Reports include changes in behaviour, reproductive success, health, and reductions in mortality, apparently in response to altered levels of human activity (figure 6.8).

Our quantitative assessments suggest a mixed role of human confinement in positively and negatively influencing wildlife (figure 6.9). Some species changed their behaviour (e.g., daily activity patterns) and relocated to entirely new areas, including seeking new food sources and roaming to unusual areas. This included air space, such as when critically endangered Griffon vultures in Israel flew further afield in 2020, apparently due to reduced military training during the lockdown (Ap- pendix 4, Table A4, StudyID 55). Some animals also moved to human settlements from rural locations (e.g., golden jackals: Appendix 4, Table A4, StudyID 28), while other species showed very little changes (figure 6.9 showing distribution of wildlife responses as effect sizes which centre on zero).

There was also qualitative evidence of increased human-wildlife conflicts (described in Appendix 3, Table A3 under the categories: Biodiversity threat, Human-wildlife interaction, Aggression). Four non- fatal shark attacks on humans occurred over a span of five weeks in French Polynesia, a number typically observed over a whole year, and an unusually high number of fatal shark attacks has been reported for Australia. On land, monkeys that normally live closely and peacefully with humans near a pilgrim centre in Uttar Pradesh, in northern India, attacked residents – atypical behaviour that may be related to starvation and corresponding aggression.

Changes in biodiversity threats

The pandemic lockdown generally highlighted the enormous and wide-ranging impacts that humans have on the environment and wild- life. For instance, in a remote forest area in Spain, a 45% reduction in NO_2 and SO_2 lead to reduced atmospheric deposition of NO_3^- and SO_4^{2-}, and limited the input of N and S to soil ecosystems (Appendix 4, Table A4, StudyID 84). Ocean fishing was also reduced by 12% based on our analysis of 68,555 vessels, representing 145 national flags and 14 gear types (including drifting longlines and nets, purse seines and trawlers, Appendix 4, Table A4, StudyID 5). Animal deaths from vehicle strikes on roads and vessel strikes in the water during peak lockdown were dramatically lower than baseline periods in two data sets (e.g., 19% reduction: South Korea, 42% reduction: USA, Appendix 4, Table A4, StudyIDs 7 & 27). There was also a marked reduction in ocean noise, which can negatively impact a wide range of marine organisms, as re- ported from several locations. For example, lockdown-related re- ductions in ferry traffic, seaplane activity, and recreational boating activity near the transport hub of Nanaimo Harbour, Canada, combined to reduce the sound pressure levels by 86% (Appendix 4, Table A4, StudyID 23). In urban parks in Boston, noise from road traffic dropped by as much as 50% in some areas as traffic volumes decreased (Appendix 4, Table A4, StudyID 52; Terry et al., 2021 [this issue]). On roadways, parks and beaches around the world, direct pollution from humans was also reduced during the lockdown. For example, surveys of 15 beaches in Colombia and Cuba found negligible evidence of noise, human waste, and litter during the strict lockdown period, in contrast to pervasive human impact before the lockdown (Appendix 3, Table A3, Lines 742–748).

While some biodiversity threats were alleviated, as discussed above, responses were highly variable. For example, marine traffic increased slightly in some regions (Appendices 4 and 5, Fig. A4 and A5) including shifts of fishing fleets to near-shore coastlines. In some regions, fishing activities intensified rather than declined (e.g., some recreational fisheries and commercial fisheries) (Fig. 5). Other impacts escalated, including massive increases in plastic waste due to discarded personal protective equipment to prevent COVID-19 transmission, and abnor- mally large crowds of visitors to parks for recreation in countries where outdoor activities were permitted (e.g., a 47% visitation increase in the Swiss National Park, Appendix 4, Table A4, StudyID 57). In many parks, hikers were observed expanding trails, destroying or changing local habitats, and even trampling endangered orchid species (Appendix 3, Table A3).

The lockdown also interrupted conservation enforcement activities with dire consequences including increased illegal activities, such as hunting, deforestation, and the dumping of waste (Figs. 4 and 5). For instance, pangolins, which are amongst the world's most trafficked mammals (for food and traditional medicine), seem to have come under even greater pressure; trade seizures increased in India by >500% (i.e., a 5-fold increase) during the lockdown period (Appendix 4, Table A4, StudyID 62). Indeed, a spike in exploitation of many animal species for food and trade was reported around the world (e.g., China, Kenya, India, Peru, South Africa, Sri Lanka, UK), often in national parks and protected areas. For example, in the protected Bugoma Forest reserve in Uganda (Appendix 4, Table A4, StudyID 19), increased use of animal snares during the pandemic was detected, which can injure and kill non-target animals, including endangered species such as chimpanzees. Likewise, during the lockdown, the conch fishery in the Bahamas shifted to smaller illegal-sized juvenile animals from a nursery area (Appendix 4, Table A4, StudyID 47).

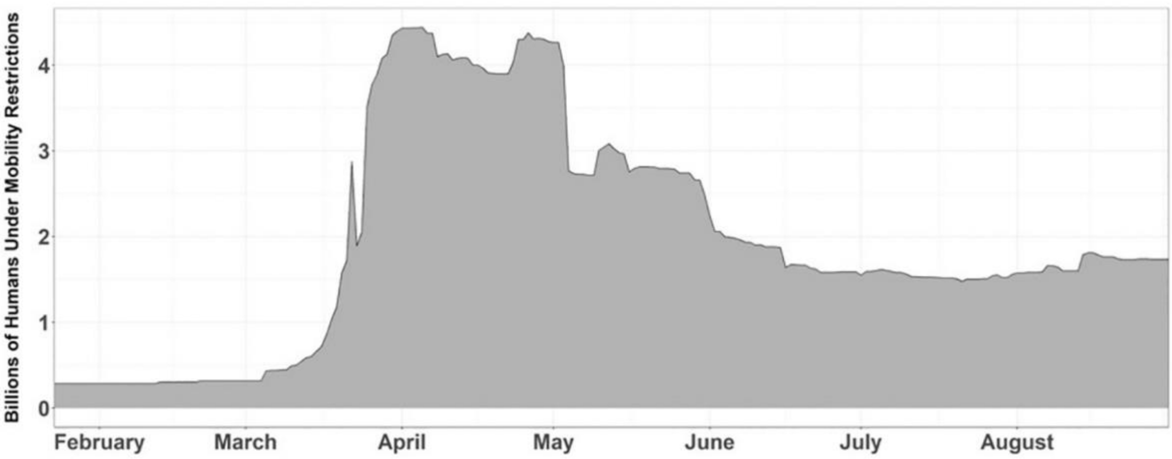
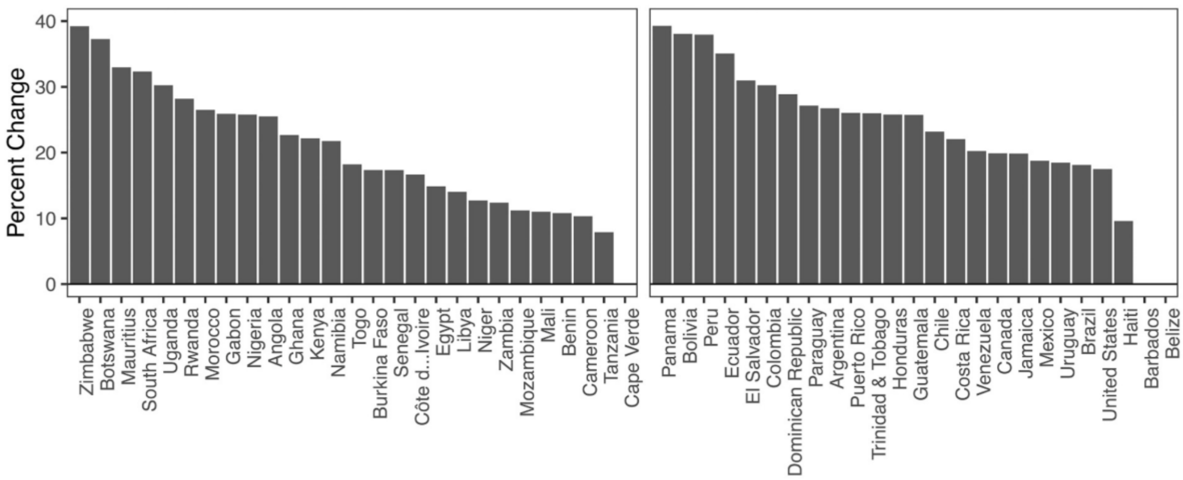
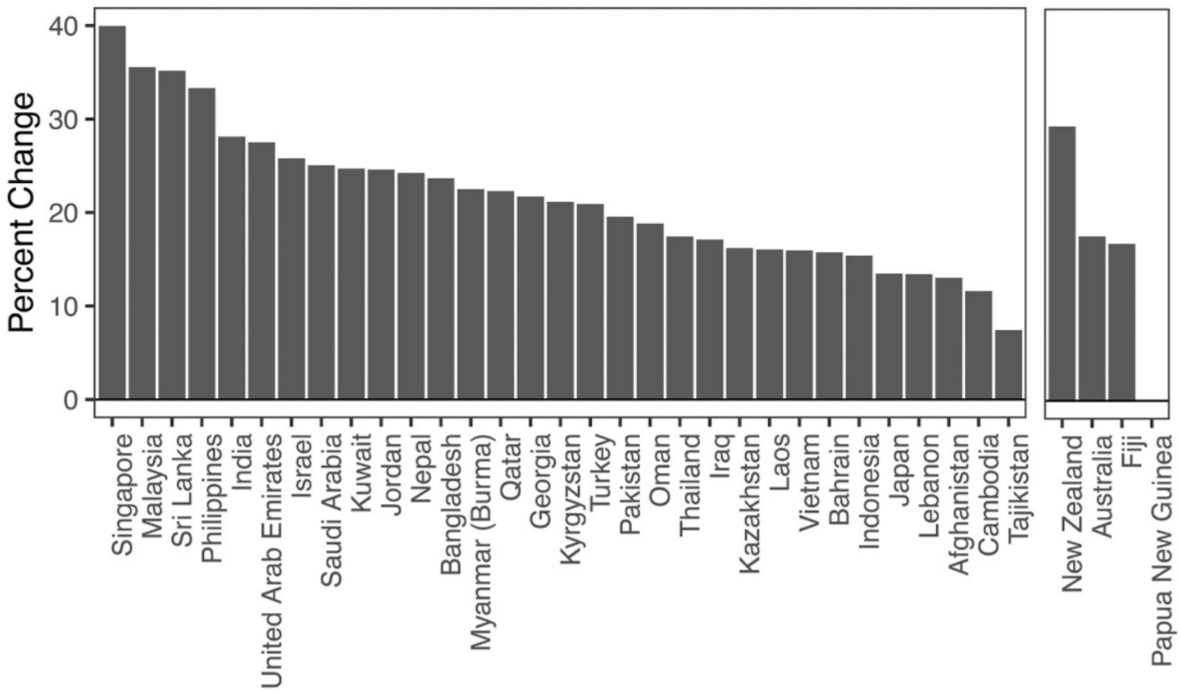


Figure 6.5 Total humans under COVID-19 mobility re- strictions. Time series of the number of humans under lockdown across the global population under the 2020 COVID-19 mitigation policies. This assumes that in countries with targeted restrictions, a fraction of 20% of the population was under lockdown. Assuming different fractions, similar time patterns but different magnitudes of populations under lock- down are obtained. For example, assuming fractions of 20% and 30%, April 5th was the day with the maximum population under lockdown equal to 57% and 61% of the global population, respectively. Assuming fractions of 5% and 10%, April 26th was the day with the maximum population under lock- down equal to 53% and 54% of the population, respectively.


Percent Change
0
10
20
30
40
Zimbabwe
Botswana
Mauritius
South Africa
Uganda
Rwanda
Morocco
Gabon
Nigeria
Angola
Ghana
Kenya
Namibia
Togo
Burkina Faso
Senegal
Côte d…Ivoire
Egypt
Libya
Niger
Zambia
Mozambique
Mali
Benin
Cameroon
Tanzania
Cape Verde
Panama
Bolivia
Peru
Ecuador
El Salvador
Colombia
Dominican Republic
Paraguay
Argentina
Puerto Rico
Trinidad & Tobago
Honduras
Guatemala
Chile
Costa Rica
Venezuela
Canada
Jamaica
Mexico
Uruguay
Brazil
United States
Haiti
Barbados
Belize


Percent Change
0
10
20
30
40
Singapore
Malaysia
Sri Lanka
Philippines
India
United Arab Emirates
Israel
Saudi Arabia
Kuwait
Jordan
Nepal
Bangladesh
Myanmar (Burma)
Qatar
Georgia
Kyrgyzstan
Turkey
Pakistan
Oman
Thailand
Iraq
Kazakhstan
Laos
Vietnam
Bahrain
Indonesia
Japan
Lebanon
Afghanistan
Cambodia
Tajikistan
New Zealand
Australia
Fiji
Papua New Guinea

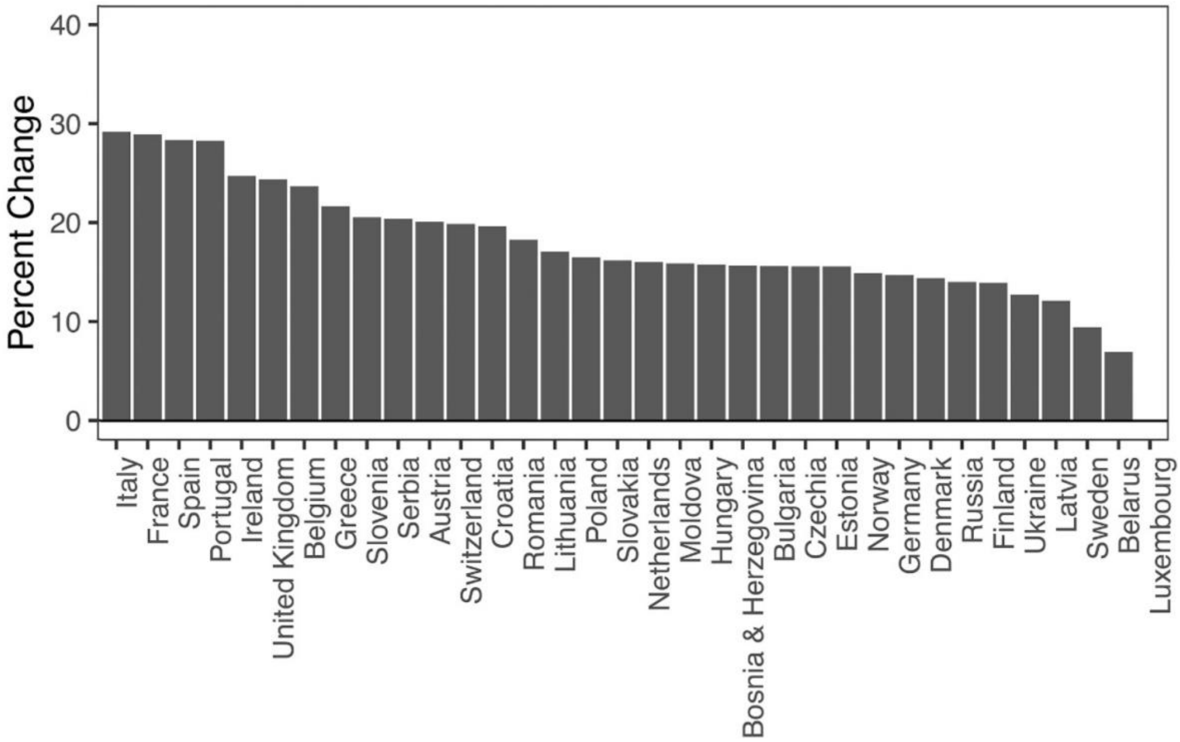


Figure 6.6 Change in mobility. Percent change in time spent within home residences (residential) following implementation of confinement measures in each country.

Responses of social systems which support biological conservation

We found that management and conservation systems were initially weakened and even ceased in many areas of the world (the median effect size was negative in both the qualitative and quantitative data sets: Figs. 4b and 5b). In one region of the Amazon, Brazil, the deforested area relative to historical years increased by 168% (i.e., a 1.68-fold change) during the lockdown, and a similar response was seen for the eruption of fire hotspots in Colombia, both attributed to a lack of enforcement (Appendix 4, Table A4, StudyID 35). Environmental monitoring and community-based programs to restore habitats or remove waste from beaches have also been severely restricted. Anecdotes highlight that pest management programs have not been able to recruit community volunteers to trap rats and mobilize personnel to combat locust outbreaks. In one dramatic example, failure to remove non-native mice from remote seabird islands is expected to lead to the loss of two million seabird chicks in 2020 (Appendix 3, Table A3, Line 265).

The number of observers contributing to community science efforts has also immediately declined for many programs (e.g., eBird Colombia, eButterfly, Nature's Notebook and the LEO Network; Crimmins et al., 2021 [this issue]), although growth was also noted in some US programs in particular cities and regions (eBird and iNaturalist, Appendix 4, Table A4; Crimmins et al., 2021 [this issue]; Hochachka et al., 2021 [this issue]). A lack of reporting can be a major conservation concern, such as when the number of whale observers declined by

50% along the Pacific Northwest during the lockdown, leading to a reduced ability of ships to avoid striking whales (Appendix 3, Table A3, Line 272).

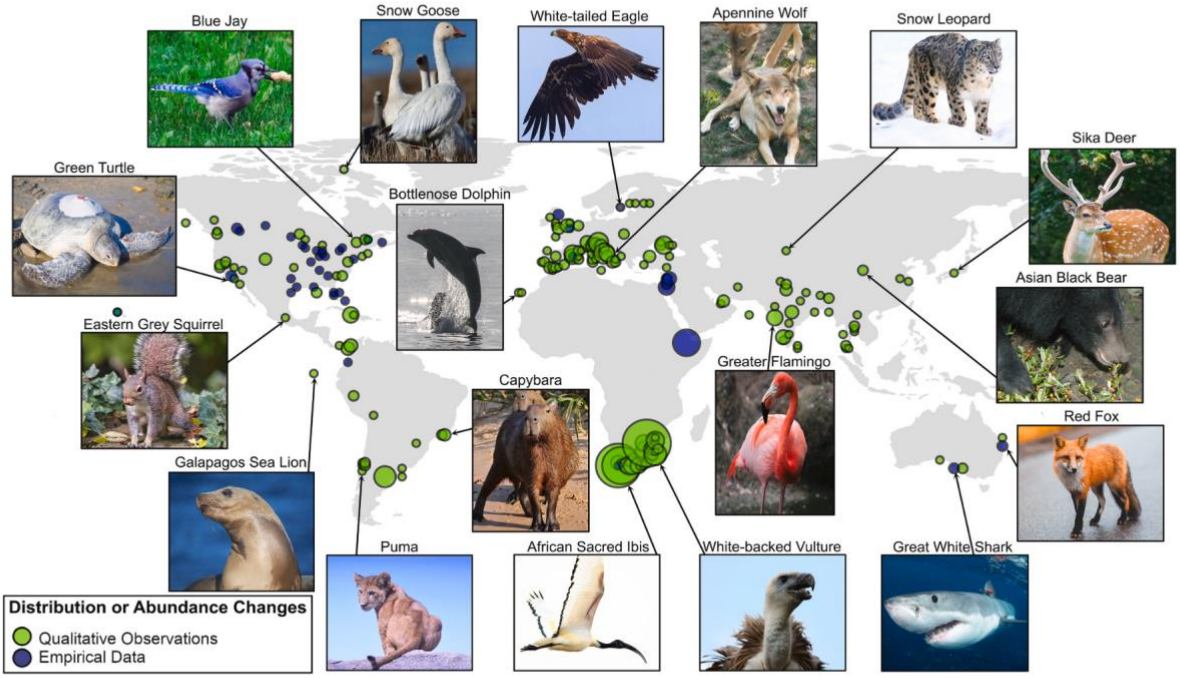


Figure 6.7 Reports of 275 species that occupied an unusual area (distribution change), or shifted in number (abundance change) were attributed to a reduction in human activities. Changes in species distributions were observed around the world as qualitative observations (Appendix 3, Table A3, albeit with biases in effort such as greater coverage in the Northern Hemisphere and South Africa), and based on empirical data of time series surveys and bio-logging data using statistical modelling to quantify change. Only changes that were attributed to the lockdown with high confidence are included here (Appendix 4, Table A4). Bubble size represents data density (the largest bubble represents 41–60 observations and the smallest is 1–20).

6.2.4 Discussion

The COVID-19 lockdown provided an unprecedented, serendipitous opportunity to examine the multi-faceted links between human activity and the environment, providing invaluable insights that can inform conservation strategies and policy making. Specifically, this lockdown has created a period during which global human activity, especially travel, was drastically reduced, enabling quasi-experimental investigation of effects across a large number of 'replicates' (Bates et al., 2020). Overall, we found that both positive and negative responses of human activity on species and ecosystems are prevalent – results that are inconsistent with the prevailing view of humans as primarily harming biodiversity. Indeed, while the qualitative observations presented here provide evidence of interpretation bias, viewing unusual behaviours in wildlife as positive (figure 6.8), our quantitative assessments were balanced between negative and positive responses (figure 6.9). Even if our dataset does not represent a random sampling design, the reports collated are a comprehensive inventory of information across the globe. Emerging from this initial dataset is support for both negative and positive responses of wildlife to human activity and the systems in place to monitor and protect nature. Thus, the lockdown provides a striking illustration of the positive role humans can play as custodians of biodiversity. While negative impacts were expected, the potential for humans to positively influence biological conservation through scientific research, environmental monitoring, opportunistic citizen reporting, conservation management, restoration, and enforcement activities was strong in our datasets. Combined, these activities jointly deliver conservation benefits.

Another major take-home from this synthesis effort is that humans and their activities have measurable impacts on food availability for animals from both land and marine habitats, including that of top predators and scavengers. The role of human-sourced food is an important driver of wildlife occurrence and condition. For instance, in Singapore, feral pigeons shifted their diets from human foods to more natural food sources and their numbers declined (Appendix 4, Table A4, StudyID 75, Soh et al., 2021 [this issue]). At a university campus in South Africa, red-winged starlings lost body mass, presumably because their typical foraging grounds were bare of waste food (Appendix 4, Table A4, StudyID 58). Scavenging crows also spread to coastal beaches in Australia when human food was no longer available (Duarte et al., 2021 [this issue]). Many species that are routinely fed during wildlife tours (e.g., sharks (Gallagher and Huveneers, 2018) have not had access to this supplementary food due to drastically reduced tourism. This appeared to drive a change in the abundance and types of species that were detected at sites in the Bahamas during the lockdown period (Appendix 4, Table A4, StudyID 67). In addition to food, animal use of nutritional supplements was also influenced by human activities. For instance, in response to reduced traffic on highways in the Canadian Rockies, mountain goats spent more time at mineral licks, interpreted as a wildlife benefit (Appendix 4, Table A4, StudyID 37).

Another major take-home from this synthesis effort is that many wildlife and ecosystem responses were unexpected. A classic example is from the Baltic Sea, where due to the lockdown, only researchers and a park warden were present on a seabird island during 2020. The number of people on the island was thus reduced by 92%, by contrast to normal years where summer visitors enjoy the island. The reduction in human presence corresponded with the unexpected arrival of 33 white-tailed eagles where no more than three had been observed in each year for several decades (white-tailed eagle: fig 6.2.3). By regularly flying near a murre colony, the eagles flushed incubating birds at disturbance rates 700% greater (7-fold increase) than historical rates, resulting in abandoned ledges where the birds lay their eggs, and subsequent increased egg predation by gulls and crows (Appendix 4, Table A4, StudyID 31; Hentati-Sundberg et al., 2021 [this issue]). The absence of humans in this case seems to have negatively impacted a species of conservation concern, through changing the distribution of a species which evoked a predator avoidance response.

Hunting also increased across many countries, including in parks, to supplement incomes. A classic example is the increase in pangolin hunting which was likely due to a combination of reduced protection from forest departments, increased sales of hunting permits, and greater illegal hunting. This is surprising considering the possible role of pangolins as intermediary hosts of SARS-COV-2, and calls to halt the consumption of wildlife to avoid future zoonoses (Zhang et al., 2020). Furthermore, it is clear that resilient socio-ecological systems are fundamental to supporting nature conservation.

We further find that impacts of the lockdown on human hunting activity have created not only direct but cascading ecological impacts. For instance, in North America the large greater snow goose population is considered a pest due to grazing on crops. Goose numbers are controlled during their migration to the High Arctic by allowing spring hunting. Yet, hunting pressure decreased by up to 54% in 2020 in comparison with 2019, and geese benefitted from undisturbed foraging, resulting in rapid weight gain to fuel their northward migration (Ap- pendix 4, Table A4, StudyID 25; LeTourneux et al., 2021 [this issue]). Indeed, hunters from Mittimatalik (Nunavut) reported that those birds arriving in the Arctic in 2020 were unusually large and healthy. The cohort of geese from 2020, which graze the fragile arctic tundra and degrade the habitat for other species, will potentially drive future population growth and environmental impacts (Snow Goose, figure 6.2.3).

The magnitudes of some effects were also more dramatic than anticipated, such as in cases where the lockdown coincided with reproductive activity. For example, in Colombia, a hotspot of bird diversity, species richness in residential urban areas in Cali increased on average by 37% when human activity was lowest during the lockdown, which coincided with the beginning of the breeding season. Similarly, various species of sea turtles benefited from nesting on undisturbed beaches during the lockdown period. In Florida, for instance, lockdown- related beach closures in a conservation area were linked to a surprising 39% increase in nesting success in loggerhead turtles, attributed to a lack of disturbances from fishers and tourists with flashlights, and lack of obstructions such as sandcastles (Appendix 4, Table A4, StudyID 74).

Management implications

The global human lockdown experiment has revealed the strong potential for humans as custodians of the environment. The wealth of observations collated here provides compelling, near-experimental evidence evidence for the role of humans as a source of threats to species eco- systems, illustrated by a range of increases in biodiversity threats with release from human disturbance during lockdown. Increases in biodiversity threats are consistent with the assumed role of human activity as a source of negative impacts on the environment. These observations help identify ways in which human disturbance may play stronger roles in impeding conservation efforts than previously recognized, even for well-studied species such as sea turtles. Our data also reveal contexts where one simple change in human activity could lead to multiple benefits. For instance, in one park near Boston, noise did not decrease as traffic volumes declined – surprisingly, noise levels increased, likely because cars were moving faster (Appendix 4, Table A4, StudyID 52). At the same time, greater traffic speed near parks can increase the probability of vehicle strikes (Nyhus, 2016), impacting both wildlife and humans. Thus, rather than reducing traffic volume, reducing traffic speed would lead to less noise pollution and protect both wildlife and human safety.

Considering how wildlife and humans have responded during the lockdown offers the potential to improve conservation strategies. In particular, restrictions and enforcement mechanisms to control human activities in conservation areas and parks seem critical to their effective functioning. Adaptive conservation management during reproductive seasons, such as during the nesting season of birds and sea turtles, may also have much stronger positive impacts than previously recognized. The pandemic also highlights the value of parks near urban centres that protect species and the environment, and offer opportunities for humans to conveniently enjoy nature without traveling long distances (Airoldi et al., 2021). The role of humans in supplying food for some animal species is also apparent, and suggests that this interaction can be managed to improve conservation outcomes, and avoid risks such as wildlife-human conflicts. Regulation of marine shipping traffic speed and volume can also have a major contribution to conservation, which would require, similar to the case of terrestrial systems, the identification and regulation of hotspots where strikes are frequent and noise levels are elevated; the analysis of detailed animal tracking data could further inform such interventions (Rutz et al., 2020). Our results also provide compelling evidence for the benefits of reducing noise levels, particularly at sea, and give additional impetus to policies that incentivize the development of noise reduction technologies (Duarte et al., 2021).

While many changes were linked to the lockdown, we failed to link effects to the lockdown in 18 different studies which represent a wide range of systems and contexts. Even so, what was interesting is that 15 of these studies focussed on wildlife responses. This includes where wild- life observations were in remote areas or under effective management and protection from human activities, or on species that are unresponsive to humans. For instance, we found that reduced wildlife tourism in 2020 at the Neptune Islands Group Marine Park, Australia, had no ef- fects on white shark residency (Appendix 4, Table A4, StudyID 17; Huveneers et al., 2021 [this issue]). This is likely due to current regu- lations minimizing the impact of shark-diving tourism when it occurs, suggesting effectiveness of prior efforts to decrease animal harassment. Likewise, the distribution of hawksbill turtles (Chagos Archipelago, Indian Ocean), in an infrequently visited area that is effectively protected, was indistinguishable from previous years (Appendix 4, Table A4, StudyID 76). In remote northern Queensland, Australia, tagged estuarine crocodiles exhibited similar habitat use patterns despite restrictions on the number of people allowed into the area (Appendix 4, Table A4, StudyID 54). We also found strong changes that were attributed to other factors, such as the use of the Kerguelen toothfish fishing grounds (Australia) by seals in 2020 (Appendix 4, Table A4, StudyID 40). The seals' observed distribution changes during the lockdown period likely represent responses to other environmental factors, rather than changes in fishing effort.

It is unclear if any of the changes in animal distribution, abundance, behaviour, and sources of food will persist once the lockdown restrictions cease. Many of the responses observed may be transient. For example, animals roaming in areas typically supporting intense human activity may retreat back to smaller ranges once human activity resumes full- scale. However, negative impacts resulting from the interruption of conservation efforts may be long-lasting and reverse years and decades of such efforts. For instance, it is likely that long-term impacts of over- fishing of juveniles in nursery areas will be apparent into the future in the abundance of the queen conch from the Bahamas due to impacts on recruitment to the adult population (Appendix 4, Table A4, StudyID 47), and in most other cases where illegal activities have injured or removed animals. On the positive side, strong recruitment success of endangered species in areas where disturbance declined may have long-lasting positive effects, particularly where the beneficiary species, such as sea turtles, have long life spans. Long-term studies should track the cohorts of the 2020 wildlife generation over years and decades to integrate the positive and negative conservation impacts of the human lockdown.

Our finding of both positive and negative impacts of human confinement does not support the view that biodiversity and the environment will predominantly benefit from reduced human activity during lockdown – a perspective taken by some early media reports. Positive impacts of lockdown on wildlife and the environment stem largely from reduction of pressures that are typically an unintended consequence of human activity, such as ocean noise. In contrast, the negative impacts of the lockdown on biodiversity emerge from the disruption of the deliberate work of humans to conserve nature through research, restoration, conservation interventions, and enforcement. As plans to re-start the economic progress, we should strengthen the important role of people as custodians of biodiversity, with benefits in reducing the risks of future pandemics.

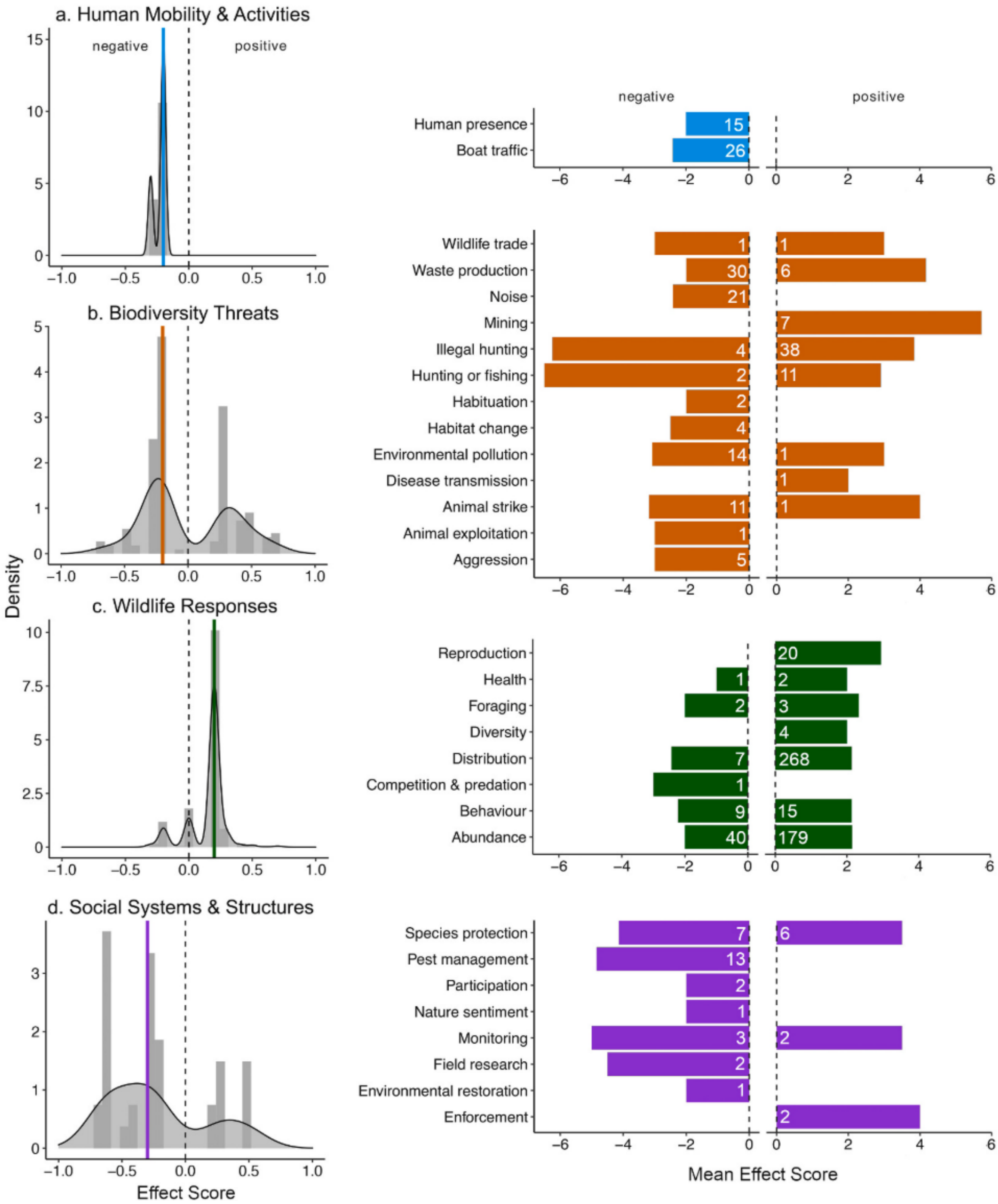


Figure 6.8 Qualitative negative and positive effects observed which were relative to the response observed (Appendix 4, Table A4). Negative effects indicate a dampening in the responses which were grouped into categories representing "Human Mobility & Activities", Biodiversity Threats", "Wildlife Responses" and "Social Systems & Structures", while positive effects indicate an increase. The effect score is based on the criteria outlined in Appendix 1, Table A2, and considered the duration, spatial extent and total impact of the effect on the response. A negative or positive effect direction is relative to each category is based on the observed effect, rather than an interpreted impact. For instance, a negative effect on noise is a

decrease in noise (which may have had positive wildlife impacts). a) Distribution of effects showing the direction and magnitude. The dotted line is the intercept, and the coloured line indicates the median effect score. b) The mean effect score for categories falling within effects on human activities (blue), biodiversity threats (orange), biodiversity (green) and social systems (purple). Bars are the mean across reports pooled for positive and negative effects on the y-axis category, and white numbers are the number of observations upon which the mean is based. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

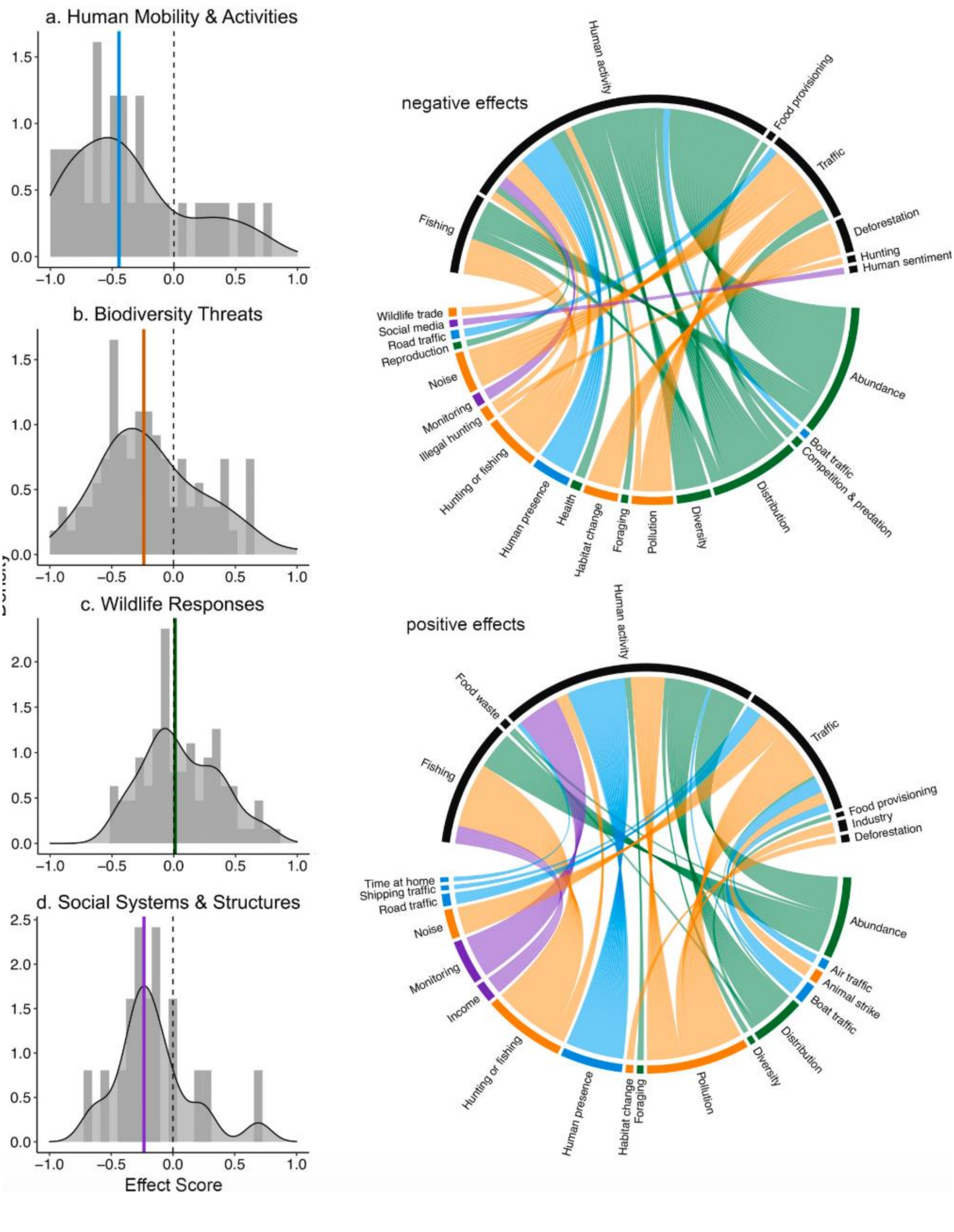


Figure 6.9 Responses during the lockdown based on our empirical data (Appendix 5, Table A5) where positive and negative effects represent the observed direction of change for the different response categories. 71 studies that attributed the observed effect to the lockdown with high confidence are included (i.e., a qualitative confidence score of 3 or greater out of a maximum of 5). Frequency histograms (panels a-d) show bars representing data density and a curve representing a smoothed distribution of effect sizes and direction. The dotted line is

zero, and the solid coloured line is the median. Only responses that were attributed to the lockdown with high confidence are included. a) Human activities and mobility (blue) includes measured responses in human activities and mobility, such as related to commuting and recreational activities (categories are described in Appendix 1, Table A1). b) Biodiversity threats (orange) include categories that harm wildlife and natural systems, such as hunting, fishing, mining, vehicle strikes, wildlife trade, environmental pollution, and deforestation. c) Wildlife responses (green) incorporate observations of animals and plants related to performance (e.g., reproduction, health, foraging) and habitat use (abundance and distribution) and community change (species richness). d) Social systems (purple) include environmental monitoring, restoration, conservation, and enforcement. The chord diagrams highlighted the observed positive and negative effects which were attributed to different lockdown-related drivers as identified by each study (black), and linked to what was measured by each study where responses were grouped into the four categories: human activities and mobility, biodiversity threats, wildlife responses, and social systems and structures. One chord represents one measured response.

(For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Supplementary data to this article can be found online at

https://doi.org/10.1016/j.biocon.2021.109175

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CHAPTER 7 – GENERAL DISCUSSION

7.1 Insights for sustainable whale and dolphin watching activities in the Strait of Gibraltar

Customers profiles and their satisfaction with WW experiences

Our studies confirmed that the majority of whale watchers in the Strait of Gibraltar had a university level education, were employed and that almost half of them had a monthly income higher than €1,500, as previously reported in literature (Cabaleiro Mora et al., 2007). The most common age-range increased from 26 to 55 years, which has increased when compared with earlier reports from 2009 (O'Connor et al., 2009)**,** with the presence of national tourists increasing from 59.9% (Cabaleiro Mora et al., 2007) to 78%.

A total of 30 different nationalities were recorded on board, with **domestic tourism** being the most highly represented in both locations, (i.e., Spanish in Tarifa and British in Gibraltar). Spanish tourism presence increased from 40%, estimated in 2001, and 43%, in 2009 (Hoyt, 2001; O'Connor et al., 2009), to 74% in the current study. This shows the importance of the domestic WW tourist. In Gibraltar 49% of customers were from the United Kingdom followed by 6% from Germany. Although this contrasts with results from 2009 showing 90% British customers among reported WW customers in Gibraltar (O'Connor et al., 2009), the data aligned with official Gibraltarian reports that 53% of tourists in 2001 were British, 58% in 2009 and 44% in 2019 (S. O. Government of Gibraltar, 2002, 2010, 2020). Among international tourists, Spanish, British and German were the most common nationalities. In Gibraltar 78% (n= 185) of customers (n= 238) had had previous encounters with cetaceans: 35% in the wild and 20% in captivity. 23% specified having seen cetaceans before but without specifying in which context. According to the results of our questionnaires, 69% of the WW customers interviewed in Tarifa had had previous experiences with cetaceans. This proportion was almost twice which was observed among the customers interviewed in the same area in 2007 (Cabaleiro Mora et al., 2007), which could indicate the development of a form of **loyalty** amongst WW customers to the activity.

Most of the respondents in Tarifa were aware of the presence of cetaceans in the Strait, and assumed that the animals were threatened, with a poor or fair conservation status. More than half of those interviewed considered protection efforts in place to be insufficient but, at the same time, that the Strait of Gibraltar is in a Good Environmental State. These results could suggest a **pro-conservative attitude** towards cetaceans on part of the customers attending WW trips in 2017-18 in Tarifa. In the study 4.1 'Insights into sustainable tourism policy: Identikit of the whale watchers and their economic contribution in Tarifa (Strait of Gibraltar*)*', it appears that place-based approaches to cetacean conservation are undervalued by the general public, as WW customers do not seem to correlate cetaceans' conservation state with the Good Environmental State of the area in which they inhabit.

In line with the reported growth of the local WW industry (Tenan et al., 2020), the percentage of WW customers spending the night in Tarifa and/or visiting the town with the intention of seeing cetaceans almost doubled compared to 2007 (Cabaleiro Mora et al., 2007). As previously reported, WW customers that did not spend the night in Tarifa travelled mainly from localities in the provinces of Cádiz and Málaga (Cabaleiro Mora et al., 2007), but in the current study there were also customers from the district of Almería, located over 300 km from Tarifa.

Similarly to that which was reported for the WW customers of the Pelagos Sanctuary, in the Mediterranean Sea (Tepsich et al., 2020), and conversely to that which was observed in Indonesia (Trianasari et al., 2021), our participants had an **overall high level of satisfaction,** independently from any prior cetacean experiences. Whilst a previous study in the Azores suggested that WW customer satisfaction was correlated to their place of residence or nationality (Bentz et al., 2016; Vieira et al., 2018), in the current study nationality did not seem to have any influence.

According to our results, customer satisfaction with both the experience as a whole, as well as with the company were consistent.

Whale watchers unsatisfied with the experience pointed to the lack of information provided and to the limited perceived time spent with the cetaceans, factors that also influenced the satisfaction score given to the company. Findings of a previous study, specifically for the WW industry of the Strait of Gibraltar (Cabaleiro Mora et al., 2007), pointed to a lack of communication (i.e., low levels of guide participation and/or a bad sound system on the boat) as an issue. Input provided by WW workers for customers has previously been recognised as key in increasing customer satisfaction (Xie et al., 2020), resulting in the requirement of a complete interpretation program on marine mammal tours in WW locations such as New Zealand and Panama (Lück, 2003; Lück & Porter, 2019; Sitar et al., 2017). In this way, a better and **more structured education programme** onboard could lead to an increase in both the satisfaction level of WW customers, and customer loyalty, which in turn, by word-of-mouth effect, could be converted into more profit for the company.

According to results, the customers in Tarifa ranked the WW company based on cetacean behaviour, giving better ratings when cetaceans autonomously approached the boat or were indifferent to it, rather than when they left the sighting site. Proximity to cetaceans, approaching speed, and time spent with the cetaceans did not show any significant relationship with customers' ranking of the WW company. The latter result of the study described in section 4.2, is in apparent contradiction with the results achieved in 4.1, where customer satisfaction was indeed influenced by the **time** spent with cetaceans. However, this result was based on time categories, distinguishing whether customers considered the time spent with cetaceans sufficient or not, and not on the actual time spent with cetaceans, as in *4.2* 'Sustainability as a common goal: Regulatory compliance, stakeholder perspectives, and management implications of whale and dolphin watching in the Strait of Gibraltar'. This inconsistency may be an interesting example of how personal perceptions, rather than the actual characteristics of a sighting, may have major effects on customer satisfaction. The importance given by customers to the cetaceans' behaviours of **approaching or being indifferent** to the WW vessel presence, could be due to the attitude of 'environmentally friendly' customers. In other areas a strong preference for minimizing impact on the animals was identified (Kessler et al., 2014), and environmentally friendly conditions were shown as the most important expectation (Bentz et al., 2016), and as an important factor influencing customer satisfaction (Tkaczynski et al., 2022). Similar to that which was observed in Queensland (Orams, 2000), the studies show that the **proximity between** cetaceans and vessels is not linked to higher ratings. Also in Sydney, despite customers preferring close proximity to whales, proximity was not a guarantee of a positive WW experience (Kessler et al., 2014). Considering this, better evaluations of the WW companies could depend on leaving cetaceans when they show signs of evasion, discomfort or alteration of behaviour (i.e., the opposite of approaching or indifferent behaviours to the vessel) and do not depend on getting close to the cetaceans (i.e., approaching them from the front or rear, without maintaining a parallel course or moving faster than the slowest individual of the pod). Furthermore, whilst regulatory enforcement will directly influence tour operators, it is more likely that WW tourism education will indirectly do so (Mallard, 2019). Results of the current study could be used to increase respect accorded to WW rules by those companies in the Strait that are willing to ensure customer satisfaction.

Other key stakeholders

Overall, of the 42 questionnaires distributed to the non-customer key stakeholders, 20 were received fully completed. Of these, seven stakeholders recognized that WW vessels generally approach cetaceans slowly and keep a safe distance from the animals. Six stakeholders highlighted that respecting WW rules depends on factors related to each single trip such as the captain and crew, the behaviour of the cetaceans sighted, the time of the day, the weather conditions and the sea state. Stakeholders estimated that the Royal Decree - RD (Spanish) and the Marine Protection Regulation - MPR (Gibraltar) are fully respected during on **average of 35%** of the WW trips (σ= 17,72). Six respondents argued that a lack of enforcement is the main reason for this low level of compliance and two stressed the need to increase enforcement and patrolling.

About half of the stakeholders that responded to the survey (n= 11) recognized that **government legislation and regulations**, including a mandatory code of conduct and a licensing system for WW tour operators, are needed for ensuring the sustainability of the activity. One respondent suggested that no vessels should be allowed in areas considered as hot-spots for pilot and sperm whales and that mandatory **speed restrictions** should be in place. It was also recommended that training for ferry professionals and, more in general, educational activities for citizens, should be implemented to inform them of the presence of cetaceans in the area and to demonstrate the importance of speed reductions. One of the respondents advocated for the development and use of a real-time information system, alerting on the presence of cetaceans.

Legislative tools for regulating WW activities, such as the RD and MPR, are in place in the Strait but effective **enforcement** isn't, despite its importance being widely recognized (Allen et al., 2007; Howes et al., 2012; Wiley et al., 2008) and despite a substantial increase in vessel compliance in its presence (Seely et al., 2017). Sanctions, such as revoking licenses, are also considered as the most effective method for increasing compliance (Gjerdalen & Williams, 2000; Tyne et al., 2014). Accordingly, it would be fitting for such measures to be considered in the Strait together with a long-term monitoring program of WW activities that could also be land-based and integrated with an Automatic Identification System (AIS) data analysis.

Stakeholders underlined that statutory tools should be integrated into an overarching

participative process and six of those interviewed highlighted the important role that the non-governmental sector can have in managing WW. To our knowledge, there are no on-going public participative processes regarding cetaceans and WW activities in the Strait, despite the fact that a combination of top-down, (e.g. enforcement), and bottom-up (e.g. participative process) approaches should be essential in the management of maritime spaces and activities (Gaymer et al., 2014). The results of this study suggest that a working group, that takes into consideration the expertise and needs of all the actors (Howes et al., 2012), be assembled by the local governments of the Strait with the aim of improving cetacean conservation. Cetacean conservation in the Strait could benefit from the assembly of a structured, multi-jurisdictional participative process similar to that which has been assembled in the Salish Sea (Canada) for protecting orcas (Southern Resident Orca Task Force, 2018, 2019).

19 stakeholders favoured the designation of new **MPAs** or the enlargement of existing MPAs as valuable management tools for the conservation of cetaceans in the Strait. One respondent pointed out the importance of extending the cetacean migration corridor between the Balearic Islands and the Spanish mainland, recently recognized as an MPA in Spain (Ministerio para la Transición Ecológica y el Reto Demográfico, 2020), to the Strait. Stakeholders also showed consensus on the introduction of more restrictive rules for vessel speed (n= 19), not only for WW operators but for all commercial, recreational or private vessels in general. The creation of a **conservation-minded regional and seasonal shipping-plan** was selected by 14 stakeholders as a further management tool, alongside the creation of quiet areas, i.e., areas with reduced underwater noise, and the adoption of new fishing regulations (n= 11 and 10, respectively). A dedicated **shipping plan** could include speed reduction, zoning and/or quiet areas. These tools are commonly proposed to promote and enhance marine conservation (Cañadas et al., 2005; Hooker et al., 1999; Hoyt, 2011), and could also be important for the protection of cetaceans (Laist et al., 2014). A local shipping plan should take into consideration the fact that cetaceans are highly mobile species with possible seasonal distribution and should therefore be adaptable (Dwyer et al., 2020). Seasonal and dynamic regional shipping plans, including mandatory rerouting and reductions in speed, have been adopted in portions of the Salish Sea[24] and the North Atlantic[25] to protect southern resident killer whales and North Atlantic right whales whilst still allowing for maritime activities. A local example could be the declaration of a temporal no-vessel entry sub-area as suggested for the bay between Algeciras and Gibraltar to protect short-beaked common dolphins mothers with calves (Espada Ruíz et al., 2018) .

Values associated with WW

WW customers mostly associated WW with educational values (85%, n=323), followed by scientific (63%, n=237), recreational (46%, n=175) and cultural (46%, n=174) values. The majority of the other, non-customer key stakeholders (85%, n= 17) associated WW with scientific and recreational values and also acknowledged its educational value (80%, n= 16).

24 https://www.pac.dfo-mpo.gc.ca/fm-gp/mammals-mammiferes/whales-baleines/srkw-measures-mesures-ers-eng.html#maps

25 https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales

The economical relevance of WW activities was highlighted by 13 non-customer stakeholders while social, spiritual, cultural and psychological values were recognized only by a minority.

The importance of the **educational** value of WW was recognized by all stakeholders consulted. This result is in line with that which was previously reported in Tarifa, where education provided prior to and during the WW trip influenced the level of WW customer satisfaction (Scuderi et al., 2022). Our results could also support the theory that customers would be interested in a more structured education programme during WW activities (Lück, 2003; Lück & Porter, 2019). Recognizing the importance of the experience and the attitudes of onboard guides (Andersen & Miller, 2008; Schwarzmann & Shea, 2020), as well as the customers' preference for interactive tours (Lee et al., 2019) and the importance given by customers to the possibility of actively speaking with staff and other tourists during their trip (Xie et al., 2020), we accordingly suggest that a structured educational programme should be compulsory. Educational programs during WW activities should be based on robust research and should be conducted by formally trained guides with a scientific background (Constantine, 2021). Such programs could also include interactive land-based activities (Lee et al., 2019), such as guided visits to the Centre of Interpretation of Cetaceans in Tarifa.

Scientific values may have been selected due to ongoing collaborations in the Strait between WW companies and the academic sector, with companies providing their vessels as research platforms, collaborating on the production of reports (Andreu Cazalla et al., 2016; Cabaleiro Mora et al., 2007), and supporting scientific contributions at international conferences (European Cetacean Society, 2018; European Cetacean Society and Society for Marine Mammology, 2019) and in peer-reviewed journals (Espada et al., 2019; Herr et al., 2020; Olaya-Ponzone et al., 2020, 2022; Scuderi et al., 2022).

Although **recreational** values have been globally associated with WW (Hoyt, 2001; O'Connor et al., 2009), they were only selected by 46% of WW customers as opposed to 85% of other stakeholders. WW customers seem to give more importance to the educational component of the activity rather than the recreational aspect, confirming the importance of a structured educational programme as previously discussed.

Direct assessment of WW trips

Although variability among operators and trips exists, WW companies tended to follow existing rules with an average of 62% of compliance to the assessed criteria. Tarifa-based operators respected 65% of criteria and those based in Gibraltar respected 59% of criteria. During all of the five trips assessed, the ban on feeding, swimming with, or touching animals was respected, together with the ban on manoeuvring backward, and not separating associated adults and calves. During four trips, vessels avoided surrounding the pod of cetaceans and respected the restriction of maximum one vessel for 20 minutes in the RAZ rule. The most frequent illegal behaviours (n=3) were approaching animals from the front or rear without maintaining a parallel course, maintaining a speed higher than the slowest individual of the pod, the simultaneous presence of more than one vessel in the AZ, the absence of radio coordination between vessels, and not leaving cetaceans displaying signs of evasion, discomfort or alteration of behaviour. These illegal behaviours had already been observed in the Strait in 2007 (Cabaleiro Mora et al., 2007), and the infringement of the maximum numbers of vessels was observed in the bay between Algeciras and Gibraltar in 2018 (Espada Ruíz et al., 2018). Both WW professionals interviewed in the pre-test survey mentioned adverse weather conditions (affecting approaching and manoeuvring), a lack of knowledge of cetacean behaviour and the competition among WW companies for the best position (resulting in poor radio coordination), as **factors that could lead to the non-observance o**f WW rules. Cooperation among WW operators and an increase in radio communication is essential in the sustainable planning of trips, in order to both stop the simultaneous presence of various vessels with animals, as well as to improve the quality of approach manoeuvres.

Enforcement agencies were not seen in the area during the assessment, even though their presence would increase rule compliance and would therefore reduce risks to cetaceans (Andreu Cazalla et al., 2016; Cabaleiro Mora et al., 2007; Espada Ruíz et al., 2018).

Results of the evaluation given by stakeholders (35% of stakeholders estimation of the compliance with the local WW rules) concerning the compliance with local WW rules do not align with what observed in the direct assessment (62% estimation based on the WW trip direct assessment), this incongruence should be investigated in the future setting of a long-term WW monitoring program. Despite this, both results confirm the partial respect of WW legislations in the Strait.

Considering that the Strait includes various IMMAs (https://www.marinemammalhabitat.org/imma-eatlas/) and considering the growth of the WW sector (Elejabeitia et al., 2012; Scuderi et al., 2022; Tenan et al., 2020), a long-term WW monitoring programme is necessary together with an increase in surveillance. Land-based surveys and analyses using AIS data are commonly used in maritime research (Robards et al., 2016; Shelmerdine, 2015; Svanberg et al., 2019; Yang et al., 2019) for the planning, management and conservation of critical cetacean habitats (Almunia et al., 2021; L. H. McWhinnie et al., 2021) and for the monitoring of WW activities (Marega-Imamura et al., 2018; Schaffar et al., 2009), and could therefore be useful tools in augmenting cost-effectiveness of monitoring and surveillance in the Strait of Gibraltar.

Economic contributions of WW and the post-pandemic contest

The DE calculated in this study (section 4.1) for the summer seasons 2017-2018 of the company Turmares Tarifa is €2,980,100; much higher than the €624,000 estimated for the same company in 2015 (the overall annual DE was €960,000, with high season corresponding to 62% of DE) (Andreu Cazalla et al., 2016).

Previous estimations of IE and TE are hard to compare with our results based on data collected from a single WW company during two trimesters. The IE and TE estimated for the Spanish WW industry in 2011 were \$4,579,482 and \$7,548,443, respectively (Elejabeitia et al., 2012), corresponding to €3,266,544 and €5,384,304, respectively (calculation based on the average euro-dollar exchange rate in 2011: \$1 = €0.7133[26]). The economic contributions calculated here are only based on two summer trimesters and thus cannot be used to assess any economic trend. However, these results do increase the knowledge of the economic impact of

[26] https://www.exchangerates.org.uk/USD-EUR-spot-exchange-rates-history-2011.html

the WW on the local community of Tarifa. To our knowledge, no other quantitative data on the indirect economic contributions of the WW customers has previously been published.

Regarding the **typologies of expenditures** made by WW customers, it is worth noting the slight reduction in the percentage of WW customers renting accommodation or staying in hotels compared to data from 2007 (Cabaleiro Mora et al., 2007), a change probably due to the increase of rental apartments on offer. Whilst the expenses related to leisure activities resulted here are significant, in a similar study in Mexico, accommodation and restaurants were the most represented expenditures (Brenner et al., 2016).

The **average daily expenses** per person calculated considering all the WW customers interviewed (€97), fall well within the values of €124 published by the INE – 'Instituto Nacional de Estadística' (Instituto Nacional de Estadística, 2022), and €65 published by the IECA – 'Instituto de Estadística y Cartografía de Andalucía' (Instituto de Estadística y Cartografía de Andalucía, 2022) for tourists visiting Andalusia in the same trimesters of the same years. The IECA also estimated an average daily expense of €73 for tourists visiting the province of Cádiz, where Tarifa is located. The higher average daily expenses in this study may indicate that customers visiting Tarifa for WW activities are willing to spend more than a general visitor to the province of Cádiz as a whole.

Finally, our results show that **the sociodemographic-economic profile** of WW customers in the Strait of Gibraltar affects their IE, which is consistent with the findings of a study by Mitra et al. (2019) in Australia, in which income, educational qualifications and employment status were among the most important factors influencing expenditure (Mitra et al., 2019). Furthermore, our results confirm that aside from WW, Tarifa is an important location for sports tourists, whose expenditures contribute the most to the town's economy.

The curtailment of international travel in 2020 due to the **outbreak of COVID-19** (Hoque et al., 2020; Uğur & Akbıyık, 2020; United Nations World Tourism Organization - UNWTO, 2020b) was reflected in Tarifa, in a shortened WW season and a reduction in the presence of international tourists[27]. Despite this, national tourism grew in Spain at the end of 2020 (Moreno-Luna et al., 2021) and local tourism was consequently considered as an important opportunity (United Nations World Tourism Organization - UNWTO, 2020a). Additionally, the global increase in the demand for nature-based tourism that was seen before the pandemic (Balmford et al., 2009; Goodwin, 1996; Orams, 1996) was enhanced by the imposition of lockdowns and the subsequent need for outdoor, natural experiences (Venter et al., 2020). With WW representing not only a nature-based activity, but also by far the most remunerative economic activity based on cetaceans (Cisneros-Montemayor et al., 2010, 2020; Guidino et al., 2020; Hoyt, 2001; O'Connor et al., 2009), two new WW companies (Ecolocaliza - https://ecolocaliza.com and Estrecho Natura - https://estrechonatura.com) were recently set up in the Strait of Gibraltar. Additionally, the company Turmares Tarifa raised their ticket prices by almost 20% (from €30/35 low/high season to €45 all year for 2 h trip and from €40 to €65 for 3 h trip). The foundation of new WW companies along with price increases could suggest that the WW sector is confident in its recovery and is aware of its customers purchasing power. Indeed, tourism has previously shown a fast recovery following periods of crisis (i.e., after the September 11 attack in 2001, the SARS outbreak in 2003, or the global

[27] https://www.firmm.org/es/news/article/items/recordando-la-corta-temporada-del-2020

economic crisis of 2009) (United Nations World Tourism Organization - UNWTO, 2022a) and the presence of national tourists in the growing industry of WW, as well as the outdoor nature of this activity, are good indicators of the economic relevance of this sector for Tarifa.

Insights for a sustainable tourism policy in Tarifa

To guarantee the long-term sustainability of WW, it will be necessary to find a good balance between the economic, socio-cultural and environmental dimensions, which minimises the negative impacts and maximises the positive impacts of WW. Indeed, to achieve sustainability, tourism policy should consider the current and future economic, social, and environmental impacts; and simultaneously respond to the needs of the visitors, the industry, the environment, and the local community (United Nations World Tourism Organization - UNWTO, 2022b).

Our results showed that the WW industry contributes to Tarifa's economy through the direct and indirect expenditures made by WW customers, and that customers generally have a high spending capacity and are inclined to repeat the WW experience (i.e., loyalty to the activity). These findings highlight the importance of WW for the local community and thus the need for its well-targeted management in the area.

The most relevant local policies that are currently in place in the area to manage tourism are the Touristic Strategic Plan of Tarifa; 'Plan Estratégico de Turismo para el municipio de Tarifa 2016-2020', (Ayuntamiento de Tarifa, 2015), and the Touristic Action Plan of Cádiz, 'Plan de acción 2021, Patronato Provinical de Turismo de Cádiz' (Diputación de Cádiz, 2021).

The Council of Tarifa planned to organise an international conference on marine mammals in the town, and to renew and activate the local Centre of Interpretation of Cetaceans (Ayuntamiento de Tarifa, 2015), but these actions were only partially achieved during the 2015-2020 plan implementation period. Moreover, despite recognising the importance of WW being defined as a not-fully exploited resource, the Touristic Strategic Plan of Tarifa underestimated the importance of national tourism and of the WW sector to generate employment. Actions such the reactivation of the Cetaceans' Interpretation Centre in Tarifa, in which a dedicated section on the WW code of conduct could be developed, and the organisation of thematic events, such as an international conference on cetaceans, whale festival or cetaceans week, could engage the community and attract WW customers. We strongly recommend that all the actions mentioned in the Touristic Strategic Plan of Tarifa are reviewed and carried out, thus shifting the focus of current marketing campaigns from international to national tourism.

The relevance given to the WW activity by the Touristic Action Plan of Cádiz is scarce; while it recognises the importance and sustainability of nature-based tourism, as well as that of the use of open-air spaces, it rarely mentions WW and does not foresee any action to support the sector (Diputación de Cádiz, 2021). The importance of national tourism that emerged in our study seems underestimated by the district strategy and remains an unexploited source of opportunities. A national WW marketing campaign targeted to the specific profile of the customers described by our results could positively affect the WW sector and, consequently, the economy of Tarifa.

In terms of education, the Council of Tarifa and the District of Cádiz could boost WW trips as extra-curricular activities for local schools, in order to extend the working season of the WW companies, whilst the Spanish department for education could be engaged to incorporate lessons focusing on cetaceans and local marine wildlife into teaching curriculums.

Improving communication and collaboration between the public administrations/entities and WW operators could result in mutual benefit. WW companies should regularly provide the data collected on cetaceans during their activities[28] to the Spanish Ministry MITERD 'Ministerio para la Transición Ecológica y el Reto Demografico'. However, as these data cover mainly the spring and summer seasons, it would be beneficial for public administrations to finance year-round cetacean monitoring campaigns in order to support the WW companies during the low touristic season and to obtain data for all seasons. This would provide economical support to the WW sector and valuable data on the presence and distribution of cetaceans in the area throughout the year.

To promote best practice, public administrations could also develop a WW sustainability award or certificate for those WW companies that respect WW rules, that provide high quality programs of environmental educational, and that adopt measures to reduce the activity's environmental impact both onboard and on land.

To support long-term study on the economic impact of WW activities on the local communities, a permanent fund could be generated with contributions made by both WW companies and public administrations.

Taking into account the pro-conservative attitude that emerged from WW customers in this study, any marketing campaign should also focus also on the respect of the WW rules and should promote respectful and environmentally sustainable WW. The enforcement of WW rules by public bodies could notably reduce the potential impact of WW on cetaceans and increase the overall compliance. In addition, an improvement in educational programs throughout the WW sector would make it easier to highlight why compliance with WW roles is important, and to clarify why time with cetaceans is limited, which in turn, could further increase customer satisfaction and their awareness of sustainability.

All of the previously described measures, along with a participative process that would allow the inclusion of all relevant stakeholders to develop the management of WW activities, could positively influence both the economic and the socio-cultural dimensions of this activity, and, indirectly, its ecological dimension.

7.2 Monitoring from ferries as an instrument to support management

The **use of a non-dedicated platform to monitor large marine areas** is a cost-effective method that allows a long-term investigation of cetacean species and the pressures in their environment, such as maritime traffic (Campana et al., 2017). The Fixed Line Transect Mediterranean monitoring Network (FLT MED Net) is a network of research bodies using ferries as a platform of observation to perform systematic surveys along several trans-boundary transects in the Mediterranean Sea.

[28] https://www.miteco.gob.es/es/biodiversidad/temas/biodiversidad-marina/habitats-especies-marinos/especies-marinas/AROC.aspx

The synoptic collection of species and main threats data permitted the assessment of high-risky areas and seasons in which species are most exposed to threats; highlighting a complex situation in which the type and level of risk faced by cetaceans are determined by a combination of factors including species diversity and abundance, juvenile presence, and diverse primary biological needs. Results thus highlight the need for an adaptive conservation and the important contribution of continuous high sea monitoring effort, across seasons, in the gathering of robust long-term datasets. The high number of repeated surveys also provided interesting insights that contribute to the monitoring and modelling of rarer pelagic species.

In the study described in section 5.1 data collected from the ferries travelling across the Strait of Gibraltar provided useful insights into the seasonal presence of the species along with the characterization of maritime traffic. Although this information is generally grounded in ship tracking or port monitoring systems, relationships with different vessel types were provided here. All of the data obtained by the monitoring program that uses ferries as a platform of observation provided critical information for an effective evaluation of the spatial management tools.

Results corroborate the **presence of the seven cetaceans species** inhabiting the Strait's waters (Cañadas et al., 2005; de Stephanis, Cornulier, et al., 2008), all showing a constant presence over the investigated period. Only the fin whale presented an increase in the second year, perhaps due to its highly dynamic seasonal behaviour (Geijer et al., 2016). Furthermore, the number of fin whale sightings per year in the Strait has shown a high degree of variability in the past, oscillating between 7 and 29 in data from 1999 to 2014, (Gauffier et al., 2018). For the most frequently sighted species, the common and striped dolphin, seasonal variations in abundance were also documented by this study, in accordance with that which was reported by Espada Ruíz *et al.* (2018).

Results show a high level of **maritime traffic intensity** throughout the year, with an increase during summer and with variations in composition, in accordance with other areas (Campana et al., 2017; Coomber et al., 2016) (marinetraffic.com). Sampling data results coincided with the general information obtained from 'Tarifa Tráfico', but added more specific information about the smaller types of vessels and their activity, confirming the reliability of the visual sampling protocol (Campana et al., 2017). On this basis, it was possible to describe the specific relationships with the different sectors of maritime traffic.

The spatial analysis of **cetaceans and maritime traffic** allowed us to highlight the main areas of overlap, where interaction is most likely to occur (figure 5.8, 5.9, 5.10 and supplementary materials 5.1, III). The study area is dominated by high levels of maritime traffic, especially in the central part of the Strait due to large ships transiting along the Traffic Separation Scheme of the Strait of Gibraltar, while areas with a higher frequency of cetacean sightings were identified in the Bay and the central-southern part of the Strait, close to the main ports. The investigation of different vessel types, which can affect species in different ways (Grossi et al., 2021; Herr et al., 2020; Tenan et al., 2020), is therefore important for the planning of effective management measures.

Considering all cetaceans, the difference in vessel abundance was positive for small, motor and fishing boats, probably indicating a real overlap between traffic and cetacean hotspots, that could be also driven by a possible positive approaching behaviour of some species towards human activities and some species, such as fishing during autumn and winter (sometimes also represented by small boats) or whale watching (motor boats). These differences were confirmed in autumn, winter and spring when fishing vessels were even observed only in the presence of cetaceans. A negative difference in vessel abundance instead, can be related to the effect of traffic on the animals' avoidance behaviour or to the independent spatial segregation of cetacean and vessel observations (Campana et al., 2017). This was found when considering all data for sailing and big vessels, even if on a seasonal basis more variable and no significant results were obtained. For example, during winter and spring, a higher number of sailing boats resulted during sightings, probably due to the approach of vessels to the dolphins during sailing boat trainings (Espada Ruíz et al., 2018). However during summer, no relationship was found between maritime traffic and cetacean presence, although few data were collected during this season. This result is probably a consequence of the actual co-presence of species and vessels in the season of major abundance for both, and has also been reported in other studies, where potential areas of increased risk were identified (Campana et al., 2015; Pennino et al., 2017).

The study confirms that the central part of the Bay is an important area for the **common dolphins** (Olaya-Ponzone et al., 2022), especially from April to December, with a peak in their presence during summer (Espada Ruíz et al., 2018). In spite of the Dolphin Protection Zone (L. N. 2018/134 Government of Gibraltar, 2018) that partially covers the hot spot of the Endangered *Delphinus delphis* (Bearzi et al., 2021), a higher presence of small boats and fishing boats, as well as motor boats, was noted during the sightings, which is consistent with existing literature (Espada Ruíz et al., 2018; Olaya-Ponzone et al., 2020, 2022). In fact, Espada Ruíz and colleagues described in fact a co-presence of different types of vessels during sightings of common dolphin, 43% of which were whale watching boats, 29% recreational boats (that could encompass motor boats and small boats) and 22% of Atlantic bluefin tuna fishing boats (Espada Ruíz et al., 2018). In particular, taking into account the presence of fishing boats during the sightings, fishing activities must be regulated as dolphins are frequently used as signs to locate aggregations of bluefin tuna. Additionally, the ‘popping’ technique (where an artificial lure or ‘popper’ is presented to feeding tuna aggregations via the casting out and reeling in of a braided fishing line, using short bursts to pull the lure across the shoals of fish) should be controlled by penalizing fishers who cast on dolphin–tuna feeding aggregation groups (Espada Ruíz et al., 2018; Olaya-Ponzone et al., 2020). Moreover, there are documented injuries inflicted on common dolphins by human activities, including fishing interactions and propeller strikes, probably as a result of the high level of fishing, recreational and whale-watching activities in the area (Olaya-Ponzone et al., 2020). Therefore the findings of this study strongly support the request to design a specific micro-sanctuary in the central part of the Bay preventing or restricting navigation, and prohibiting bluefin tuna fishing (Olaya-Ponzone et al., 2022) to protect the local Endangered population of common dolphins, especially pertinent when considering the peak in the presence of pods containing mothers with calves pods during the summer season (Espada Ruíz et al., 2018), which are more vulnerable and more prone to changes in behavior (Castro et al., 2022).

Even though **striped dolphins** were spotted in mixed groups with common dolphins (Olaya-Ponzone et al., 2022), we observed that striped dolphins have a wider distribution throughout the Strait. This result could be in line with the spatial separation of the core areas of distribution of the two species (Giménez et al., 2017). Both species showed signs of injuries of an anthropogenic nature (Herr et al., 2020; Olaya-Ponzone et al., 2020) and in the current study, a higher presence of small and fishing boats was observed during their sightings. A positive association with these types of vessels has also been reported in the Sardinian waters by Pennino and colleagues (Pennino et al., 2016). Accordingly, the previously proposed micro-sanctuary, together with the enforcement of surveillance and with coordinated efforts among Gibraltarian and Spanish patrolling forces, could also improve the conservation of the striped dolphin.

Bottlenose dolphins were sighted from July to March in the Strait and in the central part of the Bay from April to June, along with common dolphin, albeit with spatial segregation among species observed in the Bay (whale watching operators' personal communication), as has been observed elsewhere (Methion & Díaz López, 2021). *Tursiops truncatus* is listed in the EU Habitat Directive (its transpositions Spanish the R.D. 1997/1995 and the British Conservation Natural Habitats &c. Regulations 1994) as a species of special interest whose conservation requires the designation of SAC. It is also included in Annex IV as a species of community interest and one that requires strict protection. The Strait includes three SAC and one SIC. Even so, it is notable to observe that all of our bottlenose sightings as well as those of other studies (de Stephanis, Cornulier, et al., 2008), only partially overlap with some areas of protections in force in the Strait. The Intercontinental Mediterranean Biosphere Reserve, which has unfortunately neither cetacean protection measures nor a management plan, covers the highly suitable habitat in the central part of the Strait; whilst the SAC - ES6120032 and the Dolphin Protection Zone, which establish measures directed to the protection of dolphins, moderately include an important area for bottlenose dolphin identified in spring. A possible measure to mitigate impact could be the improvement of surveillance during spring (April-June) in the Bay to optimize conservation efforts for the species. Moreover, the bottlenose population of the Strait seems to be spatially segregated from the adjacent population in the Gulf of Cádiz (Giménez et al., 2018), their apparent annual survival probability was negatively correlated with ferry traffic (Tenan et al., 2020) and showed evidence of anthropogenic injuries (Herr et al., 2020), so an adjustment of the conservation management tools applied in the Strait is necessary. As observed for striped and common dolphins, during the sightings of bottlenose dolphins the presence of small boats and fishing boats was high. Considering the similarity of these results for the three dolphin species, we assume that in addition to the common dolphin (Espada Ruíz et al., 2018), the other two species could be also used as indicators of fish aggregation by fishers. All three species showed signs of the negative effect of big ships, as is the case in other high-traffic areas (Pennino et al., 2016), despite David (2002) reporting that in the Strait dolphin species do not seem to perceive big vessels as a danger. These results strongly support the need to improve protection measures for these species, especially during summer, when a higher presence of all types of vessels was observed in the Bay during their sightings, and higher traffic is reported in the whole Strait.

We observed the presence in the central part of the Strait of the Critically Endangered **long-finned pilot whale** (Verborgh & Gauffier, 2021), a resident species that is reported as using the central and eastern parts of the Strait (Cañadas, 2008; Cañadas et al., 2005; de Stephanis et al., 2014; de Stephanis, Cornulier, et al., 2008; de Stephanis, García-Tíscar, et al., 2008; de Stephanis, Verborgh, et al., 2008), and that is afflicted by various injuries of anthropogenic origin (e.g., injuries from collisions, and entanglement in fishing lines or hooks) (Herr et al., 2020; Verborgh et al., 2016). These observations agree with the association observed with fishing boats (+1,214%), while a general avoidance of other vessel types was also shown by the species. The study also reported two NMEs in the southern part of the Strait, where there is a high level of large ship traffic and where no specific spatial management measures (such as speed reduction) have been implemented.

The reduced number of sightings of **fin, sperm and killer whales** did not allow for a description of their distribution and seasonal presence. Nevertheless, all three species were sighted in the central-southern part of the Strait, overlapping the Traffic Separation Scheme of the Strait of Gibraltar and within the area of major presence of large ships such as container ships, bulkers, cargo ships, and cruise ships. It has been reported that a portion of this area deemed important for these species was designated as a precaution zone called a 'Cetacean Critical Navigation Zone', in which speed must be restricted to 13 knots in order to avoid collisions with whales, and a good lookout should be maintained between April and August (National Geospatial Intelligence Agency, 2022), in particular for the sperm whale (Silber et al., 2012). Indeed the percentages of NMEs of fin (12.5%) and sperm (16.6%) whales are quite high compared to the low number of sightings.

The presence of dedicated observers on board and the training of the crew members (Gende et al., 2019) could be applied as effective measures for reducing the risk of collision. Considering the aforementioned points concerning pilot, sperm and killer whales, we suggested that the 'Cetacean Critical Navigation Zone' (as named in the Marine Spatial Planning of the Strait and of Alborán Sea by the Spanish Environmental Ministry[29]) should be extended to the west and a reduction in speed of all vessels to 13kn should be changed from 'recommended' to 'mandatory'.

All three states that line the Strait (i.e., Morocco, Spain and United Kingdom) are signatories to the conventions ICRW, CITES, BCCEW and CMS that aim to conserve and protect endangered species as well as their habitats, including cetaceans. On the other hand, to the best of our knowledge there is currently no **common management plan** for the water of the Strait that focuses on conserving cetaceans. The importance of the Strait for cetaceans is confirmed by the designation of several IMMAs crossing it and the criticality of the area was clearly highlighted by naming it as CCH. The presence of the SAC and SIC, although

[29] https://www.miteco.gob.es/es/costas/temas/proteccion-medio-marino/estrategias-marinas/demarcacion-estrecho-alboran/

important management tools, may not be sufficient to conserve highly mobile species such as cetaceans (Dwyer et al., 2020). It is important to consider the temporality and variability of cetaceans' presence when managing the space (Wilson et al., 2004). For instance, seasonal and dynamic regional shipping plans including mandatory reductions in speed and/or rerouting, have been adopted in portions of the Salish Sea[30] and the North Atlantic[31] to protect southern resident killer whales and North Atlantic right whales (NARW). In the case of the NARW, the effectiveness of this approach was proved with a reduction in mortality due to ship strike events (Laist et al., 2014). Recently, in the Strait a temporal spatial management tool was used to reduce negative interaction among orcas and vessels; navigation limitations from the Gulf of Cádiz to Tarifa were in full force in order to increase vessels' safety between the 8 of August and the 22 of September 2021 (Ministerio de Transporte Movilidad y Agenda Urbana, 2021a, 2021b)[32]. This supports the idea that a temporal plan including speed restrictions and a no-take zone inside a micro-sanctuary could be designed to protect the cetaceans of the Strait.

7.3 Local and global COVID-19 lockdowns

Although the effects of noise pollution and the role of auditory masking on animal behaviour have been well studied (Shannon et al., 2016), it has never been possible to investigate what happens to ambient sound levels and communication ranges when vessel traffic decreases to exceptionally low volumes. The COVID-19 lockdown in New Zealand provided a means to understand the effects of small boat traffic (as commercial shipping continued during the lockdown, although at a reduced level) on shallow water noise levels near a busy metropolitan centre through the collection of baseline data with very little anthropogenic noise.

These data showed that ambient noise levels dropped 2 dB for every 10% fall in daily vessel noise presence, equating to tens of metres in expected communication ranges being gained by fish and hundreds or thousands of metres for dolphins in shallow (<20 m) or deeper (<50 m) water, respectively. The data collected during the lockdown confirm that vessel noise is likely a key anthropogenic noise source contributing to ambient sound levels within the **Hauraki Gulf Marine Park** – HGMP. After the lockdown, overall ambient sound levels fell by up to 8 dB re 1 μPa over the first 12 h and by up to 10 dB re 1 μPa over the entire lockdown period. The proportional presence of vessel noise per day was calculated as a proxy for vessel activity because (1) vessels operating in the area are directly related to the presence of vessel noise, and (2) masking in marine animals is related to vessel noise emission rather than the number of vessels operating. The counting of multiple vessels at the same time, since overlapping noise signatures from two or more vessels were not differentiated, or distant/proximate vessels impacting the rate at which ambient sound levels changed in response to vessel activity were controlled for using multiple sites around the inner HGMP of

30 https://www.pac.dfo-mpo.gc.ca/fm-gp/mammals-mammiferes/whales-baleines/srkw-measures-mesures-ers-eng.html#maps

31 https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales

32 https://www.orcaiberica.org

differing depths and wind exposures. The resulting 2 dB change in ambient levels for every 10% rise/fall in vessel activity was seen in both the shallow and deeper sites. Direct translation of our findings to other areas should be carried out carefully, especially if no local data are available and particularly in waterways narrower than those in this study (such as fjords) where vessels would operate in closer proximity to each other and at consistently closer ranges to the hydrophones. In contrast, the relationship between communication ranges and vessel activity levels, in contrast, did show some site-dependence, with the largest gains in communication ranges occurring at the deeper and more exposed sites (i.e. further from Auckland City). Those deeper and more exposed sites experienced greater Sound Pressure Level (SPL) decreases during the lockdown than the shallower sites due to vessels being recorded from a greater distance by the hydrophone (because low- frequency vessel noise propagates further in deeper water). Therefore, the difference in vessel noise being detected at the deeper sites after the lockdown began was greater than at the shallower sites, meaning the overall drop in SPLs was higher. There is a mounting body of evidence showing vessel noise to be highly invasive and audible to nearly all marine mammals (Erbe et al., 2016) and fishes (Sound exposure guidelines for fishes and sea turtles: A technical report prepared by ANSI- Accredited Standards, 2014). Smaller vessels, particularly recreational boats, can present a substantial threat in the marine environment in some areas as an unregulated noise source with higher interaction rates with marine animals than any other source (González Correa et al., 2019). Furthermore, the sheer volume of recreational boat traffic can dilute the mitigating effect of their transient nature (L. McWhinnie et al., 2017). Assessing the effects of these vessel movements on the marine environment has become a management challenge. The lockdown measures imposed in New Zealand during the busy summer/autumn boating season provided the fundamental data needed to statistically test relationships between vessel traffic and noise levels, and the effects of cumulative vessel noise on the overall communication range of dolphins and fish. Furthermore, the seven week period during which lockdown occurred allowed for the obtainment of an extensive data set, and provided better baseline values compared with previous recordings and estimates. This event provided an unprecedented chance to rigorously assess some key parameters, including relating the number of vessels required topass through an area to raise the ambient noise floor of that area by a single decibel (i.e., cumulative noise), and relating vessel noise exposure to impacts on the communication range in marine animals. The unprecedented low SPLs recorded during the lockdown were particularly interesting due to the known influence vessel noise can have on the ability of marine animals to communicate (Erbe et al., 2016; Hawkins & Picciulin, 2019). The masking of marine animals' acoustic communication signals by small vessel noise is a key research question that has been somewhat neglected when compared with the attention given to noise from commercial shipping (Erbe et al., 2019). For many coastal areas, small vessels are likely to be the most prevalent and ongoing source of masking noise in shallow waters. Previous studies have investigated reductions in animal communication ranges from individual commercial or small vessels, including within the HGMP, with small vessels raising ambient noise levels at least 47 dB re 1 μPa (Li et al., 2015) or as much as 75 dB re 1 μPa nearer the passing vessel (Pine et al., 2016). However, the cumulative effect of many individual vessels passing during daylight hours on the overall communication range has not previously been measured, as vessel activity had never dropped low enough to obtain true baseline data. The New Zealand lockdown provided a unique opportunity to obtain these baseline data as the daily presence of general vessel noise decreased to 8%. During the lockdown, there was a significant increase in dolphin and fish communication ranges; from hundreds of meters to several kilometres for dolphins and from tens of meters to hundreds of meters for fish.

The expected benefits of the reduced interference by boat noise are an improved ability for marine animals to communicate and maintain social cohesion over longer distances, including when foraging, and an improved perception of their environment and associated threats, which would most likely resulting in lower stress levels (Rolland et al., 2012). Although the first two benefits are more intuitive, lower stress levels occur because anthropogenic noise (including continuous noise, such as small vessel noise) is a well-known stressor in marine mammals (Nowacek et al., 2007; Rolland et al., 2012; Wright et al., 2007) and fishes (Hawkins & Popper, 2017; Popper & Hawkins, 2019; Slabbekoorn et al., 2010). For example, North Atlantic right whales (*Eubalaena glacialis*) showed lower baseline levels of glucocorticoids in faecal samples following a 6 dB reduction in ambient noise from reduced vessel activity after the 9/11 terrorist attacks in the United States of America (Rolland et al., 2012). Yangtze finless porpoises (*Neophocaena asiaeorientalis asiaeorientalis*) had higher serum cortisol levels in areas with high vessel activity than conspecifics in areas without vessels (Nabi et al., 2018). Noise-induced stress has also been seen in coral reef fish (Mills et al., 2020), temperate kelp fish (Nichols et al., 2015), European seabass (Spiga et al., 2017) and freshwater fishes (Smith et al., 2004). With sustained decreases in vessel activity due to various lockdowns around the world, the physiological changes in wild fishes and marine mammals, in response to lower vessel presence would be of particular interest, especially as much research on fishes is carried out in captivity environments.

The **global COVID-19 lockdown** provided an unprecedented, serendipitous opportunity to examine the multi-faceted links between human activity and the environment, providing invaluable insights that can inform conservation strategies and policy making at global level. Specifically, this lockdown has created a period during which global human activity, especially travel, was drastically reduced, enabling quasi-experimental investigation of effects across a large number of 'replicates' (Bates et al., 2021).

Overall, we found that the results that human activity has both positive and effects on species and ecosystems are inconsistent with the prevailing view of humans as primarily harming biodiversity. Indeed, while the qualitative observations presented in section 4.6 provide evidence of interpretation bias, viewing unusual behaviours in wildlife as positive, our quantitative assessments were balanced between negative and positive responses (figure 6.8 and 6.9). Even if our dataset does not represent a random sampling design, the reports collated are a comprehensive inventory of information across the globe. This initial dataset suggests both negative and positive responses from wildlife to human activity and the systems in place to monitor and protect nature. Thus, the lockdown provides a striking illustration of the positive role humans can play as custodians of biodiversity. While negative impacts were expected, the potential for humans to positively influence biological conservation through scientific research environmental monitoring, opportunistic citizen reporting, conservation management, restoration, and enforcement activities was high in our datasets. Combined, these activities jointly deliver conservation benefits.

Another major take-home message from this combination of effort is that humans and their activities have measurable impacts on food availability for animals in both land and marine habitats, including that of top predators and scavengers. The role of human-sourced food is an important driver of wildlife occurrence and condition.

For instance, in Singapore, feral pigeons shifted their diets from human foods to more natural food sources and their numbers declined (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 75, (Soh et al., 2021)). At a university campus in South Africa, red-winged starlings lost body mass, presumably because their typical foraging grounds were bare of waste food (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 58). Scavenging crows also spread to coastal beaches in Australia when human food was no longer available (Duarte et al., 2021). Many species that are routinely fed during wildlife tours, such as sharks (Gallagher & Huveneers, 2018) have not had access to this supplementary food due to drastically reduced tourism. This appeared to drive a change in the abundance and types of species that were detected at sites in the Bahamas during the lockdown period (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 67). In addition to food, animal use of nutritional supplements was also influenced by human activities. For instance, in response to reduced traffic on highways in the Canadian Rockies, mountain goats spent more time at mineral licks, which was interpreted as a wildlife benefit (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 37).

Another major take-home from this combined effort is that many wildlife and ecosystem responses were unexpected. A classic example came from the Baltic Sea, where due to the lockdown, only researchers and a park warden were present on a seabird island during 2020, reducing the number of people on the island was thus reduced by 92%, in contrast to normal years where summer visitors enjoy the island. The reduction in human presence corresponded with the unexpected arrival of 33 white-tailed eagles in a place where no more than three had been annually observed for several decades (white-tailed eagle: figure 6.7). By regularly flying near a murre colony, the eagles flushed incubating birds at disturbance rates 700% greater (7-fold increase) than historical rates, resulting in abandoned ledges where the birds lay their eggs, and subsequently increasing egg predation by gulls and crows (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 31; (Soh et al., 2021). The absence of humans in this case seems to have negatively impacted a species of conservation concern, through the changing of distribution of a species which evoked a predator avoidance response.

Hunting also increased across many countries, including in parks, to supplement incomes. A classic example is the increase in pangolin hunting which was likely due to a combination of reduced protection from forest departments, increased sales of hunting permits, and more frequent illegal hunting. This is surprising considering the possible role of pangolins as intermediary hosts of SARS-COV-2, and calls to halt the consumption of wildlife to avoid future zoonoses (Zhang et al., 2020). On this note, it is clear that resilient socio-ecological systems are fundamental to supporting nature conservation.

Findings also show that impacts of the lockdown on human hunting activity have created not only direct but also cascading ecological impacts. For instance, in North America the large greater snow goose population is considered a pest due to crop grazing. Goose numbers are controlled during their migration to the High Arctic by allowing spring hunting. However when hunting pressure decreased by up to 54% in 2020 in comparison with 2019, the geese benefitted from undisturbed foraging, resulting in rapid weight gain to fuel their northward migration (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 25; (LeTourneux et al., 2021)).

Indeed, hunters from Mittimatalik (Nunavut) reported that those birds arriving in the Arctic in 2020 were unusually large and healthy. The cohort of geese from 2020, which graze the fragile arctic tundra and degrade the habitat for other species, will potentially drive future population growth and environmental impacts (Snow Goose).

The magnitudes of some effects were also more dramatic than anticipated, such as in cases where the lockdown coincided with reproductive activity. For example, in Colombia, a hotspot of bird diversity, species richness in residential urban areas in Cali increased on average by 37% when human activity was at its lowest during the lockdown, which coincided with the beginning of the breeding season. Similarly, various species of sea turtles benefited from nesting on undisturbed beaches during the lockdown period. In Florida, for instance, lockdown-related beach closures in a conservation area were linked to a surprising 39% increase in nesting success in loggerhead turtles, attributed to a lack of disturbances from fishers and tourists with flashlights, and lack of obstructions such as sandcastles (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 74).

Management implications

Increases in biodiversity threats are consistent with the assumed role of human activity as a source of negative impacts on the environment. These observations help identify ways in which human disturbance may play stronger roles in impeding conservation efforts than previously recognized, even for well-studied species such as sea turtles.

Our data also reveal contexts where one simple change in human activity could lead to multiple benefits. For instance, in one park near Boston, noise did not decrease as traffic volumes declined; surprisingly, noise levels increased, likely because cars were moving faster (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 52). At the same time, greater traffic speed near parks can increase the probability of vehicle strikes (Nyhus, 2016), impacting both wildlife and humans. Thus, rather than reducing traffic volume, reducing traffic speed would lead to less noise pollution and protect both wildlife and human safety. Considering how wildlife and humans have responded during the lockdown offers the potential to improve conservation strategies. In particular, restrictions and enforcement mechanisms to control human activities in conservation areas and parks seem critical to their effective functioning.

Adaptive conservation management during reproductive seasons, such as during the nesting season of birds and sea turtles, may also have much stronger positive impacts than previously recognized. The pandemic also highlighted the value of parks near urban centres that protect species and the environment, and that offer opportunities for humans to conveniently enjoy nature without travelling long distances (Airoldi et al., 2021). The role of humans in the food supply of some animal species is also apparent, and suggests that this interaction can be managed to improve conservation outcomes, and avoid risks such as wildlife-human conflicts. Regulation of marine shipping traffic speed and volume can also provide a major contribution to conservation, which would require, similar to the case of terrestrial systems, the identification and regulation of hotspots where strikes are frequent and noise levels are elevated. The analysis of detailed animal tracking data could further inform such interventions (Rutz et al., 2020). The current results also provide compelling evidence of the benefits of reducing noise levels, particularly at sea, and give additional impetus to policies that incentivize the development of noise reduction technologies (Duarte et al., 2021).

While many changes were linked to the lockdown, we were unable to link effects to the lockdown in 18 different studies which represent a wide range of systems and contexts. Even so, 15 of these studies focussed on wildlife responses. This includes examples of where wild-life observations were in remote areas or under effective management and protection from human activities, or species that are unresponsive to humans. For instance, we found that reduced wildlife tourism at the Neptune Islands Group Marine Park, Australia, in 2020 had no effects on white shark residency (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 17; (Huveneers et al., 2021). This is likely due to current regulations minimizing the impact of shark-diving tourism when it occurs, suggesting the effectiveness of prior efforts to decrease animal harassment. Likewise, the distribution of hawksbill turtles (Chagos Archipelago, Indian Ocean), in an infrequently visited area that is effectively protected, was indistinguishable from previous years (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 76). In remote northern Queensland, Australia, tagged estuarine crocodiles exhibited similar habitat use patterns despite restrictions on the number of people allowed into the area (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 54). We also found strong changes that were attributed to other factors, such as the use of the Kerguelen toothfish fishing grounds (Australia) by seals in 2020 (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 40). The seals' observed distribution changes during the lockdown period likely represent responses to other environmental factors, rather than changes in fishing effort.

It is unclear if any of the changes in animal distribution, abundance, behaviour, and sources of food will persist once the lockdown restrictions cease. Many of the responses observed may be transient. For example, animals roaming in areas typically supporting intense human activity may retreat back to smaller ranges once large-scale human activity resumes. However, negative impacts resulting from the interruption of conservation efforts may be long-lasting and reverse years and decades of such efforts. For instance, it is likely that the long-term impacts of over-fishing of juveniles in nursery areas will be apparent into the future in the abundance of the queen conch in the Bahamas due to impacts on recruitment to the adult population (Supplementary materials 6.2, Appendix 4, Table A4, StudyID 47), and in most other cases where illegal activities have injured or removed animals. On a positive note, high level of recruitment success amongst endangered species in areas where disturbance declined may have long-lasting positive effects, particularly where the beneficiary species, such as sea turtles, have long life spans. Long-term studies should track the cohorts of the 2020 wildlife generation over years and decades to come, in order to integrate the positive and negative conservation impacts of the human lockdown.

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CHAPTER 8 – OVERALL CONCLUSIONS

8.1 Whale watching in the Strait: conclusions and management recommendations

The identification of the expectations and sociodemographic profile of Whale Watching (WW) customers, and the assessment of their expenditures, represent important knowledge for providing satisfactory WW experiences and for improving the management of the industry.

Although the total expenditures calculated based on the two summer trimesters of 2017 and 2018 are probably an underestimate of the overall expenditures generated by WW in the area, it is relevant to consider that more than half of these expenditures contributed directly to the economy of Tarifa and that the daily expenses of WW tourists, especially those spending the night in Tarifa, are higher than those of a generalist tourist in the Province of Cádiz. In spite of the relevant expenditures made by Northern European customers, national tourism represents a good opportunity for the WW industry, and even more so after the COVID-19 pandemic. A national advertisement campaign targeted at a well-defined whale watcher profile, and focused on respectful and responsible WW activities, could notably increase the economic input of WW to Tarifa.

Considering the pro-conservation attitude of WW customers and the fact that their satisfaction is affected by the information provided during the WW experience, the improvement of a structured education program during WW excursions is strongly recommended. Moreover, actions such as the support for WW companies from administrative bodies, and an inclusive participative process involving all relevant stakeholders, would substantially improve the sustainability of the industry.

By delineating the profile of whale watchers and assessing their economic contributions, our results provide relevant insights for improved management of the WW industry in the area. However, a future analysis of the economic impact of WW that includes a wider range of data involving all WW companies in the area is strongly recommended.

Scientists, policymakers, Whale Watching (WW) operators, environmental NGO representatives and WW customers were able to provide important insights into WW activities in the Strait. The collaboration of WW customers and other stakeholders is essential when facing the challenge of creating a sustainable WW industry.

Local statutory tools regulating WW activities are only partially respected by the WW fleets in the Strait, despite the fact that their customers give better rankings to companies that abide by WW rules.

Management proposals for WW:

- **Royal Decree 1727/2007 and Marine Protection Regulation 2014/180** should be uniform, i.e., adding to the Spanish Decree the maximum time permitted to spend with the cetaceans during each encounter and the maximum number of vessels allowed to remain in the RAZ.

- A more structured **system of sanctions**, which includes the revoking of licenses, could be further added to the current legislations.

- A coordinated effort among **patrolling forces** is also highly desirable in order to optimize the efficiency of surveillance.

- There is a need for a **dedicated, long-term monitoring programme** to accurately assess levels of compliance. A land-based programme together with AIS data analysis could provide important information and could minimize economic effort.

Management proposals for the conservation of cetaceans and, indirectly, the improvement of the sustainability of the WW industry:

- The designation of an **MPA and of a seasonal regional shipping** plan are the most appropriate tools for the conservation of cetaceans throughout the Strait.
- A **structured multi-jurisdictional participative process** headed by governments, but with the inclusion of all stakeholders, that is based on scientific knowledge is strongly recommended.

Considering the valuable environmental resources at stake, the only partial respect of WW rules, the amount of stakeholders involved, the consistent presence of economic activities and the multi-jurisdictional nature of the Strait, it is imperative that WW activities be managed using an integrated management approach.

8.2 FLT Mediterranean Monitoring Network in the Strait of Gibraltar

Monitoring cetaceans using ferries as a platform allows for the provision of significant insights on cetacean distribution and maritime traffic, which is essential knowledge when improving the management of cost-effectiveness of marine areas. The synoptic collection of species and main threats data in the FLT Med Network, allowed for the assessment of high-risk areas and seasons in which species are most exposed to threats, highlighting a complex situation in which the type and level of risk are determined by the combined effects of species diversity, abundance, juvenile presence, and diverse primary biological needs. Results thus support the need for adaptive conservation and the importance of the contribution made by continuous high sea monitoring across seasons to gather robust long-term datasets. The high number of repeated surveys allowed also the delivery of interesting insights for the monitoring and modelling of rarer pelagic species.

In the Strait of Gibraltar, the presence of dedicated observers of cetaceans (DOs) on board the ferries should be supported by the local administrations, beyond private nautical companies and environmental NGOs. Similarly, monitoring efforts should cover all seasons, including the summer, equally, in order to improve understanding of highly mobile cetacean distribution patterns. Furthermore, mandatory training for bridge officers and other ferry crew members, together with the presence of DOs on board, would reduce collision risks significantly.

In the Strait, despite being widely recognized as an important area for the diversity of highly protected and mobile species, spatial management tools in force only partly cover cetacean hot spots and are static tools. In addition, the transboundary area of the Strait of Gibraltar does not have a respective transboundary management effort. It is time for the Spanish, Gibraltarian and Moroccan administrations to move from the conservation intentions (i.e., international agreements and conventions) to conservation actions (e.g., a transboundary zone with a mandatory reduction in vessel speed).

An international temporal, or in some zones, permanent speed reduction area (i.e. Cetacean Critical Navigation Zone) and a micro-sanctuary in the bay between Algeciras and Gibraltar, could be effective management measures that allow for the harmonization of maritime activities and cetacean conservation.

Moreover, the presence of the long-term monitoring program carried out throughout the Mediterranean Sea (i.e., for the FLT Med Network), and the methods employed in this study, which combined cetacean SPUE, maritime traffic, and spatial management tools analysis, may be applicable to other sensitive areas.

The synoptic collection of data by all partners of the FLT Med Network allows long-term monitoring that provides relevant knowledge on cetaceans, including the low-density species, and provides valuable results that can help to assess cetacean trends in the Western Mediterranean and Adriatic Seas as required by the European directives.

8.3 COVID-19 lockdown at local and global scales

The COVID- 19 lockdown measures in New Zealand put a stop to all non-essential vessels operating, bringing a high degree of masking relief for marine life. The dramatic cessation of human activity on the water provided new baseline data on ambient sound levels due to very low levels of vessel activity, revealing the measured cumulative effect that vessel noise has on the ambient soundscape and masking in fishes and dolphins. The key advantage of these new data is that they provide strong empirical evidence that small vessels, when in sufficient numbers or presence, directly influence ambient sound levels and are not an acute noise source with limited impact as sometimes believed by regulators. The data also, for the first time, demonstrate how small vessels are already contributing to ambient sound levels in ecologically important areas that are near busy metropolitan centres.

Considering how wildlife and humans have responded during the global lockdown offers the potential to improve conservation strategies. In particular, restrictions and enforcement mechanisms to control human activities in conservation areas and parks seem critical to their effective functioning. Adaptive conservation management during reproductive seasons, such as during the nesting season of birds and sea turtles, may also have much stronger positive impacts than previously recognized.

Our finding of both positive and negative impacts of human confinement does not support the view that biodiversity and the environment will have predominantly benefited from reduced human activity during lockdown, a perspective taken by some early media reports. The positive impacts of lockdown on wildlife and the environment stem largely from the reduction of pressures that are typically an unintended consequence of human activity, such as ocean noise. In contrast, the negative impacts of the lockdown on biodiversity emerge from the disruption of the deliberate work of humans to conserve nature through research, restoration, conservation interventions, and enforcement. As plans to restart the economy progress, we should strengthen the important role of people as custodians of biodiversity, with benefits in reducing the risks of future pandemics.

SUPPLEMENTARY MATERIALS

Supplementary materials 4.1

Questionnaire direct to the Whale and dolphin Watching customers

PLEASE FILL IT ALONE

This study is carried on by a PhD student of the University of Cádiz to improve knowledge of conservation and management of the cetaceans hosted in the Strait of Gibraltar. Your participation is voluntary, anonymous, and does not includes commitments. Data obtain are confidential and are going to be analysed respecting the General Data Protection Regulation (GDPR).

Tick this box to agree to use your answers for the study above described ❑

Session: PREVIOUS KNOWLEDGE ON CETACEANS

1. Have you ever seen cetaceans (whales, dolphins or porpoises) before?

❑ Yes, I've seen cetaceans in the wild

❑ Yes, I've seen cetaceans in captivity

❑ No

❑ Don't know/Don't answer

❑ Other:

2. Were you aware of the presence of cetaceans in the Strait of Gibraltar before joining us?

❑ Yes, I was

❑ No, I was not

❑ Don't know/Don't answer

3. Do you think cetaceans are threatened in the Strait?

❑ Yes, I do

❑ No, I do not

❑ Don't know/Don't answer

4. How do you think the conservation status of cetaceans in the Strait?

❑ Good

❑ Fair

❑ Poor

❑ Don't know/Don't answer

5. Do you think enough effort is into place to protect cetaceans in the Strait?

❑ Yes, I do

❑ No, I do not

❑ Don't know/Don't answer

6. Do you think the area of the whale watching tour is in a good environmental state?

❑ Yes, it is

❑ No, it is not

❑ Don't know/Don't answer

Session: CUSTOMERS' EXPECTATIONS AND SATISFACTION

7. Are you satisfied with the information on cetaceans you have received on board?

❑ Yes, I am

❑ No, I am not

❑ Don't know/Don't answer

8. Are you satisfied with the information on cetaceans you have received on land?

❑ Yes, I am

❑ No, I am not

❑ Don't know/Don't answer

9. Do you consider the time spent with cetaceans sufficient?

❑ Yes, I do

❑ No, I do not

❑ Don't know/Don't answer

10. Has your knowledge of cetaceans changed due to this trip?

❑ Yes, they have changed

❑ No, they have not changed

❑ Don't know/Don't answer

11. Why did you decide to join the trip?

❑ Animals

❑ Boat tour

❑ Sail across the Strait

❑ Other

12. What has motivated you to visit Tarifa?

❑ Cetacean sighting

❑ Sport

❑ Leisure

❑ Nature

❑ Culture

❑ Other

13. Are you satisfied with the overall experience provided by this whale and dolphin watching tour?

❑ Yes, I am

❑ No, I am not

❑ Don't know/Don't answer

14. General evaluation of the company Turmares (rate 1 dissatisfied to 10 completely satisfied) ________

Session: ECONOMIC CONTRIBUTIONS

15. Are you on holiday in

❑ Tarifa ❑ other location, where?____________

How many days?_____

16. Have you joined the whale watching trip with other people?

❑ Yes, I have. How many beside you?______________

❑ No, I have not

❑ Don't know/Don't answer

The following questions are referred to your holiday location (Tarifa or other)

17. Do you use public transport?

❑ No, I do not

❑ Yes, I do.

Daily expense (in euros/per person):

- ❑ <10
- ❑ 10-20
- ❑ 21-30
- ❑ 31-50
- ❑ >51

18. Do you have a rental car?

❑ No, I do not

❑ Yes, I do.

Daily expense (in euros/per person):

- ❑ <10
- ❑ 10-20
- ❑ 21-30
- ❑ 31-50
- ❑ >51

19. Type of accommodation

- ❑ Camping
- ❑ Hostel
- ❑ Hotel
- ❑ Rental
- ❑ Other

20. Accommodation daily expenses (in euros/per person)

❑ <10

❑ 10-20

❑ 21-30

❑ 31-50

❑ >51

21. Where do you get your food from?

❑ Bar-restaurant

❑ Supermarket

❑ Small shop

❑ All the previous

❑ Other

22. Food daily expenses (in euros/per person)

❑ <10

❑ 10-20

❑ 21-30

❑ 31-50

❑ >51

23. Daily expenses for each one of the following activities (in euros/per person)

Shopping	❑<10	❑10 – 20	❑21 – 30	❑31-50	❑ >51
Sport	❑<10	❑10 – 20	❑21 – 30	❑31-50	❑ >51
Leisure	❑<10	❑10 – 20	❑21 – 30	❑31-50	❑ >51
Other	❑<10	❑10 – 20	❑21 – 30	❑31-50	❑ >51

Session: PARTICIPANT INFORMATION

24. Income (in euros)

❑ <1000

❑ 1001-1500

❑ 1501-2000

❑ >2001

25. Education

❑ Primary

❑ Secondary

❑ Upper-secondary

❑ University

26. Age

❑ 18-25

❑ 26-35

❑ 36-46

❑ 47-56

❑ 56-65

❑ >65

27. Gender

❑ Female

❑ Male

❑ I prefer not to answer

28. Nationality________

29. Employment type

❑ Self-employed

❑ Employed

❑ Unemployed

❑ Student

❑ Retired

❑ Other

Session: PERCEPTION ON THE WW EXPERIENCE

30. Which value or service do you associate to whale watching activities?

❑ Aesthetic

❑ Spiritual/Psychological

❑ Political

❑ Educational

❑ Scientific

❑ Recreational

❑ Cultural

❑ Social

❑ Hereditary

❑ Monetary

❑ Other:

31. Were you satisfied with the amount of time spent with cetaceans (whales, dolphins or porpoises) on the tour?

❑ Yes, I am

❑ No, I am not

❑ Don't know/Don't answer

32. How was the approach of the boat to cetaceans?

- ❑ Slowly
- ❑ Slowly and keeping the distance
- ❑ Fast and keeping distance
- ❑ Fast
- ❑ Don't know/Don't answer

33. How do you describe the behaviour of the cetacean with the boat?

- ❑ Approaching
- ❑ Leaving
- ❑ Indifferent
- ❑ Don't know/Don't answer
- ❑ Other:

34. Has your knowledge on the cetaceans changed due to this tour?

- ❑ Yes, they has changed
- ❑ No , they has not changed
- ❑ Don't know/Don't answer

Further comments or suggestions:

Session: DATA COLLECTED BY THE WW GUIDES

Date/Time:

Vessel:

Kind of trip:

Number total of passengers onboard/Number total of passengers answered the questionnaires:

Species sighted:

The total amount in min spent with cetaceans (summing all the encounters):

Supplementary Materials 4.2

Supplementary Material I - Spanish Royal Decree

REAL DECRETO 1727/2007, de 21 de diciembre, por el que se establecen medidas de protección de los cetáceos –https://www.boe.es/buscar/doc.php?id=BOE-A-2008-516

Supplementary Material II - Gibraltarian Marine Protection Regulation 2014

https://www.gibraltarlaws.gov.gi/legislations/marine-protection-regulations-2014-2653

Supplementary Material III - Questionnaires to the Experts on the area of Strait of Gibraltar, its cetaceans and on the Whale and dolphin Watching (WW) activities

This study is carried out by a PhD candidate of the University of Cádiz (Spain). This form aims to improve our knowledge on conservation and management of cetaceans in the Strait of Gibraltar. Your participation is voluntary and doesn't include any further commitments. Your name will not appear. All the data obtained by this study are confidential, and will be analysed in accordance with the EU General Data Protection Regulation (GDPR) and the policy of Google form.

Session: PROFILE EXPERTS

1) Your name and affiliation:

2) Your profession?

- ❏ Biologist
- ❏ Environment guide
- ❏ Researcher
- ❏ Manager
- ❏ Technician
- ❏ Don't know/Don't answer
- ❏ Other:

3) Nationality and residence:

4) Age:

5) Gender

- ❑ Female
- ❑ Male
- ❑ Gender-neutral
- ❑ Prefer not to say
- ❑ Other:

Session: WW ACTIVITIES

6) Which values do you associate with whale watching activities?

- ❑ Aesthetic
- ❑ Spiritual/Psychological
- ❑ Political
- ❑ Educational
- ❑ Scientific
- ❑ Recreational
- ❑ Cultural
- ❑ Social
- ❑ Hereditary
- ❑ Monetary
- ❑ Don't know/Don't answer
- ❑ Other:

7) How do whale/dolphin watching boats approach cetaceans in the Strait of Gibraltar?

- ❑ Slowly
- ❑ Slowly and keeping a safe distance
- ❑ Fast and keeping a safe distance
- ❑ Fast
- ❑ Don't know/Don't answer
- ❑ Other:

8) Do you know of any guidelines or laws concerning whale/dolphin watching activity in the Strait of Gibraltar?

9) How much are the "Marine Protection Regulation 2014" and the "Real Decree 1727/2007" respected?

- ❑ 25%
- ❑ 50%
- ❑ 75%
- ❑ 100%
- ❑ Don’t know/Don’t answer
- ❑ Other:

Session: MANAGEMENT OF THE WW ACTIVITIES

10) Which management technique do you think would be most effective for ensuring sustainability of the whale/dolphin watching industry?

- ❑ Government legislation and regulation (i.e. enforced code of conduct and licensing permits for operating as a wildlife tour operator)
- ❑ Environmental NGOs or operated led management (i.e. voluntary codes of conduct for wildlife tour operators)
- ❑ Participative process involving both government, NGO's and stakeholders (i.e. new regulations)
- ❑ Other:

11) What management tools could be effectively used to improve conservation of the cetaceans in the Strait of Gibraltar?

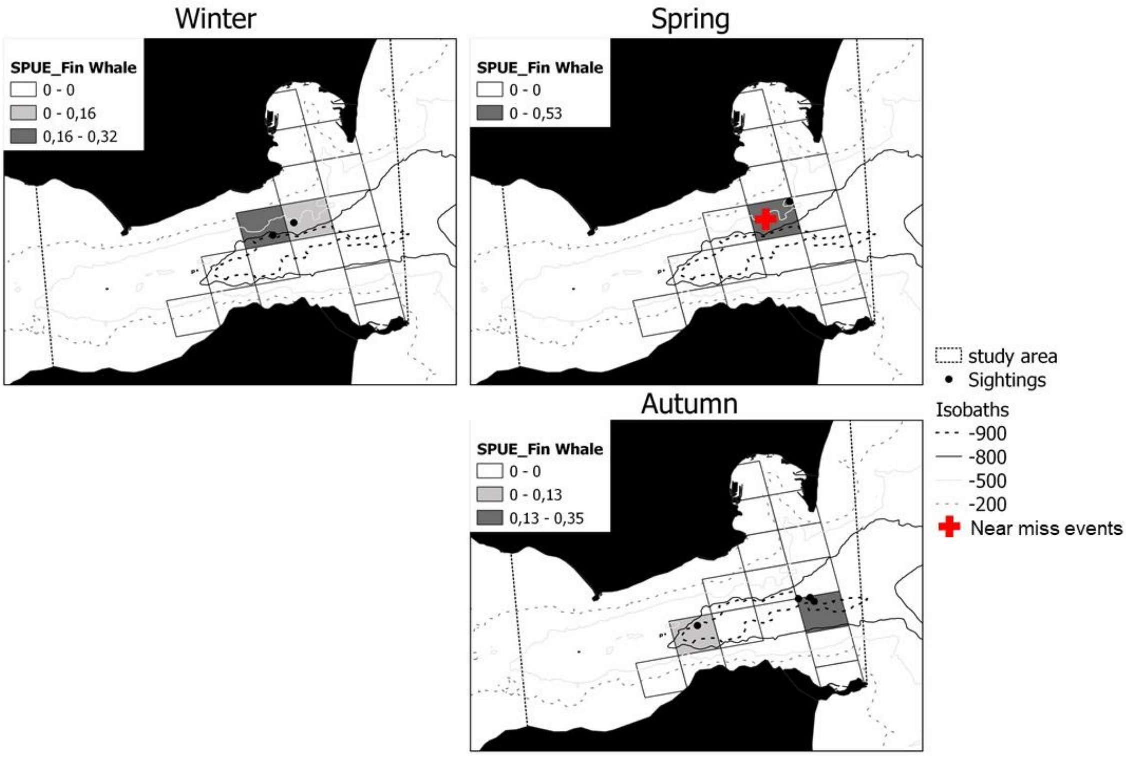
- ❑ Marine Protected Areas
- ❑ Fishing limits (i.e. size, restrictions)
- ❑ No take area
- ❑ Quiet area
- ❑ Additional pilot
- ❑ Escort tugs
- ❑ Regional shipping for the Strait of Gibraltar
- ❑ Improving communication and access to real time maritime information
- ❑ Speed restriction
- ❑ Changes to shipping routes and lanes
- ❑ Avoidance areas
- ❑ Other:

12) Based on these questions, who would you suggest interviewing to obtain further information? If you have any other comments that you would like to add please feel free to do so here!

Supplementary Materials 5.1

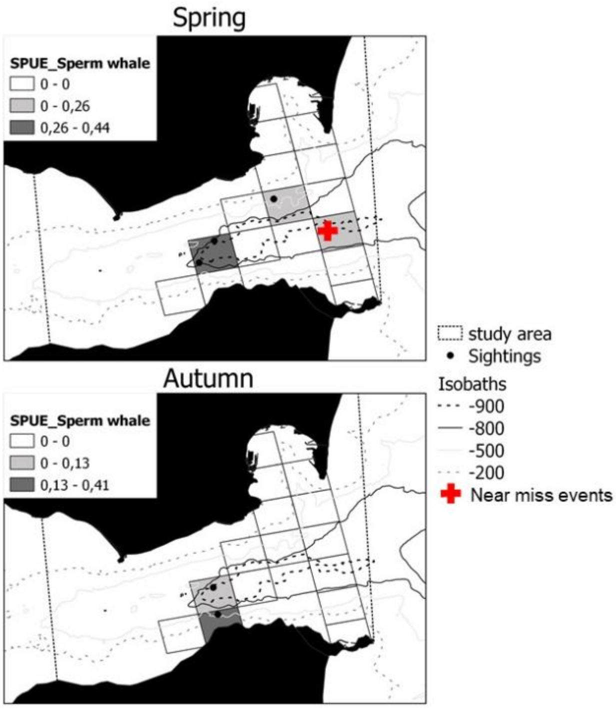
Supplementary Material I

Maps of relative abundance of fin whale expressed as Sightings Per Unit of Effort (SPUE), per autumn (October-December), winter (January-March) and spring (April-June).



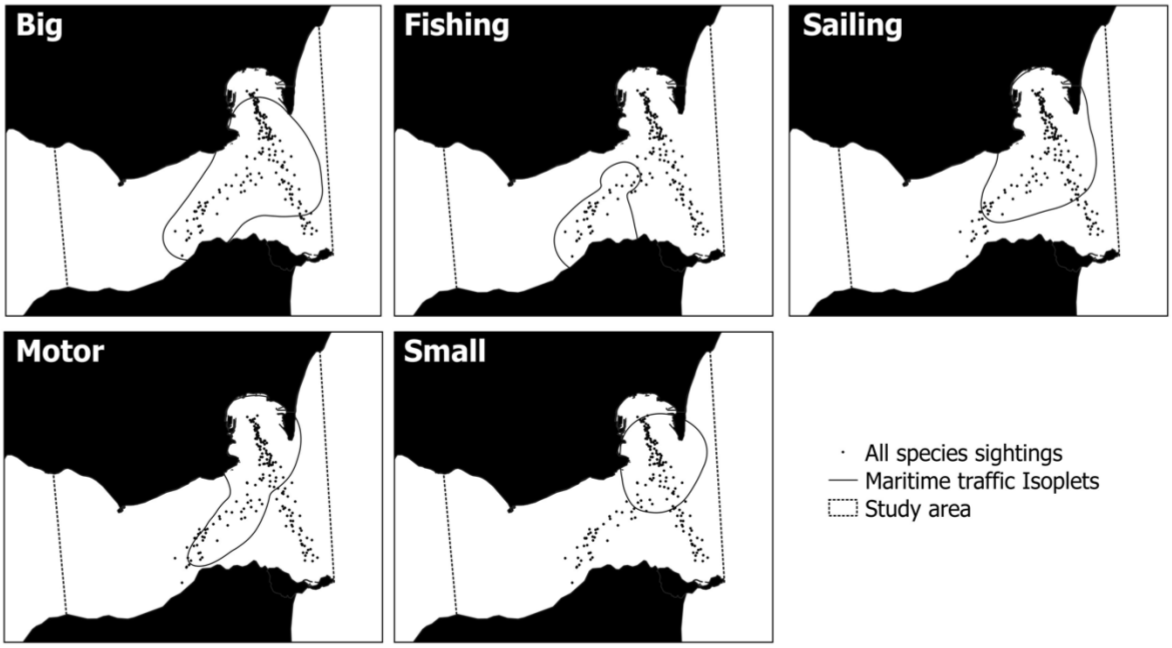
Supplementary Material II

Maps of relative abundance of sperm whale expressed as Sightings Per Unit of Effort (SPUE), per autumn (October-December) and spring (April-June).



Supplementary Material III

Maps of the Strait of Gibraltar with all species sightings georeferenced and divided by vessel type to mark their respective isopleths.



Supplementary Material 5.2

Technical Annex II 'Protocol for monitoring by vessel of floating marine macro litter and marine macro fauna along a fixed transept width' can be found online at https://www.isprambiente.gov.it/files2021/progetti/technical-annex-ii_marine-litter-protocol_2015.pdf

Supplementary Material 6.2

Supplementary data to this article can be found online at

https://doi.org/10.1016/j.biocon.2021.109175

ANNEXES

I. Europass CV

II. Mobility passport

III. Certificates of stay in other institutions

IV. Presentation of research results: poster

V. Presentation of research results: oral presentations

VI. Seminar, courses and conferences

VII. Participation in activities requiring only proof of attendance

VIII. Collaboration in teaching or in the organization of scientific events