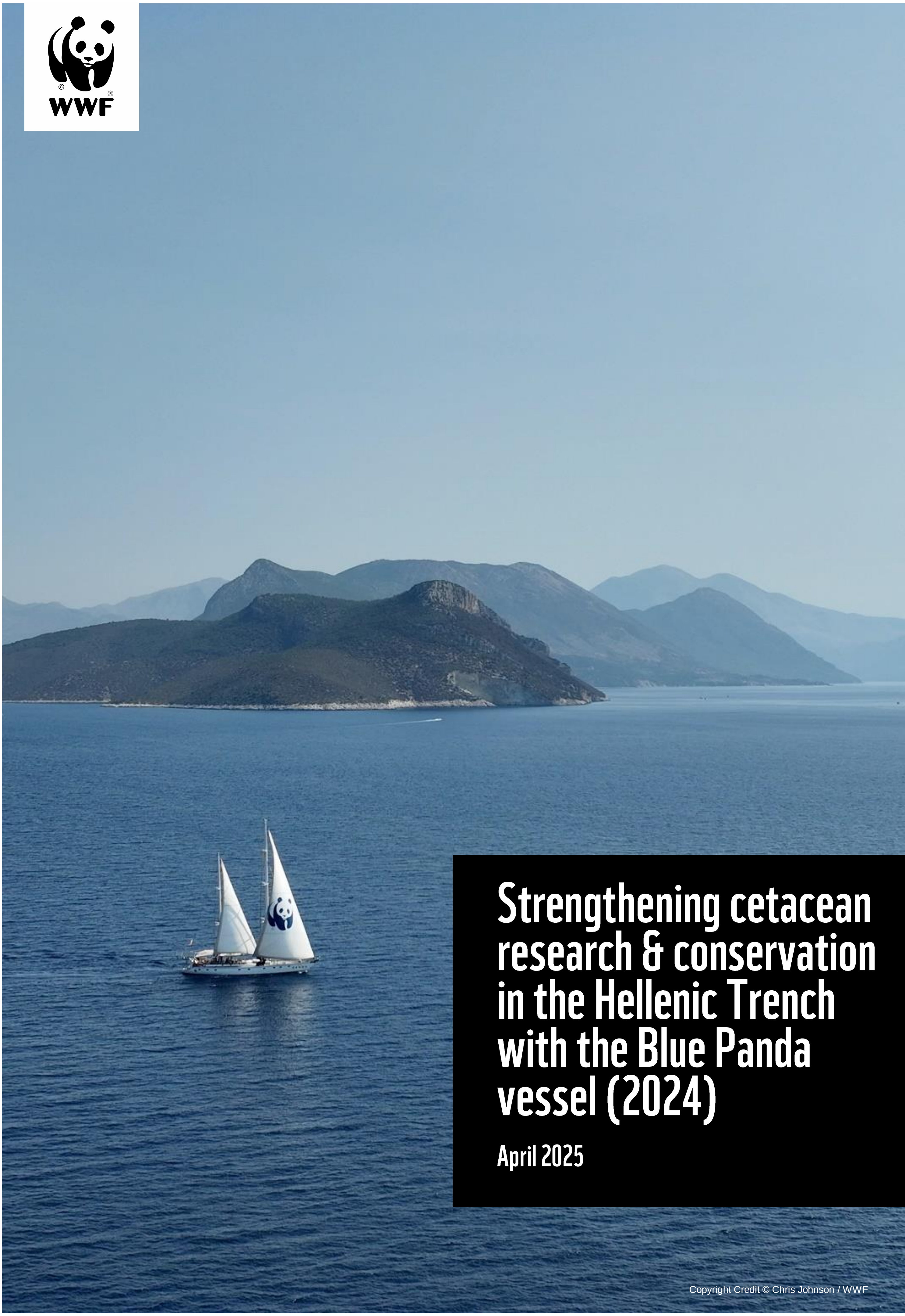

Strengthening cetacean research & conservation in the Hellenic Trench with the Blue Panda vessel (2024)

April 2025

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WWF Greece:

Nicole Godsil, Project lead
Amalia Alberini, Marine officer
Demetres Karavellas, CEO
Sissy Gkournelou, Marine communications associate
Christy Sotiriou, Media officer

WWF Whales and Dolphins Initiative:

Chris Johnson, Global Lead

Tethys Research Institute:

Simone Panigada, Scientific coordinator and data analyst lead
Nino Pierantonio, Researcher and data analyst
Margherita Zanardelli, Researcher and data analyst
Viola Panigada, Researcher and data analyst

Blue Panda Team:

Gregory Rondeau, Head of the Blue Panda Program
Nicolas Bin, Captain
Hugo Pierre, Crew member
Louis Du Petit Thouars, Crew member

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Licensing:

All research activities were conducted under permits obtained from the Marine Research Licensing Committee (MRLC), the Ministry of Environment and Energy, and with the assent of the Natural Environment & Climate Change Agency (NECCA).

This project was implemented in coordination with the LIFE MareNatura consortium and has facilitated the exchange of information and knowledge towards the protection of cetaceans in the Eastern Mediterranean Sea, recognising the importance and the benefit of multilateral cooperation on research, conservation and policy work, supporting and feeding into the ongoing efforts in the area.

With the support of the: Greek Wildlife Alliance

THE WWF BLUE PANDA CETACEAN SURVEY IN 2024

During the summer of 2024, a research survey was conducted with the WWF Blue Panda vessel between the 15th and 29th of July in the Hellenic Trench, Ionian Sea, to investigate the presence, behaviour and migration patterns of cetaceans and the threats they face in the region[1].

The **Blue Panda**, the WWF Mediterranean Marine Initiative is a 26-meter sailboat built in 1987 by a famous French naval architect, André Mauric, initially used as a private pleasure boat. Since 2018, when it was leased to the WWF Mediterranean Network, it serves as a **powerful medium and an attractive tool that interacts with the world and inspires the public to connect with the sea** and marine life, while also supporting the implementation of research work.

Sailing along the onshore and offshore waters of the northern and central part of the Hellenic Trench, between the islands of Corfu and Zakynthos, covering almost 1,000 nautical miles, Tethys Research Institute, with the support of WWF Greece through the Greek Wildlife Alliance Initiative[2] and WWF Whales and Dolphins Initiative, implemented research activities targeting endangered cetacean species (including sperm whales, Cuvier's beaked whales, and other cetaceans), to complement prior research efforts by collaborating organisations, including the 2018 ACCOBAMS Survey Initiative (ASI), the long-term research activities conducted by the Pelagos Cetacean Research Institute in the Hellenic Trench, as well as the ongoing LIFE MareNatura project.

Using different scientific methods, and based on standard protocols[3], data were collected throughout the 15-day cruise both in the onshore and offshore waters of the Ionian Sea. Daily visual and acoustic surveys were conducted. Cetaceans were located through visual observations, while echolocating odontocetes were acoustically located using a towed horizontal hydrophone array. Photographs suitable for photo-identification and drone footage for photogrammetric purposes were also collected. Finally, tag deployment was attempted on healthy adult individuals to assess mid- and long-term movements, habitat use and behaviour with a focus on Cuvier's beaked whales and sperm whales.

As described in the Tethys Technical Report (available at the end of this document), twelve sightings of four different species were recorded over the study period, confirming the presence of several cetacean species in the Hellenic Trench. Furthermore, the movements of one adult sperm whale equipped with a satellite transmitter spending considerable time in the east Aegean region indicate that sperm whale favourable habitats extend beyond current knowledge, providing an important insight into the species' habitat use and distribution in Greek waters.

In addition to conducting research, the mission aimed to promote the need for effective protection and implementation of spatial measures in the Hellenic Trench and raise awareness on the necessity to protect one of the most ecologically important marine areas in the Mediterranean and its unique marine life. For this purpose, the vessel docked at the central port of Zakynthos on the 31st of July and the 1st of August for the implementation of public engagement and awareness-raising activities. During that time, visitors and local stakeholders had the opportunity to learn about the expedition's rationale and findings, discuss with WWF and Tethys members and see up close the scientific equipment used during the survey.

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[1] The main threats in the area are increased maritime traffic, degradation of their habitats due to pollution (plastic and chemical), reduced fish supply due to overfishing, and underwater noise caused by seismic tests for hydrocarbon extraction and naval exercises.

[2] The "Greek Wildlife Alliance" initiative represents the collaborative effort of 11 environmental, nongovernmental organizations to enhance the impact of their work, through a shared vision for the well-being of wildlife and humans.

[3] The protocols used were the ones of the ACCOBAMS Survey Initiative (ASI).

In conclusion, targeted research activities are increasing our understanding of these sentinel species and their threats and can support advocacy and conservation efforts (including the promotion of the 30X30 objective of an ecologically representative, coherent and well-managed marine network of MPAs, supporting the implementation of vessel collision mitigation measures, fighting against Oil & Gas developments). The insight into the sperm whale movement in the Greek waters is invaluable for sperm whale conservation efforts in Greece and the development of mitigation and conservation strategies, and highlights the need to expand connectivity research efforts that will further investigate cetacean exposure to anthropogenic threats and help identify additional areas requiring protection.

Building on the scientific information collected, and to expand our knowledge of the region's endangered cetacean species and their threats, a second complementary survey during the summer of 2025 is being planned.

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WWF Greece

Charilaou Trikoupi 119 - 121, Athens 11473
Tel: 210 3314893
Fax: 210 3247578
www.wwf.gr
e-mail: support@wwf.gr

For more information, please contact:

Nicole Godsil,
Marine programme associate, Project lead
n.godsil@wwf.gr

Strengthening cetacean research and conservation in the Hellenic Trench with the Blue Panda Vessel (2024)

Simone Panigada, Viola Panigada, Margherita Zanardelli, & Nino Pierantonio

Tethys Research Institute, Viale G.B. Gadio 2, 20121 Milan, Italy

Final report

Tethys Research Institute, March 2025

Simone Panigada, Viola Panigada, Margherita Zanardelli & Nino Pierantonio. Strengthening cetacean research and conservation in the Hellenic Trench with the Blue Panda Vessel (2024). Final report. March 2025. 38 pp.

1. Executive summary

The primary objective of this project was to bridge existing knowledge gaps regarding the presence, behaviour, habitat preferences, and small to medium-scale movements of resident cetacean species, along with the associated threats they face. The focal study area was the less-studied northern part of the Hellenic Trench, in the Ionian Sea, Greece. The area is an important feeding and breeding ground for the eastern Mediterranean sperm whale sub-population. Solitary males, loose male aggregations and members of long-term resident social units of sperm whales – including calves and newborns – are regularly observed.

The rationale for this effort was to conduct a comprehensive survey of the offshore and coastal waters of the area to complement prior research efforts by collaborating organizations, including the 2018 ACCOBAMS Survey Initiative (ASI), the long-term research activities by the Pelagos Cetacean Research Institute in the southern portion of the Hellenic Trench, as well as the ongoing LIFE MareNatura project, which aims to mitigate the threats that affect nine of the most threatened EU priority species of seabirds, marine turtles and marine mammals. Furthermore, another goal of the effort was to raise awareness of the region's ecological significance and the threats faced by cetaceans, by using data and visual material collected during the survey. Ultimately, this initiative aims to support advocacy efforts for enhancing legal protection and biodiversity conservation in the area, with a particular focus on the Hellenic Trench Important Marine Mammal Area (IMMA) and surrounding waters.

To ensure effective protection for whales and dolphins in Greek waters, conservation efforts must be bolstered through science-based policies, enhanced enforcement of existing regulations, and increased awareness among stakeholders. Strengthening the legal framework for marine protected areas (MPAs), expanding monitoring programs, and fostering international collaboration are vital steps toward mitigating and reducing threats.

The approach used during the cruise included visual observations and acoustic surveys from the WWF Blue Panda sailing boat to track sperm whales, as well as photo-identification to distinguish and catalogue individual sperm whales, and other species observed, such as Cuvier's beaked whales. Photogrammetry techniques were also utilised to measure the length of animals and evaluate the health status of large whales observed. Additionally, drone footages were captured during the observations of sperm whale social units, to facilitate counting the animals, document interactions and provide insights into their surface and underwater behaviour. This material was also used for communication and raising awareness.

In addition, satellite transmitters (LIMPET tags – Low Impact Minimally Percutaneous Electronic Transmitters) were available for deployment on adult sperm whales to provide initial insights into small to medium-scale movements, habitat use and behavioural patterns. Only adults -previously photo-identified - and visually healthy animals, apart from family units, were approached for tagging, and their immediate reactions were recorded using dedicated handheld cameras (GoPro) for subsequent assessment.

Fieldwork activities took place in July 2024, with the WWF sailboat 'Blue Panda' covering almost 1,000 nautical miles in 15 days surveying for cetaceans between the islands of Corfu and Zakynthos. The participating crew consisted of scientists from Tethys Research Institute, WWF Greece, WWF Protecting Whales & Dolphins Initiative and Blue Panda crew, as support. One adult sperm whale was equipped with a satellite transmitter, which remained on the animal for 57 days. The animal spent approximately 15 days slowly moving between the area southwest of Kefalonia and Zakynthos, before travelling southward, along the Hellenic Trench, with a few days spent along the Peloponnese. Before reaching the island of Crete, the animal turned towards the Aegean Sea and swam directly towards the area south of Ikaria and west of Patmos, where it stayed, with minor movements, for 23 days, until the tag detached and stopped transmitting. Despite the small sample size, these data are invaluable for sperm whale conservation efforts in Greece. These findings indicate that the favourable habitats and ranges of sperm whales likely extend beyond current knowledge and show that these animals in the area may be exposed to an increased risk of collision with maritime traffic in portions of the Greek seas not yet identified as being of concern. Consequently, these preliminary results stress the need for further investigations into sperm whale connectivity in the area, the patterns of it and the correlates to their movements and their exposure to anthropogenic threats. Hence, they are relevant for the development of mitigation and conservation strategies, as well as for the creation of new spatially explicit tools. Finally, these results, although preliminary, highlight the necessity of updating existing place-based efforts, such as the IMMA process, to review the location and extent of existing IMMAs and the creation of new ones.

2. Introduction

The Hellenic Trench, a marine region stretching from the western and southern Peloponnese to the southwestern coast of Crete and the Dodecanese, serves as a critical habitat for the endangered Mediterranean sperm whale (*Physeter macrocephalus*) subpopulation. It is also the largest of the five high-density zones for the vulnerable Cuvier's beaked whale (*Ziphius cavirostris*) in the Mediterranean Sea. Published data further indicate the presence of another endangered species in the region, the fin whale (*Balaenoptera physalus*), mainly observed in the northern Ionian Sea.

These deep-diving and highly mobile cetaceans face a diverse range of threats, including shipping traffic, oil and gas exploration (such as seismic surveys), and naval exercises. The broader Hellenic Trench has been identified as a Cetacean Critical Habitat (CCH) and proposed as a Marine Protected Area by the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and Contiguous Atlantic Area (ACCOBAMS). Additionally, in 2016 two IMMAs have been identified in the areas, the Ionian Archipelago IMMA and the Hellenic Trench IMMA, for common dolphins (*Delphinus delphis*) and Mediterranean monk seals (*Monachus monachus*) and sperm and Cuvier's beaked whales, respectively, by the IUCN SSC/WCPA Marine Mammal Protected Areas Task Force.

A research cruise led by WWF Greece, onboard the WWF sailing boat Blue Panda and as part of the "Greek Wildlife Alliance" initiative[1] was conducted in July 2024 to collect data on the presence, behaviour, habitat preferences, and small to medium-scale movements of sperm whales and other cetacean species, focusing on the less-studied northern part of the Hellenic Trench IMMA. Between the 15th and the 31st of July 2024, the Blue Panda sailed along the northern section of the Hellenic Trench, between the islands of Corfu and Zakynthos, covering 965 nautical miles in 15 days.

The findings from this research emphasize the need for strengthened conservation measures and efforts in the Hellenic Trench, including the implementation of effective Marine Protected Areas and stricter regulations on human activities, such as shipping, seismic exploration, and naval exercises. Ensuring the long-term protection of these critical habitats is essential for the survival of the endangered and vulnerable cetacean species in Greek waters.

[1] The "Greek Wildlife Alliance" initiative is a collaboration of 11 environmental Non-Governmental Organizations, working for the conservation of Greece's natural wealth, through the harmonious coexistence of wildlife and humans.

All fieldwork activities (including data and visual material collection) were implemented under the necessary permits acquired by the relevant state authorities.

3. Methods

3.1 Study area and data collection

Daily visual and acoustic surveys were conducted in the northern portion of the Hellenic Trench across an area encompassing both coastal and pelagic waters and extending from north of the Island of Corfu to the south of the Island of Zakynthos (Figure 1). Field work was carried out on board the sailing vessel Blue Panda (MMSI 227245000; Figure 2). The area is a tectonically active region and is characterised by steep bathymetric gradients and abyssal depths ranging from 2,000 to 4,000 metres. The complex geomorphology and oceanographic characteristics of this portion of the Ionian Sea makes it one of the most dynamic ecosystems of the entire Mediterranean with strong seasonal, interannual, and decadal oscillations that have a direct influence on the functioning of the marine ecosystem and affect the presence and distribution of cetaceans and other large marine vertebrates. In fact, the monitored area is home to several species of conservation and economic importance and, as such, is protected under several national and international agreements and regulations resulting in the establishment of numerous Marine Protected Areas (MPAs) and other spatially explicit conservation tools (Figure 3A). Moreover, the area is also included in the Ionian Archipelago IMMA[2] and the Hellenic Trench IMMA[3] (Figure 3B), as well as the recently announced marine park, stretching from northern Corfu to Antikythera islands.

[2] https://www.marinemammalhabitat.org/wp-content/uploads/imma-factsheets/Mediterranean/Ionian-Archipelago-Mediterranean.pdf
[3] https://www.marinemammalhabitat.org/wp-content/uploads/imma-factsheets/Mediterranean/Hellenic-Trench-Mediterranean.pdf

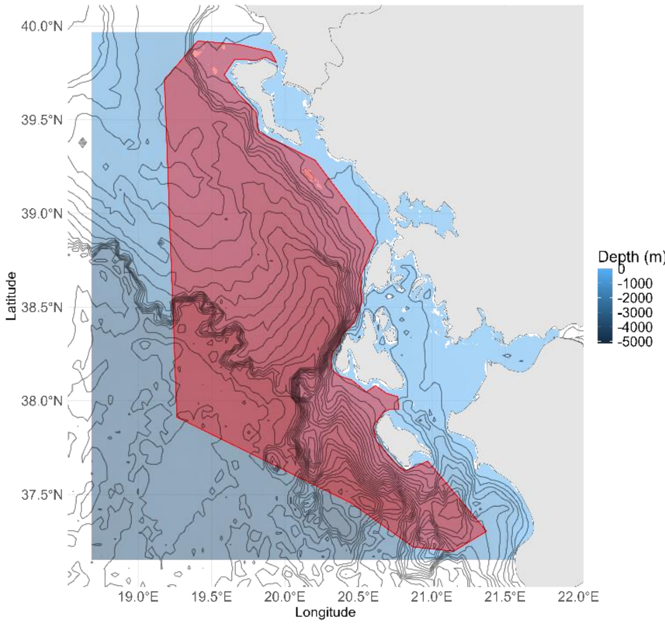


Figure 1. Study area (in red) with highlighted the bathymetric characteristics of the monitored region.

Figure 2. The sailing vessel Blue Panda used as the research platform during the survey.

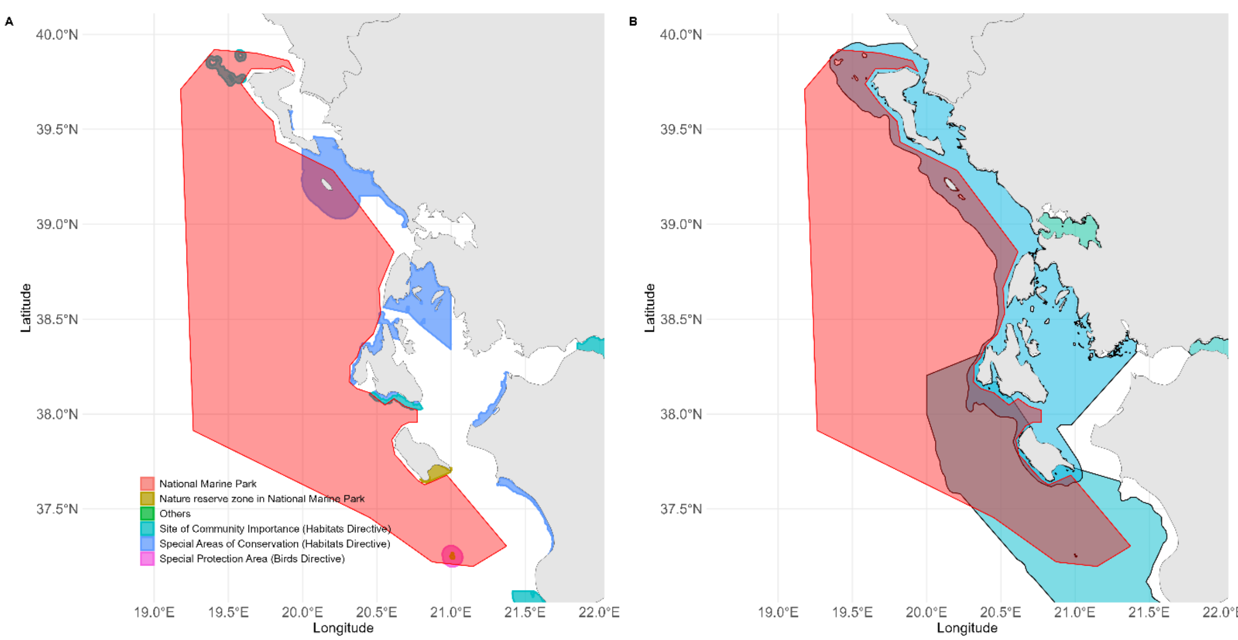


Figure 3. A) Marine Protected Areas in the monitored region, colour-coded by designation type. Special Protection Area (Birds Directive), Site of Community Importance (Habitats Directive) and Special Areas of Conservation (Habitats Directive) are European Union level designations, while the remaining types are Greek national level designations. The boundaries of these areas and the associated designation information were obtained from the World Database on Protected Areas (WDPA) available at https://www.protectedplanet.net/en/thematic-areas/wdpa?tab=WDPA. B) Important Marine Mammal Areas identified in the monitored region. In both panels the study area is highlighted in red.

Cetaceans were located visually at the surface and, for echolocating odontocetes, acoustically, using a towed horizontal hydrophone array, following standard protocols, as those used during the ACCOBAMS Survey Initiative (ASI). Data were stored in relational databases using the dedicated software Logger2010[4] (Marine Conservation Research, UK) and Pamguard[5] for visual and acoustic-related data, respectively. For the acoustic component of the survey, the system consisted of a 173 metres long streamer including two Benthos AQ4 elements with matching Magrec HP02 preamplifiers, two HF Magrec HP03 hydrophone/preamp units and a depth sensor based on Keller PA-9SE-10 bar 4-20mA sensor. The system was connected to a topside rack instruments case hosting a 12v power supply and all the necessary hardware for sound processing before reaching the laptop used for data collection. Given the characteristics of the cetacean species usually observed in the area, the system was set to work at a sampling frequency of 192kHz in stereo mode.

Once cetaceans were spotted at the surface and following a preliminary assessment of their behaviour and response to the research vessel, whenever possible the onboard rib was deployed to collect photographs suitable for photo-identification, notes on the general behaviour of the animals, drone footage and data for photogrammetric purposes and for deploying satellite-linked transmitters (hereafter tags). Audio recordings of cetaceans' vocalisations were performed from the main research platform on an *ad hoc* basis considering the location, the weather and the distance to the animals.

For photogrammetry, a commercial DJI Mavic 3 drone equipped with an OSU Lidar Box[6] (Oregon State University, Marine Mammal Unit) for accurate measurements of the flight altitude was used.

To assess mid- and long-term movements, habitat use and behaviour and with a focus on sperm and Cuvier's beaked whales, tag deployment was attempted after assessing the animals' behaviour and status; only adult individuals of no specific sex were selected for tagging after being visually considered as healthy. Argos Smart Position Only (SPOT-365; Wildlife Computers Inc., Redmond, WA, USA) satellite tags in the Low Impact Minimally Percutaneous External-electronic Transmitters (LIMPET, Wildlife Computers) configuration were deployed on the dorsal fin of whales using a 150 lb draw weight crossbow (Vixen Excalibur II). To allow for an *a posteriori* qualitative evaluation of the position of the transmitter on the whale and the animal's immediate reaction to deployment, a GoPro Hero 8 camera was used to record

[4] https://www.marineconservationresearch.co.uk/downloads/logger-2000-rainbowclick-software-downloads/
[5] https://www.pamguard.org/contact.php
[6] https://mmi.oregonstate.edu/centers-excellence/codex/software-hardware/lidarbox

tagging operations. Whenever possible, tagged animals were followed after tag deployment to assess the whales' behaviour at the surface, the quality of the deployment and to collect further data using a CLS RXG-234 Goniometer (Collect Localisation Satellites, France)[7].

3.2 Data analysis

3.2.1 Sperm whales

3.2.1.1 Telemetry data, behaviour and movements

Kalman-filtered data from the tagged sperm whale were downloaded from the Wildlife Computers portal and additionally filtered and regularized with the package *aniMotum* for the software for statistical computing R. This fits a continuous-time state-space model (SSM) to predict regularized positions along the most likely movement path taken by the whales, incorporating process and observation errors. Moreover, a move persistence model (MPM), a continuous behavioural index that captures autocorrelation in both speed and direction, was fitted to infer how an individual's behaviour changed along the movement path. An advantage of using this approach is that uncertainty in the location is included in the move persistence fit. Two critical behavioural states are distinguished with this modelling framework: Area Restricted Search (ARS) characterised by high turning angles and low autocorrelation in direction and speed, and Transiting, characterised by very low turning angles and higher speed of movement. To determine differences in movement behaviours, a move persistence model was fitted to all tracked individuals' interpolated locations at regular intervals of 3 hours. The time-step of 3 hours was obtained by calculating the average time between transmissions. Specific details on the full analytical approach are given in Panigada et al. (2024).

3.2.1.2 Home Range estimation

Home ranges, defined here as realised habitats, were assessed by calculating Kernel Utilization Distributions (UD) — the probability that an animal is found at a given point in space — only for the tagged sperm whale. Utilization Distributions provide the likelihood of an animal being present at a given point within its core (50% isopleths) and home (95% isopleths) ranges, critical to delineate areas of high

[7] https://telemetry.groupcls.com/argos-solutions/argos-products/platform-finder/

conservation priority. UDs were calculated through the *kernelUD* function in the *adehabitatHR* R package using the regularised positions resulting from the SSM. UDs were calculated at a spatial resolution of 1X1 km to assess the minimum extent of the animals' distributional ranges and to measure the spatial intensity of use. Core and home range contours were computed by extracting the 50th and 95th percentile of each UD.

3.2.1.3 Interaction with maritime traffic and collision risk

The overall collision risk within the study area was quantified through a spatial analysis integrating maritime traffic density and the realised habitat utilisation of the tagged sperm whale. This risk metric was derived as the multiplicative product of two key datasets: the maritime traffic density maps and the realised habitat maps. The maritime traffic density maps, sourced from Global Fishing Watch[8] (GFW), provided a comprehensive representation of vessel activity, encompassing all vessel types with speeds exceeding 15 knots. The inclusion of all vessel types in the analysis was justified by the heterogeneous nature of vessel traffic in the region, which includes both high-volume commercial shipping lanes and seasonal recreational boating activity, the latter of which is especially prevalent in the southern Aegean Sea, the northern Cretan Sea, and the inner Ionian Sea during the summer months. While commercial shipping is a well-documented contributor to collision risk, the seasonal influx of recreational vessels introduces additional variability and potential hazards. Recreational vessels, often operating at high speeds and with less predictable navigation patterns, may pose a disproportionate risk in certain areas, particularly in coastal zones and near high-use marine recreational sites. The integration of these factors into the collision risk model thus provided a more holistic assessment of the potential threats faced by the tagged sperm whale throughout its range. The realised habitat maps, which delineate the areas actively utilised by the tagged sperm whale, were spatially aligned with the traffic density maps to ensure congruity in resolution and geographic extent. The original habitat data, initially at a resolution of 0.01° × 0.01° (approximately 1 km × 1 km), were resampled to a 10 km × 10 km grid to match the resampled traffic density maps. Collision risk was modelled under the assumption that the probability of an encounter between the whale and a vessel, and thus the likelihood of a collision, is a function of both the intensity of vessel traffic and the whale’s spatial presence. By calculating the product of these two variables, the resulting collision risk index provides a spatially explicit

[8] https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://globalfishingwatch.org/map

measure of potential interaction hotspots. Areas exhibiting high collision risk are characterised by both elevated vessel traffic densities and significant overlap with the whale's realised habitat.

Furthermore, to assess the spatial overlap between the tracked sperm whale's distribution and maritime traffic patterns, we used the Structural Similarity Index (SSIM) and related metrics using the *SSIMmap* package in R. The Utilisation Distribution (UD), derived from the satellite track of the sperm whale, was compared to a traffic density raster, both with a spatial resolution of 0.1 x 0.1 degrees. Specifically, SSIM, along with Structural Information (SIM), Structural Invariance (SIV), and Structural Pixel-to-Pixel similarity (SIP), were calculated to assess both global and pixel-level similarities between the two raster datasets. These metrics enabled the evaluation of both the overall and local structural relationships between the sperm whale's movement and maritime traffic, providing insights into potential spatial overlap.

Finally, to facilitate the dynamic visualisation of sperm whale movements within the context of maritime traffic density, different animations were generated (available upon request). This animation integrates the regularised positional data derived from the SSM with the corresponding traffic density map. By combining these datasets in a dynamic way, the animation effectively illustrates the spatiotemporal overlap between the whale's movements and areas of high maritime traffic, enabling a more intuitive understanding of potential interaction hotspots and collision risk dynamics.

3.2.1.4 Body length estimation

For photogrammetry purposes, still images of sperm whales encountered were extracted from continuous video recordings obtained through the DJI Mavic 3 drone and associated to the correct location (latitude and longitude), time of day and altitude information, obtained from the LidarBox, using custom scripts for the software for statistical computing R. Photogrammetric measurements were obtained through a custom macro developed for the software Fiji[9] and then exported to a suitable file format for further analyses in the R software, following the protocol developed by Glarou et al. (2022). Photogrammetric data were used primarily to obtain sperm whales body length information and, whenever possible, a body mass index for measured individuals, through the calculation of body volumes. Total body lengths obtained photogrammetrically were then compared, whenever possible, to acoustically derived measurements obtained through the extraction of Inter Pulse Interval (IPI) information from sperm whale click trains. IPI values were extracted using the software Pamguard, following the approach of Growcott et al. (2011) and

[9] https://imagej.net/software/fiji/

Miller et al. (2013) and acoustic total body length measurements were obtained following the approach of Growcott et al. (2011).

3.2.2 Cuvier's beaked whale

For the tracked Cuvier's beaked whale, it was not possible to apply the same modelling frameworks due to paucity of data. The animal was tracked for 14 days, but only 50 location messages were received from the Wildlife Computer portal. Due to unknown transmission issues, the tag did not send data to the satellite for the first 72 hours of deployment and the animal was only detected with the CLS Goniometer. Hence, all the results and analyses we present in this report focus on the sperm whale social groups encountered and the single tracked individual.

4. Results

Between the 15th and 31st of July 2024, the Blue Panda sailed along the northern section of the Hellenic Trench, between the islands of Corfu and Zakynthos. Overall, 965 nautical miles were travelled in 15 days. Table 1 presents a summary overview of the effort carried out daily while Figure 4 presents a summary of the effort carried out daily by effort type.

Table 1. Summary of effort by day.

Date	Start Time	End Time	Effort Duration (hh:mm:ss)	Total Distance (km)	Total Distance (nm)
16/07/2024	03:46:07	17:58:15	14:12:08	183.89	99.29
17/07/2024	03:42:11	16:39:09	12:56:58	155.68	84.06
18/07/2024	03:35:37	16:32:30	12:56:53	110.74	59.80
19/07/2024	03:37:29	15:16:58	11:39:29	94.84	51.21
20/07/2024	03:44:38	23:59:52	20:15:14	139.27	75.20
21/07/2024	00:00:02	08:14:24	08:14:22	56.61	30.57
22/07/2024	07:04:50	07:11:27	00:06:37	0.0	0.0
23/07/2024	03:33:36	22:04:06	18:30:30	196.32	106.00
24/07/2024	03:33:07	14:25:09	10:52:02	128.86	69.58
25/07/2024	03:36:37	13:32:42	09:56:05	74.71	40.34
26/07/2024	03:40:08	07:34:03	03:53:55	94.36	50.95
27/07/2024	03:36:52	23:59:57	20:23:05	183.10	98.86
28/07/2024	00:00:07	13:23:35	13:23:28	149.77	80.87

29/07/2024	03:34:46	12:11:35	08:36:49	99.89	53.94
30/07/2024	03:33:06	16:15:02	12:41:56	120.48	65.06
Total			178:39:31	1788.53	965.73

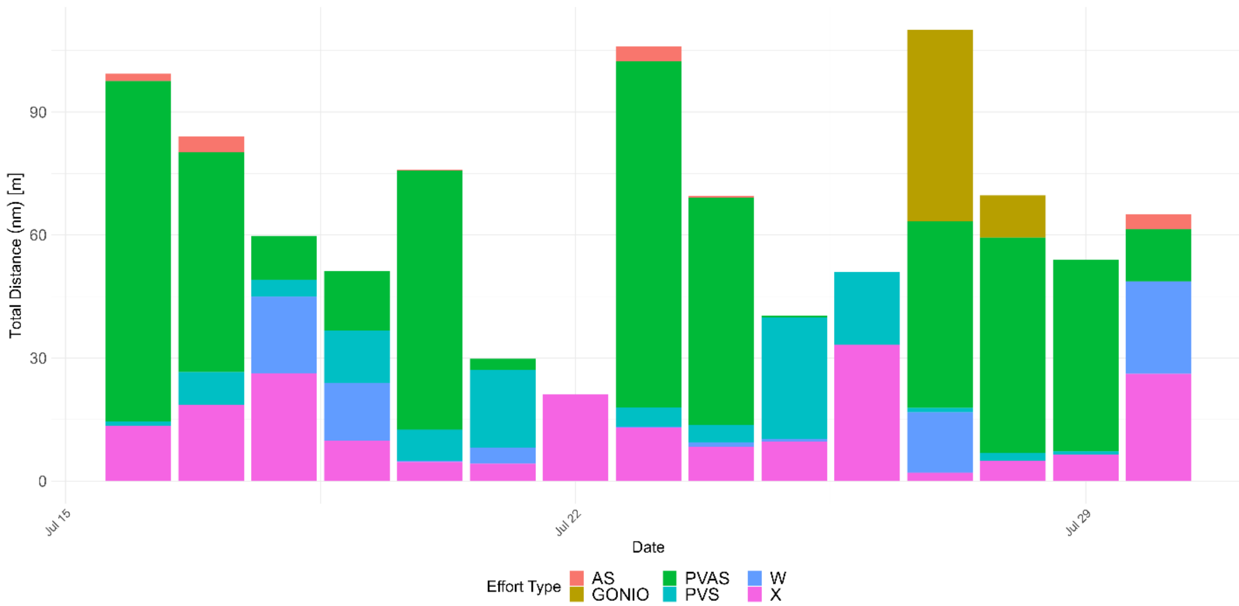
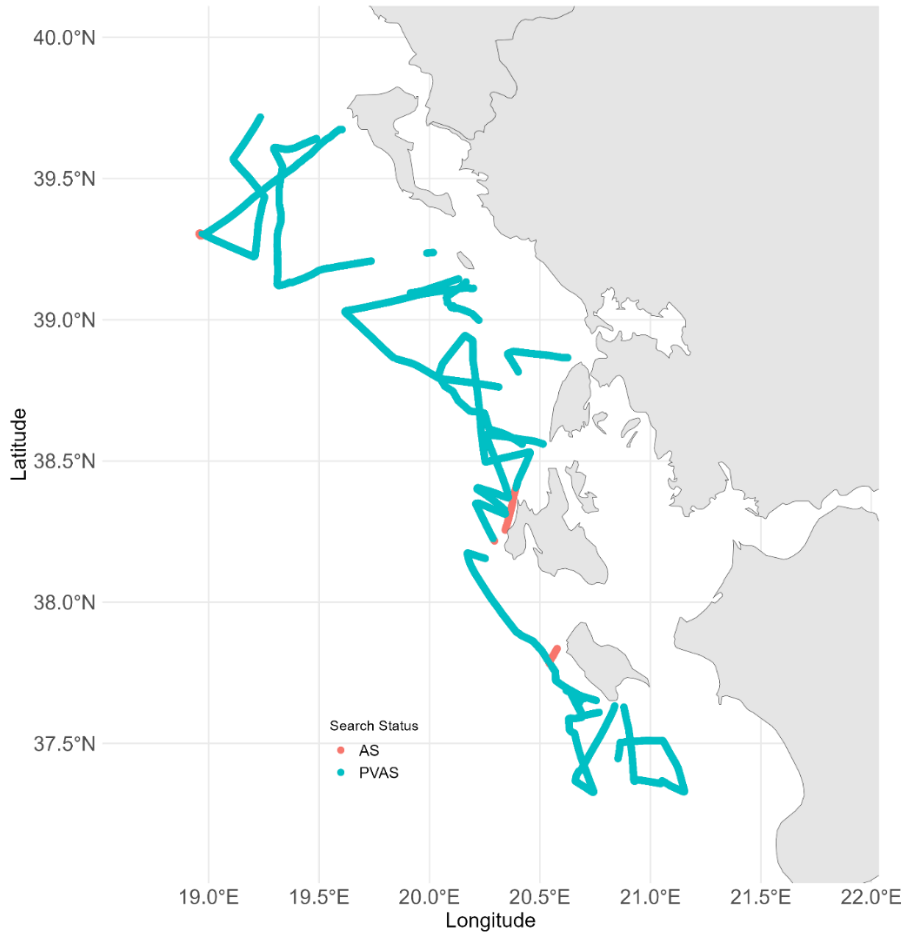


Figure 4. Total distance travelled daily in the different effort types: AS = Acoustic Searching, PVAS = Positive Visual and Acoustic Searching, W = time spent with cetaceans, GONIO = follow up of tagged animals using the CLS Goniometer, PVA = positive Visual Searching, X = Off Effort.

Whenever possible, depending on the overall sea and weather conditions as well as location, a concomitant visual and acoustic monitoring took place. During low light hours, acoustic monitoring alone was used to detect and eventually track cetaceans in real-time. For the acoustic component of the overall survey, continuous monitoring of cetaceans' vocalisations was carried out by an experienced operator. Figure 5 shows the visual and acoustic or acoustic-only sections of the monitored transects. Overall, 12 sightings of 4 different species were recorded over the study period, with only one case of unidentified cetaceans due to the animals remaining always far away from the research platform. However, given the location, general morphology and swimming behaviour the species was believed to be the rough-toothed dolphin (*Steno bredanensis*).



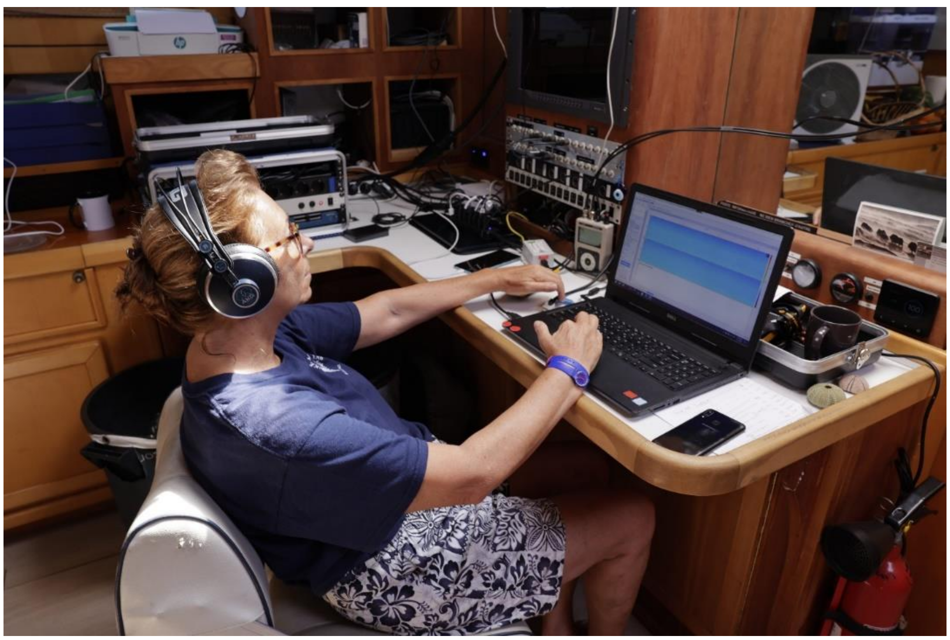


Figure 5. (Top) Visual and acoustic (PVAS) and acoustic-only (AS) sections of the transects. (Bottom) The listening station on board the Blue Panda sailing vessel.

The locations of the sightings are shown in Figure 6, alongside the monitored tracks; a summary of the sightings' information is provided in Table 2. Except for one single occurrence of bottlenose dolphins, most sightings were recorded at depth ranging between about 670 and 1,700 metres and at a distance from the closest coast between 3.5 and 23 km (Table 4).

4.1 Photo-identification

Photo-identification[10] (photo-ID) played a crucial role in the expedition's data collection efforts, particularly during encounters with sperm and Cuvier's beaked whales. Dedicated shifts for photo-ID were conducted using a combination of cameras (Canon R5 and Canon EOS 5D) and drones (DJI Mavic 3) to capture high-resolution images of individuals, focusing on distinctive features such as fluke (when possible), dorsal fin markings and specific coloration along the body of the animals. This methodology was successfully applied on July 18 and 19 during the observation of sperm whale social units, when video and still images were collected to document animal interactions, including between mother-calf pairs, and – as much as possible, due the high physical overlap between individuals – single animals. Additionally, photo-ID efforts were emphasized during tagging operations on July 27 and 30 to photo-identify target individuals. Drones were used to apply photogrammetry first and then to follow the whales while sub-surface to help and direct close approaches to deploy satellite transmitters. Finally, GoPro cameras were used to assess potential short-term behavioural responses to tag deployment.

Table 2. Summary detail of recorded cetacean sightings over the study period. A=Adults, J=Juveniles, C=Calves and N=Newborn.

Date	Species	Start Time	End Time	Sighting Duration (hh:mm:ss)	Group size	A	J	C	N
2024-07-18	Sperm whale	07:13:14	12:59:14	05:46:00	11	8	0	3	0
2024-07-19	Cuvier's beaked whale	06:48:27	08:17:00	01:28:33	4	4	0	0	0
2024-07-19	Unknown	08:50:46	09:33:27	00:42:41	4	4	0	0	0
2024-07-19	Striped dolphin	10:11:14	10:12:20	00:01:06	No Estimate	NA	NA	NA	NA
2024-07-19	Sperm whale	09:33:07	13:09:09	03:36:02	12	9	0	3	0
2024-07-20	Striped dolphin	12:48:34	12:55:18	00:06:44	10	10	0	0	0
2024-07-19	Striped dolphin	08:45:46	08:48:16	00:02:30	15	15	0	0	0

[10] Raw images are available upon request.

2024-07-23	Striped dolphin	17:50:56	17:52:11	00:01:15	No Estimate	NA	NA	NA	NA
2024-07-25	Bottlenose dolphin	12:34:50	12:42:33	00:07:43	2	2	0	0	0
2024-07-27	Cuvier's beaked whale	12:00:05	15:15:01	03:14:56	3	3	0	0	0
2024-07-27	Sperm whale	15:15:01	18:26:55	03:11:54	1	1	0	0	0
2024-07-30	Sperm whale	06:17:47	12:10:46	05:52:59	1	1	0	0	0

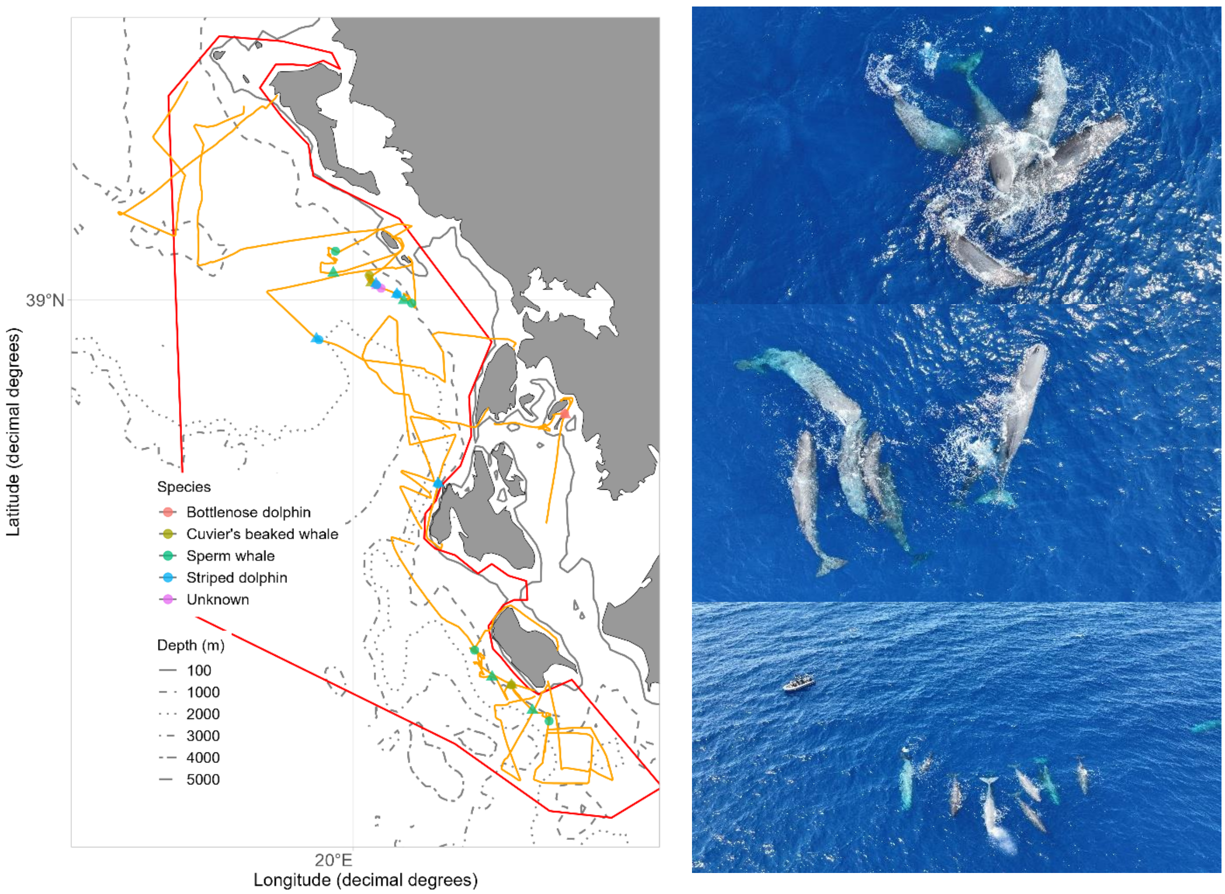


Figure 6. (Left) Survey effort (in orange) across the study area (in red) and sightings recorded over the study period. Circles and triangles represent the start and end of sighting position for each observed species. (Right) Sperm whale unit observed on the 19th of July southwest of the Islands of Paxos and Paxidi.

4.2 Sperm whales' acoustic recordings

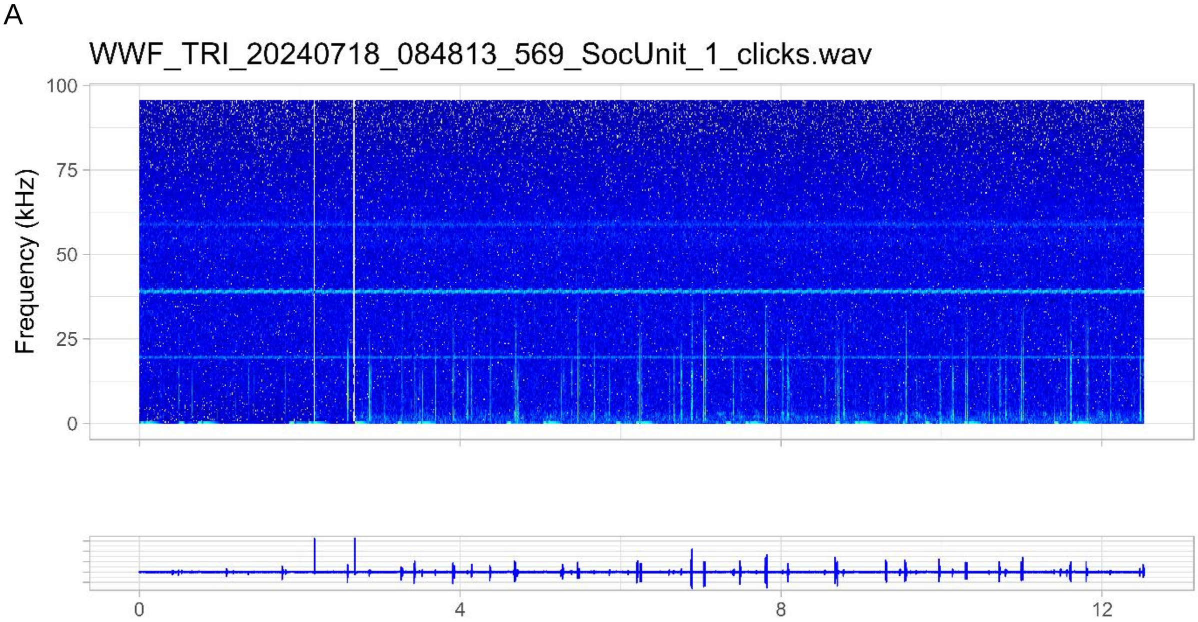
Overall, 4 sightings of sperm whales were recorded during the survey (Table 2). During all sightings, whenever possible, continuous recordings of the whales' vocalisations were collected. A summary table of the recordings made during these sightings is provided in Table 3.

Table 3. Summary details of the acoustic recordings made during the 4 sightings of sperm whales. RC = regular clicks, CR = Creaks, CD = Coda, CH = Chirrups' and SQ = Squeals.

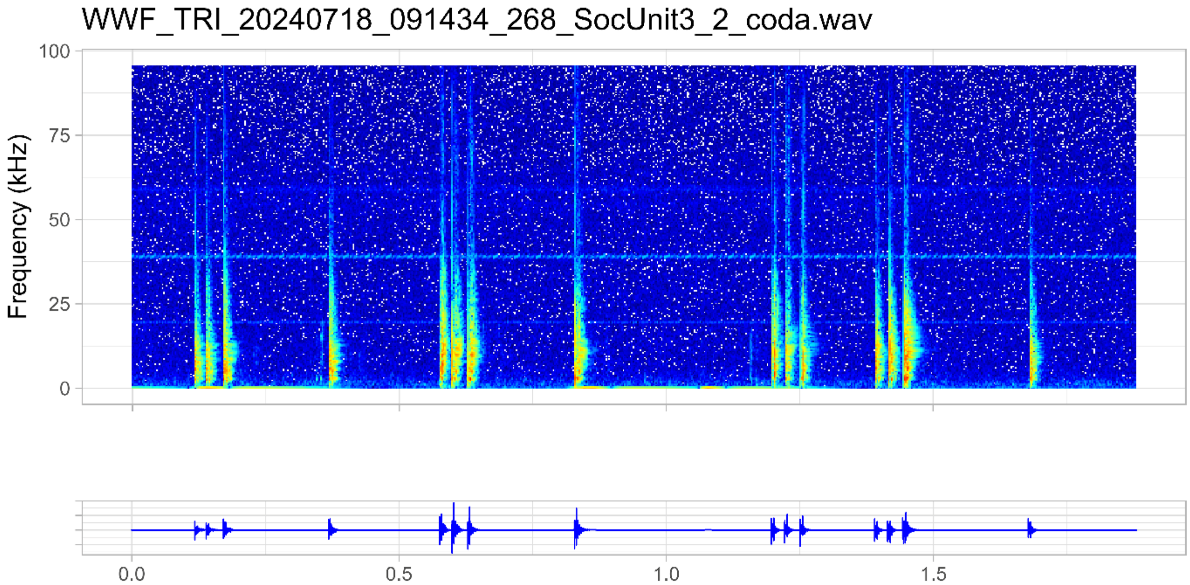
Date	Group Size	No. Recordings	Total size (Gb)	Total duration (min)	Recorded sounds
18/07/2024	11	18	9.98	03:29:20	RC, CR, CD, CH, SQ
19/07/2024	12	11	5.82	02:15:47	RC, CR, CD, CH, SQ
27/07/2024	1	16	6.59	02:21:36	RC, CR
30/07/2024	1	24	11	03:59:55	RC, CR

During the sightings of single adult males only regular clicks and sporadic creaks, associated with the search for prey, were detected indicating limited feeding activity. The vocal repertoire observed during the sightings of the two social units, as expected, was more complex and richer including regular clicks and limited creaks, as well as sound normally produced by socialising groups of sperm whales such as 3+1 coda patterns, chirrups and squeals. The latter are a relatively poor known vocalisations of sperm whales produced during social bouts that, although are perceived as tonal and appear spectrally as narrowband frequency-modulated structures with harmonics, they actually consist of pulses produced at high repetition rates exceeding 1,600 clicks/s. The fact that squeals were recorded only during encounters with sperm whales engaging in social activities is consistent with the hypothesis of them having a communicative social function. Figure 7 shows spectrograms of some of these vocalisations.

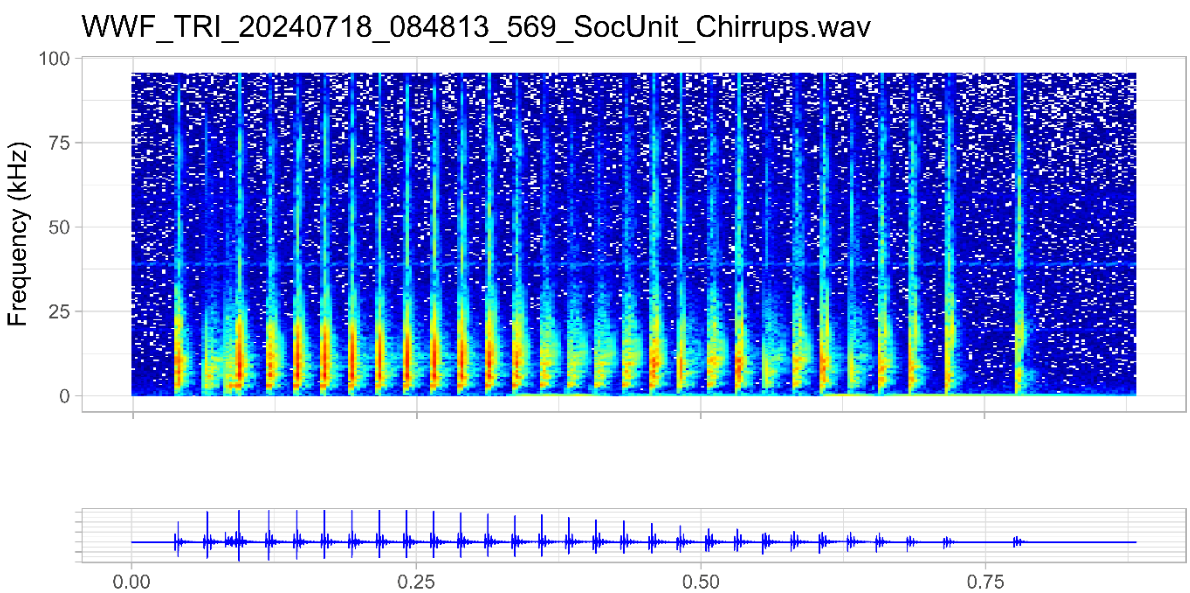
A



B


WWF_TRI_20240718_091434_268_SocUnit3_2_coda.wav
Frequency (kHz)
100
75
50
25
0
0.0
0.5
1.0
1.5

C


WWF_TRI_20240718_084813_569_SocUnit_Chirrups.wav
Frequency (kHz)
100
75
50
25
0
0.00
0.25
0.50
0.75

D

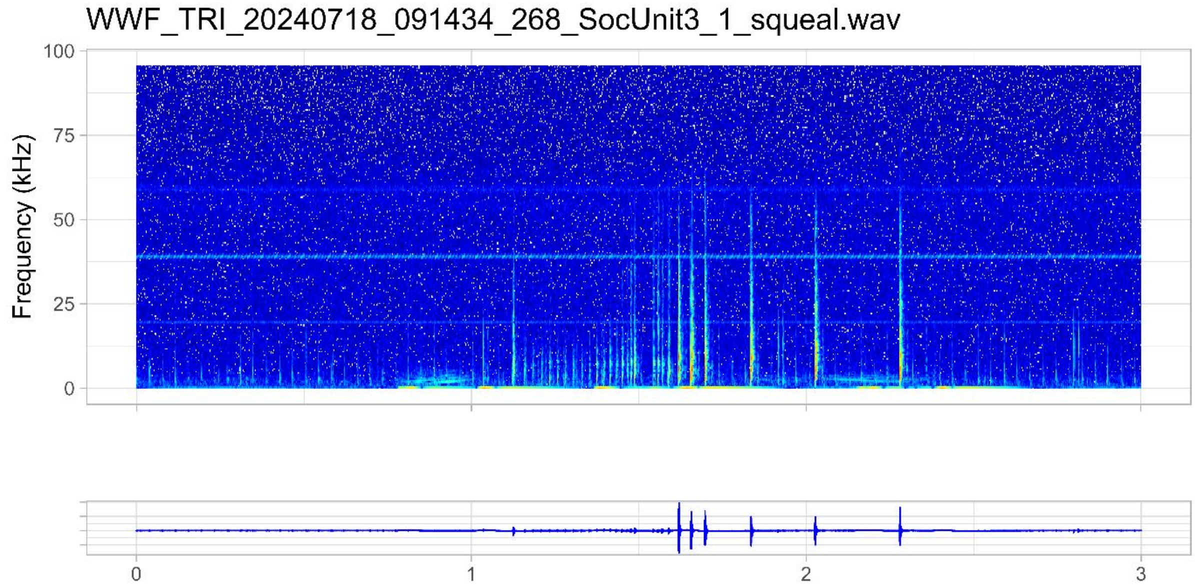


Figure 7. Spectrograms of sperm whales' vocalisations. Below each spectrogram the signal waveform is portrayed, showing the amplitude of the sounds relative to the background noise. For graphical purposes, sounds were denoised and a high-pass filter was applied. Visible continuous horizontal line at 38 kHz is an unidentified electrical interference. A) Multiple sperm whale regular clicks recorded during the first observed social unit on the 18th of July; regular clicks are visible as broadband vertical lines produced at 0.5-2 seconds intervals. B) Quick series of sperm whales (3+1) coda pattern exchange between two sperm whales; these are believed to represent the "dialect" of the Mediterranean sub-population of sperm whale. No other coda types were detected. C) Chirrups', also known as coda-creaks, are brief rapid trills of clicks that are generally heard from whales forming large and tight groups at the surface and are believed to have a social function. D) Regular clicks from three different sperm whales at different distances from the hydrophone are visible as vertical lines. At about second 1 and second 2 lower frequency tonal-like squeals are visible. These are sounds produced in social contexts that although appear and are perceived as continuous sounds with a modulated structure, are made up of sequences of click-like pulses produced at a very high repetition rate.

Table 4. Summary statistics of physiographic variable associated to cetacean sightings. Depth values are expressed in meters, slope and aspect, TPI (Terrain Ruggedness Index), TRI (Topographic Position Index) and Roughness in degrees, and the distance to the closest coast and 200, 1000 and 2000 meters contours in km.

Date	Species	Depth	Slope	Aspect	TPI	TRI	Roughness	Distance to coast	Distance to 200	Distance to 1000	Distance to 2000
2024-07-18	Sperm whale	1363	2.54	224.26	2.25	13.50	50.00	19.01	14.25	7.64	33.03
2024-07-19	Cuvier's beaked whale	1278	3.58	280.75	-5.25	16.50	64.00	13.43	10.70	3.47	24.72
2024-07-19	Unknown	1333	4.76	223.42	-4.12	26.38	98.00	16.03	10.66	4.68	21.98
2024-07-19	Striped dolphin	1154	4.66	269.43	-10.00	20.50	77.00	18.16	8.94	2.68	22.28
2024-07-19	Sperm whale	992	4.06	211.87	-9.62	26.62	86.00	22.90	8.44	0.77	20.66
2024-07-20	Striped dolphin	1708	4.01	59.26	-0.38	20.38	76.00	44.99	41.40	34.96	7.42
2024-07-19	Striped dolphin	1327	4.30	165.86	13.62	28.12	79.00	15.26	10.72	4.29	22.48
2024-07-23	Striped dolphin	1330	26.17	300.27	-42.00	144.50	539.00	3.53	3.15	0.97	1.31
2024-07-25	Bottlenose dolphin	17	4.03	44.16	14.20	34.30	100.42	1.58	11.85	41.18	47.43
2024-07-27	Cuvier's beaked whale	672	12.58	203.93	4.12	77.38	256.00	6.49	4.55	1.99	9.24
2024-07-27	Sperm whale	1200	7.10	179.22	-4.25	44.00	131.00	12.72	10.54	1.41	6.01
2024-07-30	Sperm whale	1286	7.53	262.21	0.62	36.88	111.00	9.33	8.42	2.37	7.47

Table 5. Summary of satellite tag deployment data and movement descriptors for the sperm whale equipped with satellite transmitter. Start location and End location are the longitude and Latitude of first and last transmission in decimal degrees, Deployment duration is expressed in days and the Area of the convex hull represent the extent of the minimum theoretical area across which the sperm whale moved. All linear distances are provided in km while area measurements are in squared km.

Whale ID	Tag deployment start	Tag deployment end	Start location	End location	Deployment duration	Total travelled distance	Total linear displacement	Average daily travelled distance	Area of the convex hull
PTT265491	27/07/2024 18:00	21/09/2024 10:00	20.8349 37.6039	26.16561 37.43835	55.6	1951.3	470.4	35.1	78502.2

Simone Panigada, Viola Panigada, Margherita Zanardelli & Nino Pierantonio. Strengthening cetacean research and conservation in the Hellenic Trench with the Blue Panda Vessel (2024). Final report. March 2025. 38 pp.

4.3 Telemetry data and behaviour

One adult sperm whale and one adult Cuvier's beaked whale were equipped with satellite transmitters off the coast of Kefalonia. The tag deployed on the Cuvier's beaked whale was retained for a short time and did not provide robust data to be presented and discussed. Therefore, the following sections present data concerning only the tagged single adult sperm whale.

On July 27th, 2024, one solitary adult male sperm whale was equipped with a satellite transmitter (Wildlife Computers Spot-365 LIMPET) southwest of Kefalonia, in the northern portion of the Hellenic Trench IMMA. A total of 1,725 location messages were received, providing 56 days of movement data. The whale spent 15 days southwest of Kefalonia and Zakynthos islands, performing short, localised movements before heading south along the Hellenic Trench. After a few days spent along the Peloponnese, it moved into the southern Aegean Sea, crossing the Cyclades Islands waters and progressing towards the Dodecanese region, where it remained for an additional 23 days, until the end of transmissions.

A summary of satellite tag deployment data and movement descriptors is presented in Table 5, while Figure 8 shows the movements of the tagged whales.

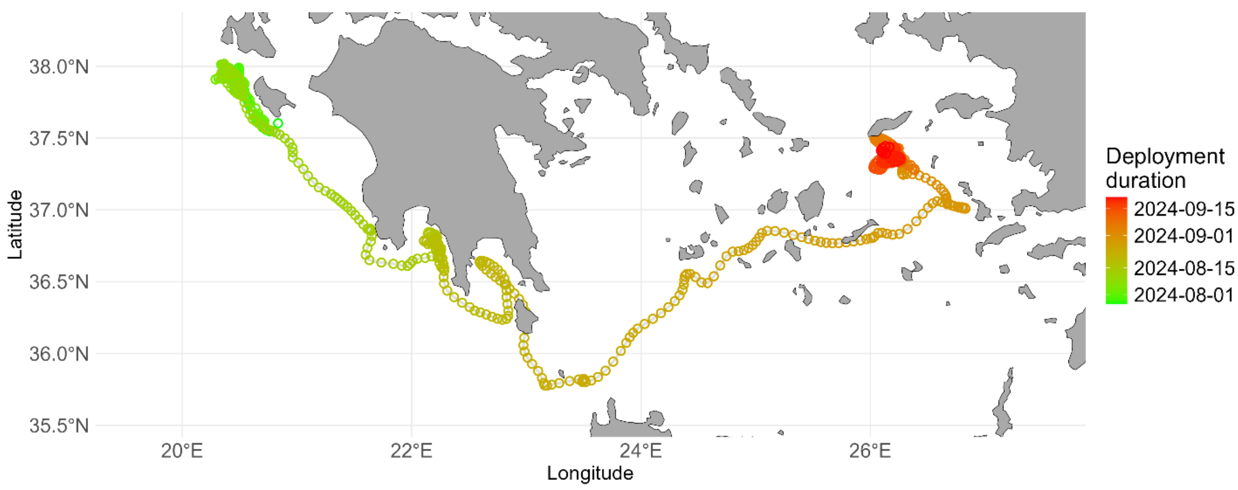


Figure 8. Filtered and regularised tracks of the tagged sperm whale. The whale's trajectory is colour-coded by the elapsed deployment time with bright green indicating the start of the transmissions and red the end.

Move persistence models quantify an animal's propensity to maintain directional consistency over time. These models estimate the probability that an animal will continue a trajectory similar to its recent path, as opposed to exhibiting abrupt directional shifts. Results from the move persistence model indicate that the tagged sperm whale displayed reduced movement persistence within the Hellenic Trench during the initial tracking period and in the Dodecanese region in the days preceding tag detachment. Higher movement persistence characterised transit between these locations (Figure 9). Reduced movement persistence is typically associated with foraging behaviour, while increased persistence is linked to directed movement. Consequently, it can be inferred that the sperm whale spent a substantial period foraging in the northern Hellenic Trench before moving to the southwestern Aegean Sea, exhibiting minimal stopovers *en-route* to the Dodecanese area. Although the Hellenic Trench is a recognised sperm whale foraging ground, the observed low movement persistence in the Dodecanese region suggests that sperm whales may utilise other, previously unrecorded, foraging areas. Finally, given that the whale was tagged in an area where females were concurrently observed, localised movements in this specific area may reflect behaviours other than feeding, such as social interactions. In this context, the observed displacement of the tagged male sperm whale could suggest that the animal may have been following female groups, but this interpretation is currently speculative. A more comprehensive understanding of sperm whale migration patterns, including the motivations behind them (e.g., foraging, mating), necessitates further data collection, including further data collection.

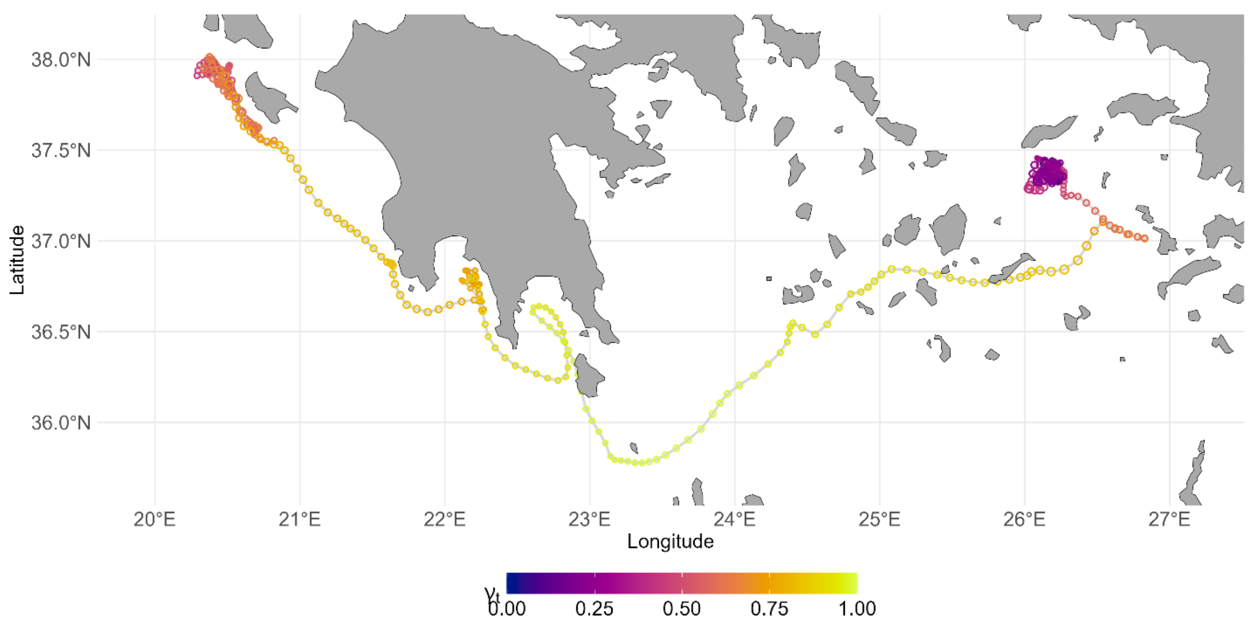


Figure 9. Maps of SSM-filtered sperm whale tracks south-east of Zakynthos. Each location is coloured according to its associated move persistence (γ) estimated from the move persistence model (MPM). Locations of foraging/feeding with a move persistence <0.8 are indicated by darker colours while travelling behaviour associated with higher move persistence >0.8 in lighter colours.

4.4 Realised habitat and ranges estimation

The tagged sperm whale moved across an area encompassing 6 degrees of longitude and 3 degrees of latitude. Most of the realised habitat, areas with the highest probability of occurrence, were highlighted in the waters south and south-west of the island of Kefalonia, South of the Peloponnese and in the Dodecanese region (Figure 10). Core ranges evaluated from the realised habitat map show how the tagged whale showed relatively high residency south-west of the island of Kefalonia, South of the Peloponnese, and in the Dodecanese region (Figure 11). Most importantly, the location of core ranges highlights how these only marginally overlap with identified IMMAs for sperm whales in Greek waters. The Hellenic Trench IMMA, in fact, only overlaps with the sperm whale core ranges in the northernmost section of the Hellenic Trench, south-west of the island of Kefalonia, South of the Peloponnese and does not include a potential important corridor of movement across the southern Aegean Sea and critical residency areas in the Dodecanese region.

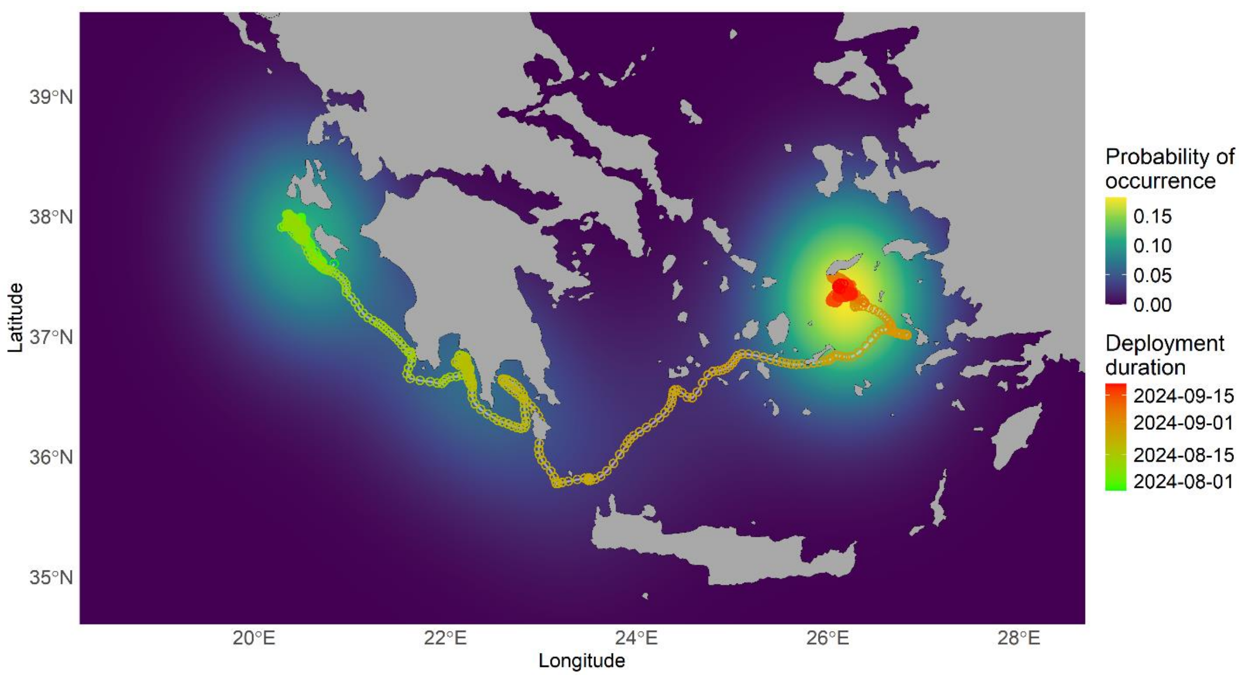


Figure 10. Sperm whale realised habitat with overlapped the regularised trajectory colour-coded by the elapsed deployment time with bright green indicating the start of the transmissions and red the end. Areas of high probability of occurrence are highlighted in the waters south and south-west of the island of Kefalonia, South of the Peloponnese and in the Dodecanese region.

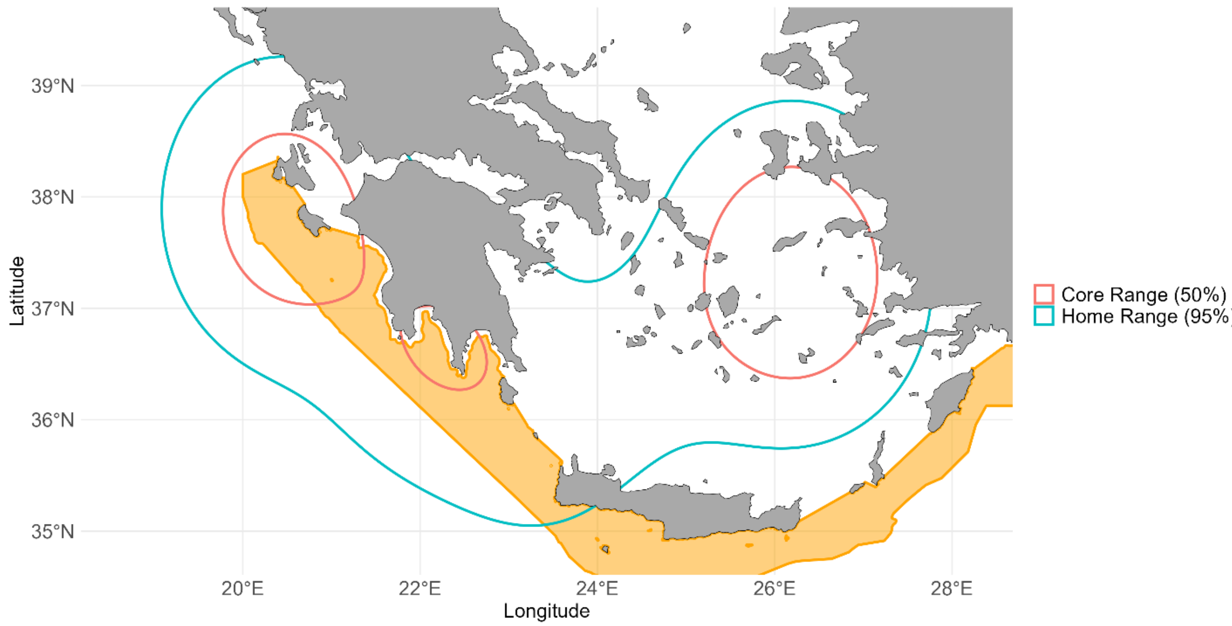


Figure 11. Core and home ranges for the tagged whale extracted from the realised habitat map. In orange the Hellenic Trench IMMA which only partially overlaps with the higher residency whale areas (core range).

4.5 Interaction with maritime traffic and collision risk

The assessed risk of vessel-whale collisions (Figure 12) within the area visited by the tagged sperm whale confirms high susceptibility along the central and northernmost sections of the Hellenic Trench. However, findings also indicate that collision risk is particularly elevated in the southeastern Aegean Sea. Collision risk was notably high in coastal waters of the aforementioned area, particularly around the islands of Kefalonia and Zakynthos, as well as in the Inner Ionian Sea, across the Cyclades Archipelago, and within the Dodecanese. This is likely due to the significant contribution of seasonal recreational boating and passenger commercial vessels. In contrast, along the Hellenic Trench, the highest risk of collision was observed in the deepest offshore sections, where commercial shipping plays a more dominant role.

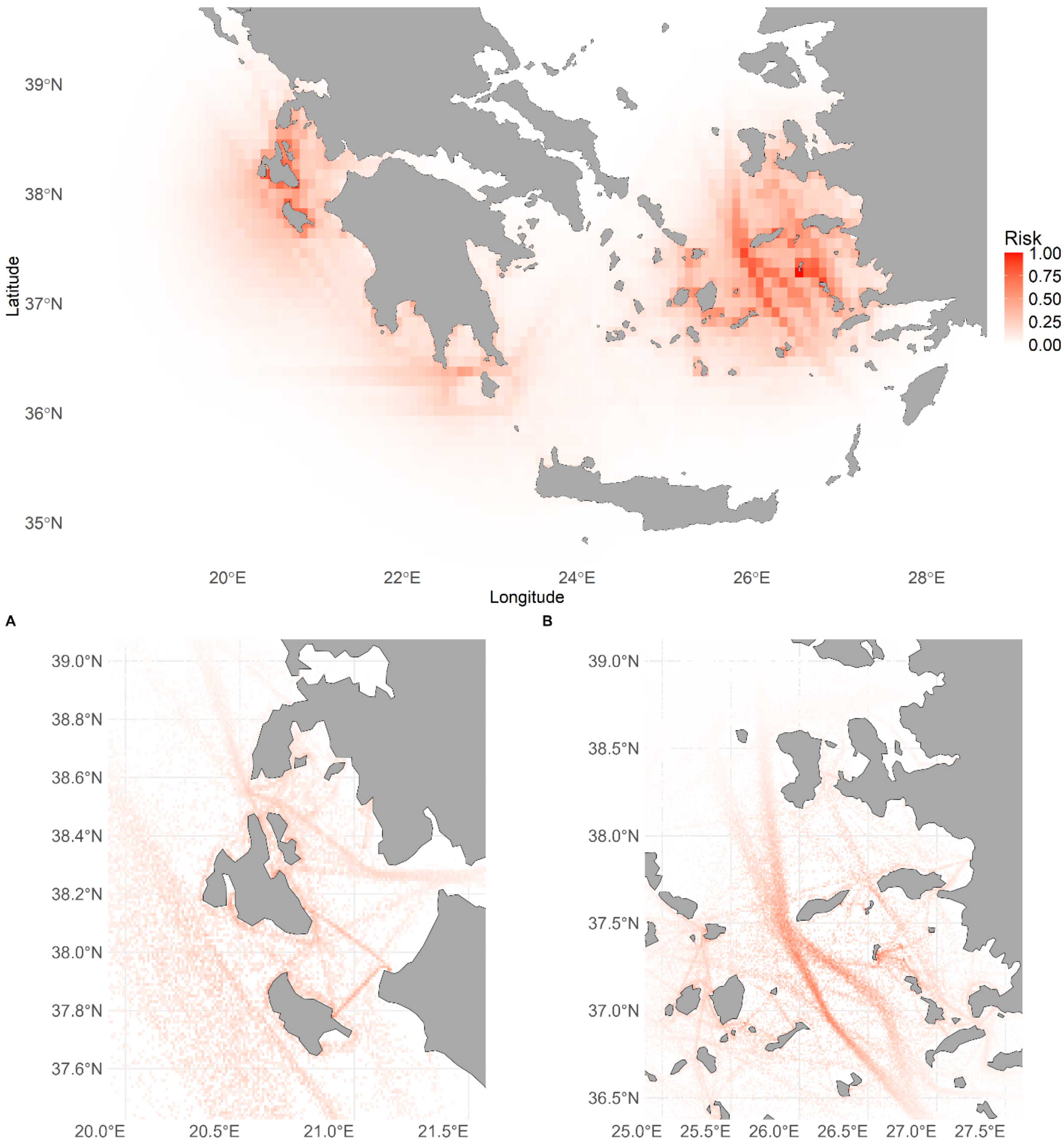


Figure 12. (Top panel) Normalised collision risk for the tagged sperm whale on a 10kmx10km grid, highlighting areas of significant spatial overlap between whale locations and vessel traffic, indicative of an elevated risk of fatal ship strikes. Panels A and B show the collision risk on a 1kmx1km grid for the Ionian Islands and the Dodecanese Region, respectively.

The global SSIM analysis indicated a marked spatial dissimilarity between the tracked distribution of the sperm whale and the maritime traffic patterns within the study area. The SSIM value of 4e-05 suggested an almost negligible structural similarity, implying minimal spatial correlation between the movement patterns of the sperm whale and maritime traffic. This finding was further supported by the Structural Information (SIM) value of 0.0403 and the Structural Invariance (SIV) value of 0.00602, both of which indicated limited overlap in structural information and a lack of invariant patterns across the two distributions. The Structural Pixel-to-Pixel similarity (SIP) value, while moderate at 0.34966, suggested some localised overlap in specific regions. While these results generally imply that, with the exception of small areas of overlap, the sperm whale's tracked movements and maritime traffic follow largely independent spatial patterns, the analysis of local patterns aligns with the outcomes of the collision risk assessments. These analyses highlighted relatively high levels of overlap in the southeastern Aegean Sea, particularly around the islands of Kefalonia and Zakynthos, as well as in the Inner Ionian Sea, across the Cyclades Archipelago and within the Dodecanese (Figure 13).

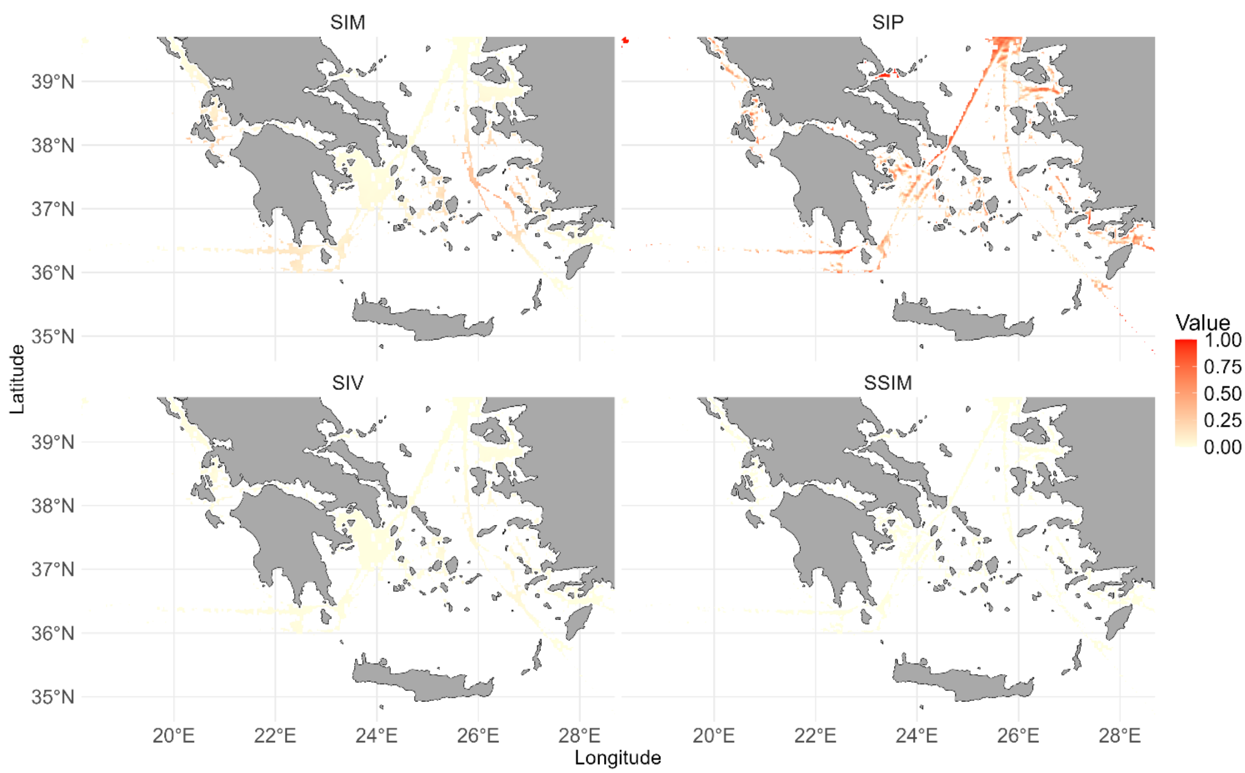


Figure 13. Spatial overlap between tracked sperm whale habitat and maritime traffic in Greece, based on SSIM analyses. The four similarity indices (SSIM, SIM, SIV, SIP) indicate varying degrees of spatial correlation, with values from 0 (no similarity) to 1 (high similarity).

4.6 Sperm whale body length estimation

Photogrammetric body-length estimates were derived for three of the four sightings of sperm whales recorded during the survey (Pm001–Pm003). For the fourth sighting, however, due to a malfunction of the drone, the recorded data and still images were not viable.

The process of obtaining robust acoustic body-length estimates from recordings of sperm whale groups in close formation presents significant challenges. In particular, distinguishing the origin of sound sources becomes problematic when clicks produced by different sperm whales reach the hydrophone at similar angles and times. This issue is especially prevalent in family units or tightly clustered groups, where the acoustic signals from individual whales overlap, making it difficult to attribute each click to a specific individual. Consequently, reliable acoustic body-length estimates were only successfully obtained for the two sightings involving single sperm whales (Pm003 and Pm004).

A total of 114 images extracted from drone video footages were used for body-length estimation across three sightings. Overall, using the length categories as defined in Glarou et al. (2022), 3 animals were classified as calves (BL = 3.37–7.29 m), 2 as juveniles (BL = 5.78–8.26 m), one as adult male and (BL = 7.54–12.67 m) and 6 as adult females (BL = 7.56–9.98 m). Twelve animals, observed during the first and second recorded sightings, could not be measured due to the lack of clear images with the whole body visible. Acoustic estimates for the two sperm whales observed alone (Pm003 and Pm004) provided body length estimates of 12.46 (CV = 12.08-12.84 meters) and 12.57 metres (CV = 12.11-13.03), respectively.

5. Conclusions

This cruise has confirmed that the Hellenic Trench, stretching from the northernmost islands of Corfu and Kefalonia, the western and southern Peloponnese to the southwestern coast of Crete, and further east, up to the Dodecanese and Turkish coasts, is a critical habitat for several cetacean species, including the endangered Mediterranean sperm whale and the vulnerable Cuvier's beaked whale. These deep-diving cetaceans rely on the deep waters of the Trench for foraging, social interactions, and breeding. Research has shown that solitary males, loose male aggregations, and long-term resident social units — including females with calves and newborns — are frequently observed in this region. The area is one of the few known breeding and feeding grounds for sperm whales in the eastern Mediterranean, making its protection vital for the survival of this threatened sub-population.

Despite its ecological importance, the Hellenic Trench faces numerous threats from human activities. Intense maritime traffic, particularly from large cargo ships and ferries, increases the risk of fatal vessel strikes — one of the leading causes of death for Mediterranean sperm whales. Additionally, underwater noise pollution from seismic surveys, naval exercises, and industrial activities disrupts their communication, navigation, and foraging behaviour. Further concerns arise from pollution, including plastic debris and chemical contaminants, which can accumulate in the whales' tissues and affect their health. As the region remains under pressure from expanding industrial and commercial activities, urgent measures are required to mitigate these threats and safeguard the sub-population.

Despite being based on preliminary data from a single individual, satellite tagging results indicate that the tracked whale crossed areas historically considered less favourable for the species and exhibited prolonged residency in the Dodecanese region, where limited ecological information is available. The Aegean Sea hosts one of the most intense shipping lanes across the Mediterranean, connecting the Black Sea with the rest of the Mediterranean Sea. In addition, particularly during the summer months, the area is crossed by very high numbers of recreational and passenger boating, as well as cruise ships, with increased risk of both lethal and sub-lethal collisions.

The unexpected movements of the tagged sperm whale into the Aegean Sea highlight gaps in our knowledge of the species' habitat use and distribution in Greek waters. While the Hellenic Trench is recognised as a key habitat, the whale's prolonged stay south of Ikaria and west of Patmos suggests that other areas, previously overlooked, may also be important for feeding or resting. Little is known about sperm whales in the Aegean, with only a handful of recorded sightings and strandings, most of which come from anecdotal sources. Apart from the Cretan Sea, sperm whales are considered rare visitors to the deep waters of the Aegean, including the North Aegean Trough, the Myrtoon Sea, and the Icarian Sea. Recent acoustic monitoring in the North Aegean Trough did not detect sperm whales, and the ACCOBAMS Survey Initiative also found no evidence of them in the Aegean using aerial and vessel-based surveys. Limited photo-identification data suggest that sperm whales seen in the Aegean were previously recorded in the Hellenic Trench, indicating a possible connection between the two areas, though more research is needed to confirm this.

Given these findings, research conducted in 2024 highlights the need to expand connectivity research efforts, such as through satellite tagging, alongside existing monitoring methods. More effort would help build a clearer picture of sperm whale movements and identify additional areas requiring protection.

Without enough tracking data, conservation efforts risk overlooking key habitats and failing to protect whales from threats like ship strikes and noise pollution.

Furthermore, it is a fact that Greece is expanding hydrocarbon exploration, with new licenses planned for the foreseeable future[11,12,13]. These prospective oil and gas exploration areas exhibit significant spatial overlap with critical habitat for Mediterranean sperm whales (Figure 14), particularly within the Hellenic Trench. Considering that seismic surveys and drilling activities associated with oil and gas prospection are demonstrably detrimental to marine mammals due to acoustic disturbance and potential habitat degradation, this overlap poses a substantial risk to the survival of this vulnerable population. Recorded sperm whale movement patterns and realised habitat, as derived from satellite telemetry data, indicate that tagged individuals frequently traverse areas currently licensed to the oil and gas industry, which also coincide with high-volume maritime traffic corridors. This confluence of anthropogenic stressors presents a further source of concern for the long-term persistence of the species. Critically, both the proposed Hellenic Trench IMMA and previously identified areas to be avoided as delineated by Frantzis et al. (2019) also overlap with zones licensed for hydrocarbon exploration and exploitation (Figure 14).

[11] https://greekcitytimes.com/2022/04/13/six-areas-greeces-gas-exploration/
[12] https://www.tovima.com/finance/call-to-tender-announced-by-greek-govt-for-2-energy-blocs/
[13] https://savegreekseas.com/en/petition/

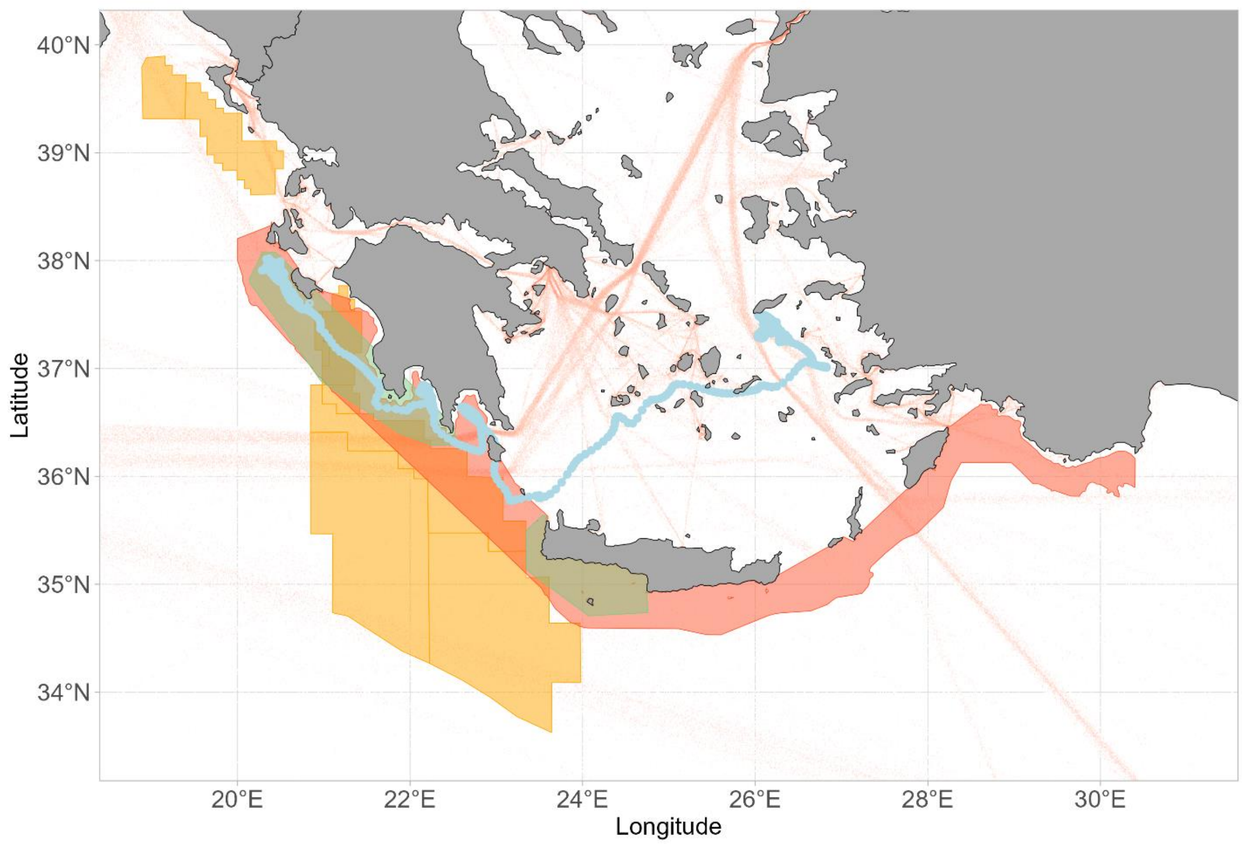


Figure 14. Spatial overlap between the proposed Hellenic Trench IMMA (in red) and the areas to be avoided (in green) by commercial shipping as proposed by Frantzis and colleagues in 2019 with areas where ongoing and future seismic prospections (in orange) are planned in the Greek seas. The movements of the tagged whale are shown in light blue also overlapped do the density of maritime traffic for the tag deployment duration.

Expanding our current knowledge of medium-scale movements would also support adaptive management by providing real-time data on sperm whale distribution. If multiple whales show similar movement patterns towards the Aegean or other lesser-known areas, it would strengthen the case for reviewing existing IMMAs and proposing new ones where needed. Long-term tracking data can feed into and help refine spatial planning initiatives, such as the designation of new marine parks and MPAs, and/or the regulation of activities within existing MPAs, adjusting maritime traffic routes or establishing seasonal protection zones, as currently ongoing in the Hellenic Trench. Given the ongoing threats to this endangered population, investing in advanced monitoring tools like satellite tracking is essential to develop effective conservation policies and ensure the long-term survival of sperm whales in Greece and the wider Mediterranean.

6. Acknowledgements

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All research activities, including visual material collection, were conducted with the relevant permits obtained from the Marine Research Licensing Committee (MRLC), the Ministry of Environment and Energy, with the assent of the Natural Environment & Climate Change Agency (NECCA).

7. Relevant literature

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