Survey of the Status of Important Fauna Species in the Kyparissiakos Lease Area

Final Report

October 2025

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Contents

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Abbreviations and scientific names

Calonectris diomedea	Scopoli's Shearwater
Caretta caretta	Loggerhead Turtle
Chelonia mydas	Green Turtle
Delphinus delphis	Short-beaked Common Dolphin
Grampus griseus	Risso's Dolphin
Hydrobates pelagicus	European Storm-Petrel
ESAS	European Seabirds at Sea (survey method)
Larus audouinii	Audouin's Gull
Larus michahellis	Yellow-legged Gull
Monachus monachus	Mediterranean Monk Seal
n.m.	nautical mile
Phalacrocorax aristotelis desmarestii	Mediterranean Shag
Physeter macrocephalus	Sperm Whale
Puffinus yelkouan	Yelkouan Shearwater
Stenella coeruleoalba	Striped Dolphin
SAC	Special Area of Conservation (Natura 2000 network)
SPA	Special Protection Area (Natura 2000 network)
SDF	Standard Data Form (Natura 2000 datasheet)
Tursiops truncatus	Bottlenose Dolphin
WP	Work Package
Ziphius cavirostris	*Cuvier's Beaked Whale*

1 Introduction

In the context of Environmental Monitoring and Recording of Critical Environmental Indicators of Biodiversity, such as marine mammals (cetaceans and monk seals), sea turtles and seabirds, the Hellenic Petroleum Exploration & Production of Hydrocarbons Kyparissiakos Gulf Single Member S.A. company has assigned to Nature Conservation Consultants (NCC) Ltd a contract for conducting the present Project, namely the “Survey of the Status of Important Fauna Species in the Kyparissiakos Lease area” (Block 10).

The Project consists of 3 work packages (WP):

I. Pelagic Surveys for marine mammals, seabirds, sea turtles, nearshore and in the open sea, using an open water RIB vessel, a sailing boat, and a single-engine aircraft.
II. Coastal surveys for monk seals and Mediterranean shag breeding sites in the coastal zones of the adjacent Natura 2000 sites, using inflatable RIB boats.
III. Colony surveys at the Strofades islets SPA and the surrounding project area, using GSM nest cameras and GPS/GSM transmitters, as well as analysis of the transmitters’ data fitted on Loggerhead turtles in the previous years.

The present document constitutes the Final Report for Work Packages WP I–III. It presents the field surveys carried out during 2025 and the results in each Work Package.

The present project represents the 2025 continuation of the ongoing project entitled “Survey of the Status of Important Fauna Species in the Kyparissiakos Lease Area”, which has been implemented during the period 2020–2025.

2 Description of the Project Area

The **Project Area** is in the Ionian Sea, southeast of Zakynthos Island and west of the Peloponnese, approximately from the northern town of Zacharo and the southern town of Methoni. It extends between latitudes of 36°50'N in the south and 37°30'N in the north and between longitudes of 20°55'E in the west and 21°30'E in the east. Its total surface area is 3,422.5 km^2.

The **Wider Project Area** envelops the project area and extends further north and east to additionally include the southwestern, south-eastern and eastern coast of Zakynthos, and the western coast of Peloponnese south of Kyllini, together with their neighbouring islets (Figure 2-1)

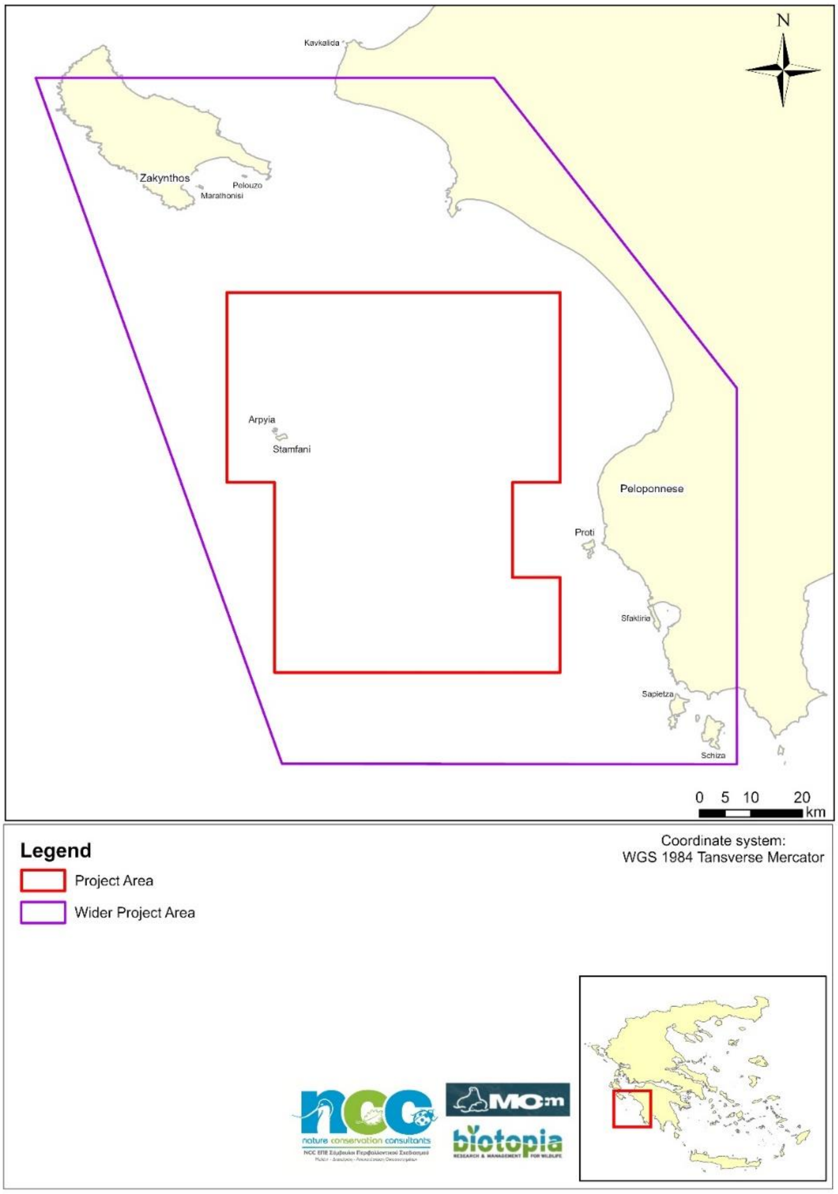

Figure 2-1. Wider project area

Oceanographic characteristics of the Project Area

The sea depth within the Project Area exceeds 500m and reaches more than 3,500m at its southwestern corner. The only exception is the Strofades islets in the west, which are surrounded by a narrow belt of coastal waters (Figure 2-2).

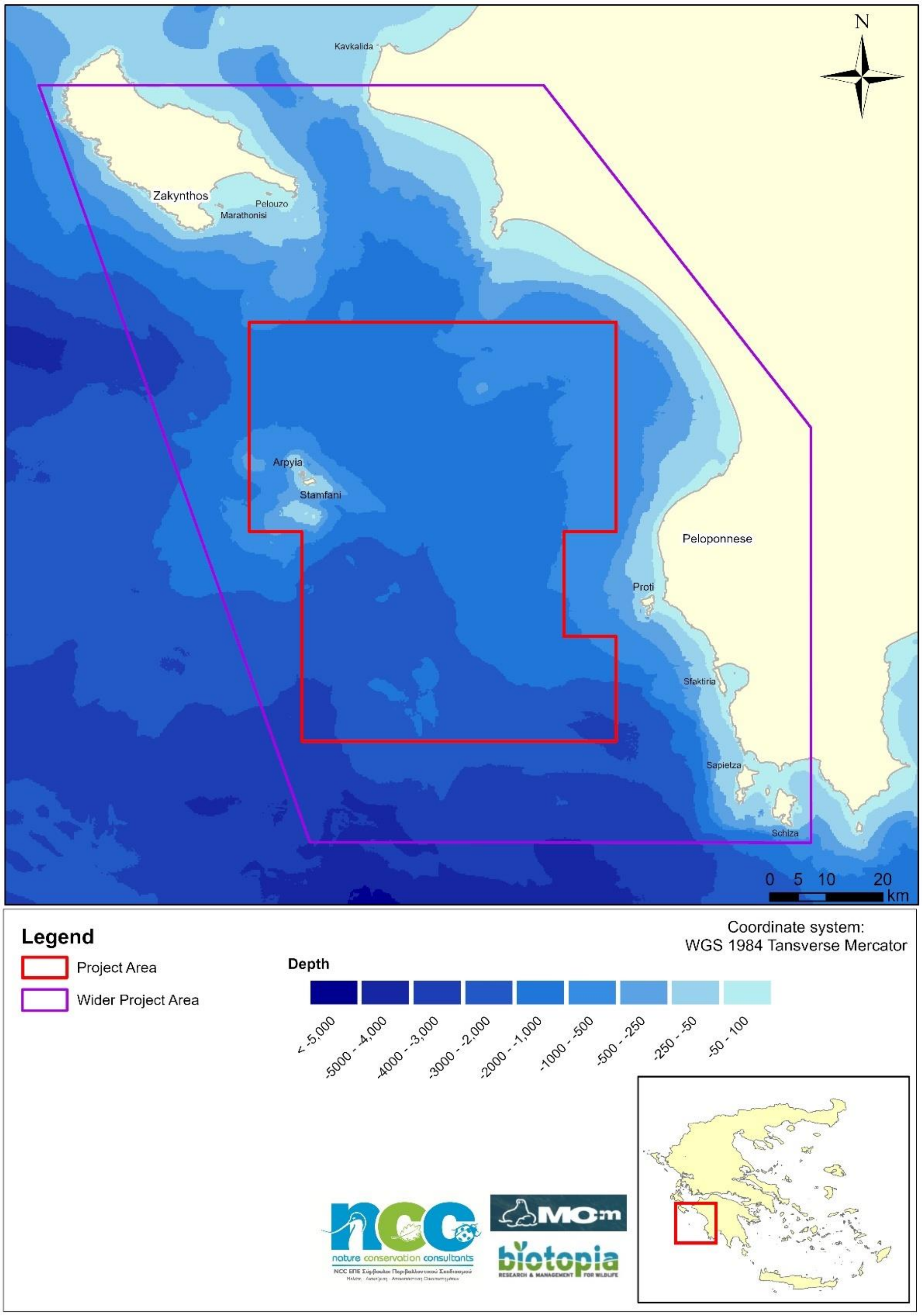

Figure 2-2. Bathymetry in the Project Area

In northern, north-eastern and eastern part of the Wider Project Area the slope of the sea floor descends gradually, without abrupt breaks towards southwest, however the southern and the western part exhibit numerous abrupt descends of the sea floor, accompanied by step slopes of the sea floor reaching up to 53^{o} (Figure 2-3).

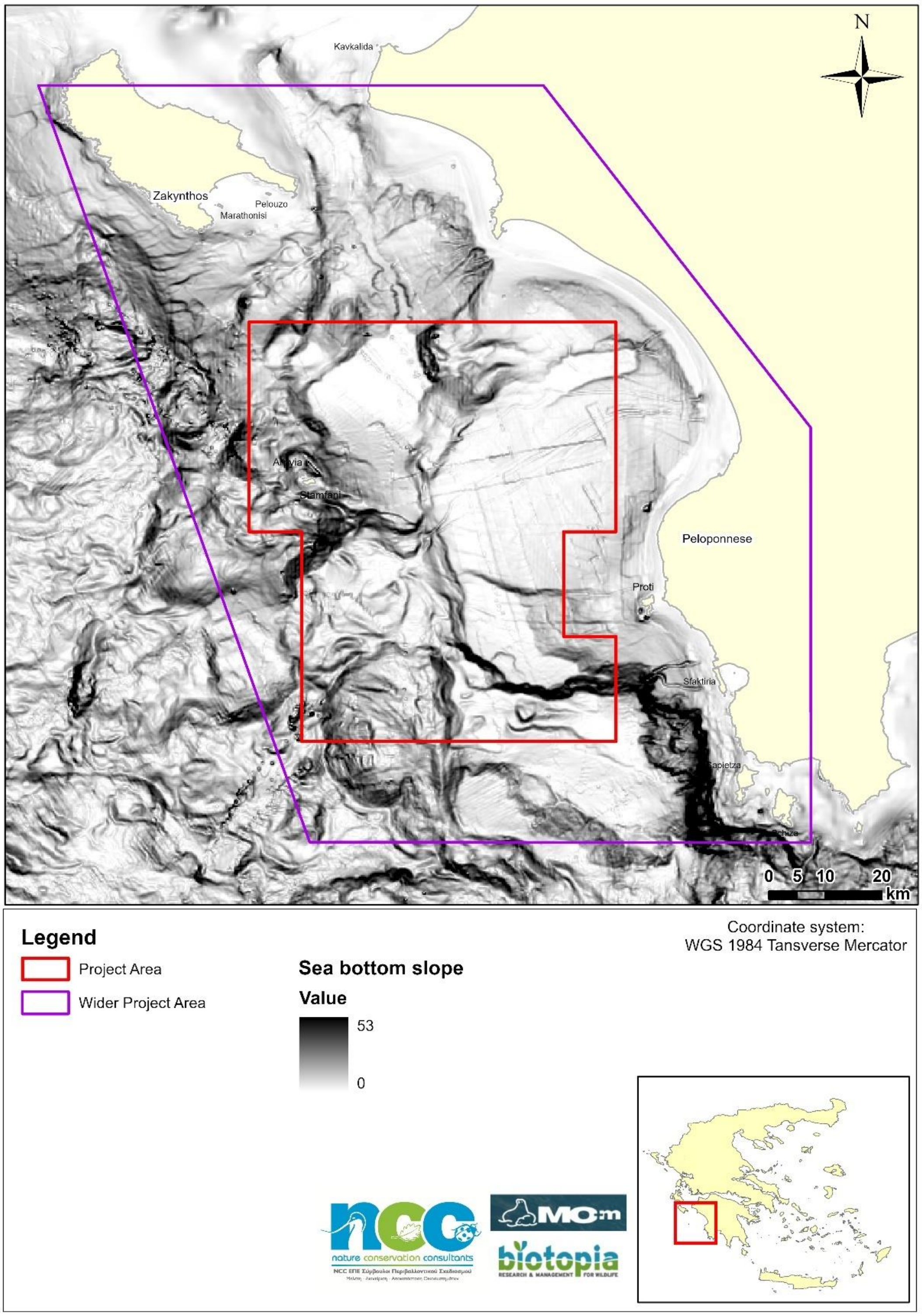

Figure 2-3. Slope of the sea floor in the Wider Project Area

2.1 General information about the main cetacean, seabird, and sea turtle species in the Project Area

2.1.1 Cetaceans

Hellenic seas host an unexpectedly high diversity of cetaceans with eight species that are resident in the area, seven of which belong to the Odondoceti suborder: Sperm Whale (*Physeter macrocephalus*), Cuvier's Beaked Whale (*Ziphius cavirostris*), Risso's Dolphin (*Grampus griseus*), Bottlenose Dolphin (*Tursiops truncatus*), Striped Dolphin (*Stenella coeruleoalba*), Short-beaked Common Dolphin (*Delphinus delphis*) and Harbour Porpoise (*Phocoena phocoena*) along with one representative of the Mysticeti suborder: Fin Whale (*Balaenoptera physalus*). The Harbour Porpoise is restricted to the Thracian Sea and North Aegean Sea, while the others are present in one or more seas in Greece (Frantzis et al. 2003).

It is important to note that due to the semi-enclosed nature of the Mediterranean basin, in combination with its very particular oceanographic features and oligotrophic waters especially moving towards the east of the basin, cetacean species populations of the Mediterranean (which occur elsewhere in the world also) are treated separately by the IUCN, when it comes to the designation of their threat status and population trends. In most cases, the Mediterranean subpopulation of cetacean species has at least one level higher in their designated threat status than the global population for the same species or is classified as Data Deficient.

The Wider Project Area is located along the Hellenic Trench, which is one of the most important areas for cetaceans in Greece. Except for the Harbour Porpoise (found only locally in the north-eastern Aegean) and the Fin Whale (observed mainly in the Ionian Sea, along the Hellenic Trench, north of Kefallonia), the remaining six commonly occurring species of cetaceans inhabiting Greek waters have been sighted or recorded as strandings in the Wider Project Area.

Table 2-1. General types of habitats, bathymetric characteristics, and distance from coast of recorded presence in Greek seas of common cetacean species that are present in the Wider Project Area (from Frantzis 2009).

Species	Common name	Habitat		
		Type	Depth	Distance from coast
Physeter macrocephalus	Sperm whale	Slope, secondarily pelagic	1235 m (510-2933 m)	8.1 km (1.6-25.2 km)
Ziphius cavirostris	Cuvier's beaked whale	Slope, probably pelagic as well	1066 m (491-2279 m)	8.6 km (2.1-26.5 km)
Grampus griseus	Risso's dolphin	Slope, probably over its shallower part	737 m (165-1717 m)	8.2 km (0.3-28.3 km)
Tursiops truncatus	Common bottlenose dolphin	Typically, coastal, also over shallow waters "offshore"	121 m (1-1504 m)	3.0 km (0.0-26.0 km)
Stenella coeruleoalba	Striped dolphin	Typically, pelagic and slope	1024 m (75-2920 m)	8.7 km (0.6-37.1 km)
Delphinus delphis	Short-beaked Common dolphin	Coastal and shallow, ("pelagic" and deep only in the Gulf of Corinth)	86 m (11-274 m) Gulf of Corinth: 713 m (275-935)	8.7 km (0.6-37.1 km)

The Wider Project Area includes coastal areas, continental shelf and slope, as well as pelagic areas. For the present study and based on the types of marine habitats typically used by the species present in the Wider Project Area, the focus of pelagic surveys is primarily on the species with regular presence in the Wider Project Area, namely the **Sperm Whale (*Physeter macrocephalus*), Cuvier's Beaked Whale (*Ziphius cavirostris*), Striped Dolphin (*Stenella coeruleoalba*)** and **Risso's dolphin (*Grampus griseus*)** in the pelagic and continental slope areas, and **Short-Beaked Common Dolphin (*Delphinus delphis*)** and **Bottlenose Dolphin (*Tursiops truncatus*)** in coastal areas. Accounts on biology, ecology, as well as conservation and threat status of the cetacean species of interest are provided below. It should be noted that large data gaps are still present regarding the distribution and abundance of cetaceans in the eastern Mediterranean (Mannocci et al. 2018).

2.1.1.1 Sperm Whale (*Physeter macrocephalus*)

Figure 2-4. Sperm Whale (Physeter macrocephalus) (© Massimo Demma/ICRAM)

The second largest cetacean found in Greece and the largest Odontocetes found globally is the Sperm Whale (*Physeter macrocephalus*). The Sperm Whale prefers deep water habitats particularly deep continental slope water where they hunt their preferred prey, large mesopelagic cephalopods (Frantzis 2009, Notarbartolo di Sciara et al. 2012).

The Hellenic Trench is the species core habitat for the eastern Mediterranean sub-population (Frantzis et al. 2014). The total species population size in the Greeks Seas is estimated at 180 – 280 individuals (2013-18 Habitats Directive Article 17 Reporting at https://nature-art17.eionet.europa.eu/article17/), the population size in the Hellenic Trench 200 – 250 individuals (Frantzis et al. 2014) and the estimated population size in the Ionian Sea, including international and Italian waters 62 individuals (95% CI: 24-165 individuals, in Lewis et al. 2003), however this is likely to be an underestimation (Frantzis 2009).

2.1.1.2 Cuvier's Beaked Whale (*Ziphius cavirostris*)

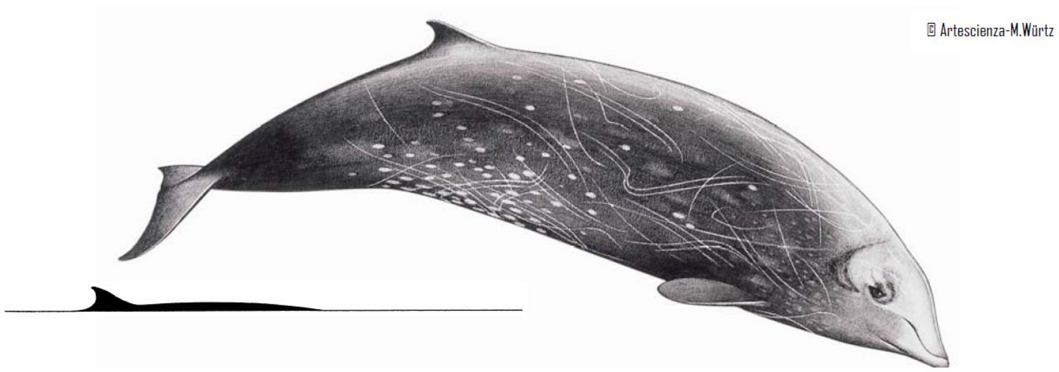

Figure 2-5. Cuvier's Beaked Whale (Ziphius cavirostris) (©Artescienza-M. Würtz)

Cuvier's Beaked Whale, a medium sized odontocetes, shares the same habitat and distribution as that described for the Sperm Whale, namely the continental slope. Almost all past species sightings occurred above depths of 500-1,500m (Frantzis et al. 2003). It is the only beaked whale common in the Mediterranean Sea. In Greece, most past sightings are associated with the Hellenic Trench, from eastern Rodos Island to northwest Corfu Island (Frantzis et al. 2003, Frantzis 2009) with the highest number of sightings south of Crete and west of Lefkada (Frantzis et al. 2003, Podestà et al. 2016). Along the Hellenic Trench the species feed almost exclusively on mesopelagic and bathypelagic cephalopods (Frantzis 2009). Several sightings and numerous strandings have been recorded in the Wider Project Area (based on Frantzis 2009).

The Hellenic Trench is one of the species of high-density areas in the Mediterranean. The total species population size in the Greeks Seas as well as in the Wider Project Area is unknown (2013-18 Habitats Directive Article 17 Reporting at https://nature-art17.eionet.europa.eu/article17/). It is worth noting that Greek seas are considered to host quite a significant portion of the Mediterranean population (Frantzis 2009).

2.1.1.3 Risso's Dolphin (Grampus griseus)

Figure 2-6. Risso's dolphin (Grampus griseus) (© Massimo Demma)

Risso's dolphin is the largest dolphin that commonly occurs in the Greek Seas. The sightings and strandings records indicate that the species is present in all parts of the Greek Seas, however the only known area where the species is predictably present is the Myrtoon Sea extending south to the north-western Crete. The species is present in the Ionian Sea, as confirmed by strandings which have been recorded from north Corfu Island to south Peloponnese. No sighting records have been made in the Ionian Sea, which indicates that either the species is present in low numbers, or it is present outside warm period when past surveys have been made. The strandings in the Ionian Sea have been recorded from the end of September until late April. The species is present primarily along the continental slope, preferably deep water and shelf break where the slope is the steepest, but also close to the coast, particularly when the shelf is narrow (Frantzis 2009). The species feeds mainly on squid and occasionally on fish.

The total species population size in the Greeks Seas is estimated to be 100 – 600 individuals (2013-18 Habitats Directive Article 17 Reporting at https://nature-art17.eionet.europa.eu/article17/). The population size in the Wider Project Area is unknown.

2.1.1.4 Bottlenose dolphin (Tursiops truncatus)

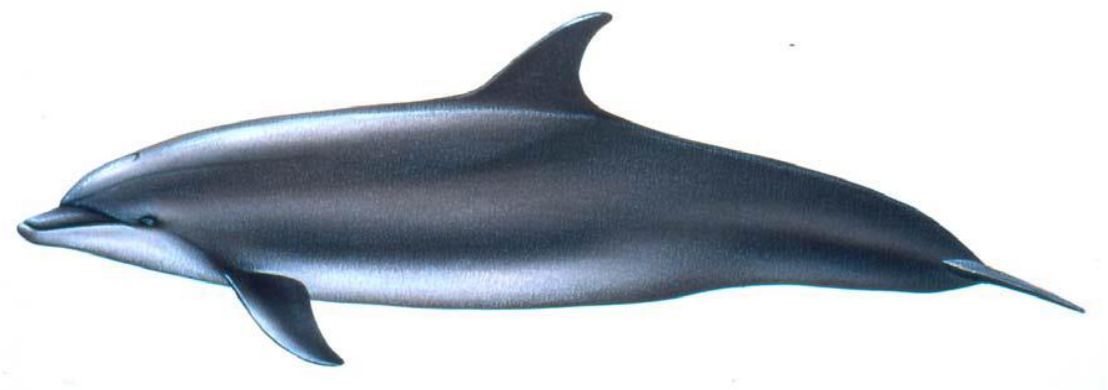

Figure 2-7. Bottlenose dolphin (Tursiops truncatus) (© Artescienza-M. Würtz)

The bottlenose dolphin is the most common species of dolphin found in coastal shallow waters of the Mediterranean (Frantzis 2009). It is homogeneously distributed across all Greek Seas as it has been sighted in most coastal areas, straights and gulfs. (Frantzis 2009). The Bottlenose Dolphin in Greece, like Short-beaked Common Dolphin prefers the continental shelf usually staying within a depth of up to 200m (Frantzis 2009). It is known to consume a variety of prey items, being quite adaptive.

The total species population size in the Greeks Seas is estimated to be 3,800 – 9,000 individuals (2013-18 Habitats Directive Article 17 Reporting at https://nature-art17.eionet.europa.eu/article17/). The population size in the Wider Project Area is unknown.

2.1.1.5 Striped dolphin (Stenella coeruleoalba)

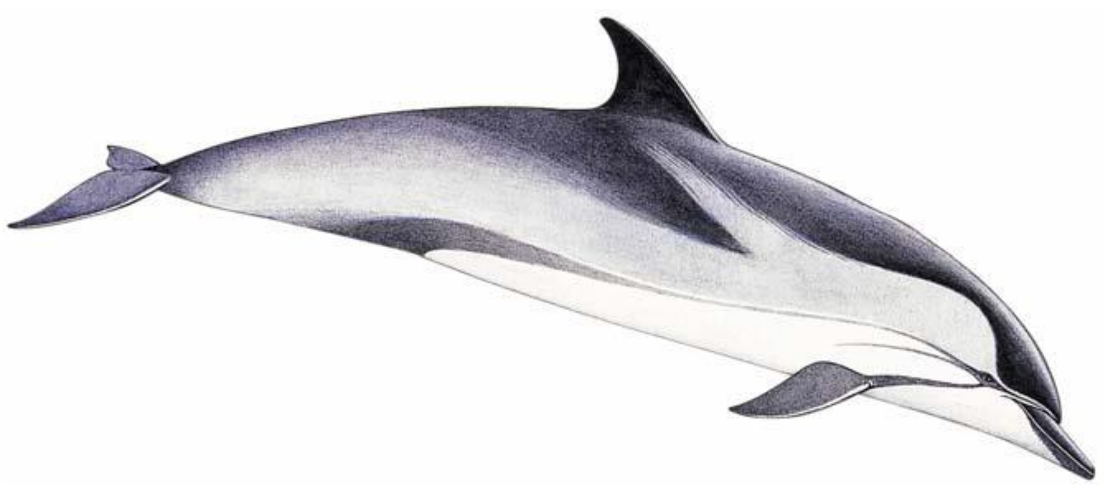

Figure 2-8. Striped dolphin (Stenella coeruleoalba) (© Massimo Demma/ICRAM)

The Striped Dolphin, a small delphinid, has a year-round presence in Greek waters. It is the most abundant dolphin species in Greece and the Mediterranean overall (Frantzis 2009). Its distribution in Greece is widespread, and it occurs in all deep (>500m), pelagic waters and the continental slope but it can also inhabit intermediate depths of 200-500m (Frantzis 2009). The Striped Dolphin is frequently sighted along the length of the Hellenic Trench. The species diet includes mainly cephalopods, as well as fish and crustaceans.

The total species population size in the Greeks Seas is estimated to be 20,000 – 80,000 individuals (2013-18 Habitats Directive Article 17 Reporting at https://nature-art17.eionet.europa.eu/article17/). The population size in the Wider Project Area is unknown.

2.1.1.6 Short-beaked common dolphin (Delphinus delphis)

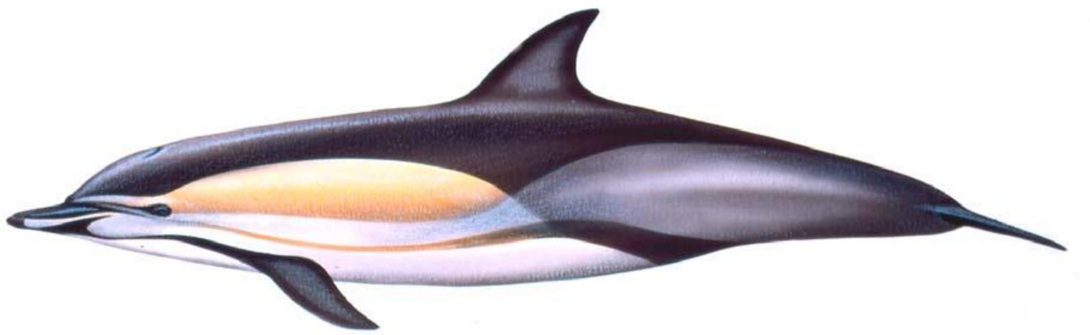

Figure 2-9. Short-beaked common dolphin (Delphinus delphis) (© Artescienza-M. Würtz)

The Short Beaked Common Dolphin (or simply Common Dolphin) is a small delphinid with a year-round presence in Greek waters. Its distribution in Greece is patchy, and their presence seems to be mostly limited to the central and northern Greek Seas (Frantzis 2009). In general, it prefers shallow (<200m) and coastal waters, with exception of Gulf of Corinth where it exhibits preference to pelagic habitats (Frantzis 2009). It exhibits flexible feeding habits. The distribution of the Common Dolphin in the Ionian Sea is limited to shallow waters between north Lefkada, Kefallonia and south Zakynthos and the mainland. In the Inner Ionian Sea, the main prey includes shoaling fish e.g., anchovies and sardines.

The total species population size in the Greeks Seas is estimated to be 750 – 4,200 individuals (2013-18 Habitats Directive Article 17 Reporting at https://nature-art17.eionet.europa.eu/article17/).

The population of Common Dolphins of the Inner Ionian Sea has been the focus of regular surveys for years and has been well documented (Bearzi et al. 2008B). The local population counted 150 individuals until the mid-90s, and their range seemed to cover the entire Inner Ionian. Since then, the population has declined dramatically with only an estimated 15 individuals encountered over the past years, mostly sighted in southern Lefkada (Bearzi et al. 2008B).

2.1.2 Seals

2.1.2.1 Mediterranean Monk Seal

Figure 2-10. Mediterranean Monk seal (Monachus monachus)

The Mediterranean Monk Seal is the only pinniped (seal) living in the Mediterranean region, the rarest extant member of the Phocidae family and one of the rarest marine mammals in the world.

Mediterranean monk seals were once widely and continuously distributed in the Mediterranean and Black Seas, and in the North Atlantic waters from Morocco to Cap Blanc, including the Canary, Madeira and the Azores Islands. A few individuals have been recorded in Senegal, the Gambia and the Cape Verde Islands in the southern end, as well as in Portugal and Atlantic France in the northern end of the species' distribution. Today the distribution of the Mediterranean is highly fragmented and consists of three to four isolated subpopulations (Karamanlidis et al. 2016). In the Mediterranean Sea, the stronghold of the species has been on islands in the Ionian and Aegean Seas, and along the coasts of Greece and western and southern Turkey (Güçlüsoy, Kiraç, Veryeri, & Savaş 2004, Gücü, & Orek 2004, Anonymous, 2007). In the North Atlantic, two subpopulations exist: one at Cabo Blanco (also known as Cap Blanc) at the border of Mauritania and Western Sahara (González & Fernandez de Larrinoa 2012, Martínez-Jauregui et al. 2012), and one at the Archipelago of Madeira (Pires, Neves, & Karamanlidis, 2008). An unknown number of monk seals might still survive at the Mediterranean coasts of eastern Morocco (and perhaps Algeria) (Mo, Bazairi, Bayed, & Agnesi, 2011), but without on-going systematic conservation actions the fate of this subpopulation is unknown.

The total species population size in the Greece is estimated to be 300 – 400 individuals (2013-18 Habitats Directive Article 17 Reporting at https://nature-art17.eionet.europa.eu/article17/).

2.1.2.2 Sea turtles

There are three species of sea turtles that regularly occur in the Mediterranean: **Loggerhead Turtle (*Caretta caretta*)**, **Green Turtle (Chelonia mydas)** and **Leatherback Sea turtle (*Dermochelys coriacea*).** The sea turtles live almost exclusively in the marine environment with females returning to land for dig nests and lay eggs, while males almost never return to land. The range of all three species extends along the Wider Project Area (Legakis & Maragou 2009, 2013-18 Habitats Directive Article 17 Reporting: species range), however only Loggerhead Turtle and Green Turtle have been recorded in the area (2013-18 Habitats Directive Article 17 Reporting: species distribution). Among these two the Loggerhead Turtle is the species of interest due to its regular presence and nesting in the Wider Project Area of the Kyparissia Bay, while the Green Turtle is regular but rare visitor in the area. The Leatherback Sea turtle to is only considered in Greece to be a visitor from the Atlantic (Casale & Margaritoulis 2010).

2.1.2.3 Loggerhead turtle (Caretta caretta)

Figure 2-11. Loggerhead Turtle (Caretta caretta)

The Loggerhead turtle is an oceanic turtle with a global distribution. It is a migratory species and may travel thousands of kilometers to forage and to return to its breeding sites. After hatching, logger-head turtles adopt an oceanic lifestyle in major current systems (Bolten and Witherington 2003). After 4-19 years spent in the oceanic zone, they move to neritic areas where they forage and mature over 10-39 years (Avens and Snover 2013). After attaining sexual maturity, they migrate between neritic foraging grounds and nesting areas. The Mediterranean, where the species is nesting in the eastern basin (Legakis & Maragou 2009), the breeding population of the loggerhead turtle is spread over tens of rookeries which are estimated to produce over 7,200 nests annually (Casale & Margaritoulis 2010) with most nests being found in Greece. The country's two most important nesting beaches are in the Wider Project Area, namely on Zakynthos (Laganas Bay) and on Peloponnese (Kyparissia Bay), which host 43% and 19% of all nests in Greece, respectively (Legakis & Maragou 2009). The average number of nests per season for the period 1984-2007 at Laganas Bay and at Kyparissia Bay are 1,244 nests/season (range: 833-2,018 nests/season) and 621 nests/season (range: 286-927 nests/season) (Casale & Margaritoulis 2010). Currently, Kyparissia Bay hosts the largest Loggerhead turtle nesting aggregation in the Mediterranean Sea (Rees et al. 2020).

In Greece and in the Central Mediterranean, the turtles after hatching disperse mainly in the Ionian, south-central Mediterranean and Adriatic Seas (Casale & Mariani 2014). Loggerhead turtles, especially juveniles, forage in almost all oceanic areas in the Mediterranean. Water circulation system has the greatest effect on their distribution (Casale et al. 2018). The neritic foraging areas (i.e., those located above continental shelf) are more frequently used by larger turtles, including adults (Casale et al. 2018). Loggerhead turtles generally overwinter within or close to their foraging areas, however some may move from cold areas e.g., Adriatic Sea during winter (Casale et al. 2018).

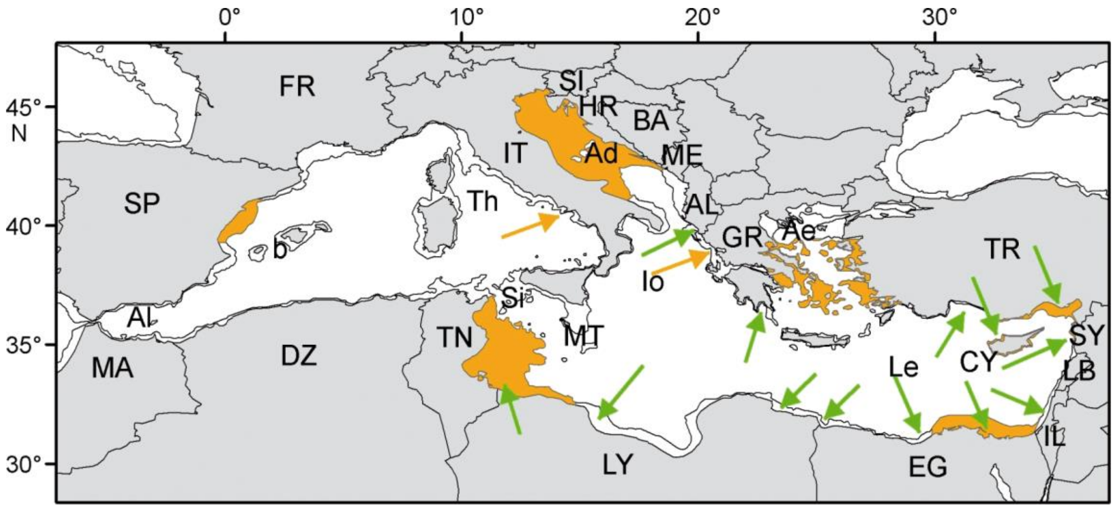

Figure 2-12. Neritic foraging and wintering sites for loggerhead turtles (orange areas and arrows) and green turtle (green arrows) (adopted from Casale et al. 2018).

Migration corridors are areas which are frequently used by migrating turtles, mainly for adult breeding migration and particularly for post-breeding migration from breeding areas to foraging grounds. Therefore, these migratory corridors are used at the end of the breeding season, in May and June by males, while in July and August, mostly by females (Casale et al. 2018). The main migration corridors are presented in Figure 2-13.

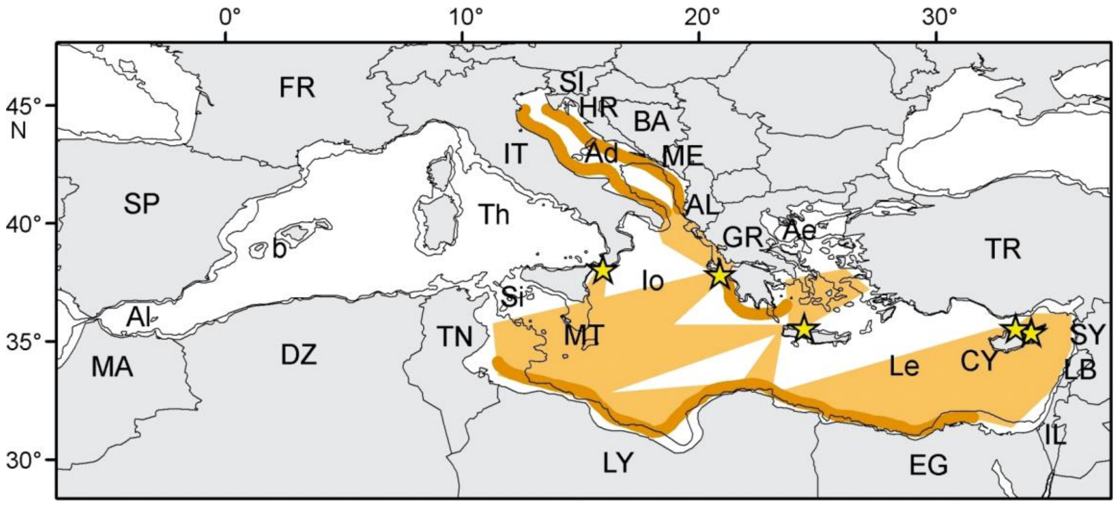

Figure 2-13. Main known migratory corridors for adult loggerhead turtles to and from breeding sites (stars). Light brown areas represent migratory funnels in the open sea while darker strips represent paths along the coasts, typically in shallow waters (adopted from Casale et al. 2018).

The movements of the Loggerhead turtles nesting in the Ionian Sea, particularly those from Zakynthos have been well studied by satellite or GPS telemetry (e.g., Zbinden et al. 2008, Schofield et al. 2010a-c, Schofield et al. 2013, Luschi & Casale 2014). The data from 75 tracked turtles breeding on Zakynthos showed after breeding the turtles migrate to neritic sites with waters shallower than 100m, with the majority of turtles migrate north to the Adriatic Sea and Amvrakikos Gulf (42%) or south-west to Libya and Tunisia (32%), while the remaining either stay in the Ionian Sea or move to the eastern or western Mediterranean (Zbinden et al. 2008, Schofield et al. 2013). After leaving their foraging areas (in October – November) the tracked turtles move to their overwintering areas further south (Zbinden et al. 2008). The main foraging and overwintering areas are presented in the Map 11, below. The main foraging areas are located over the continental shelves and slopes (Ullmann & Stachowitsch 2015) in the Northern and Southern Adriatic Sea, Ionian Sea, the Strait of Sicily and the Tunisian shelf. A small proportion (~7%) were residents of Zakynthos. Significantly more males than females remain within 100km of Zakynthos (Schofield et al. 2013).

2.1.2.4 Green turtle (Chelonia mydas)

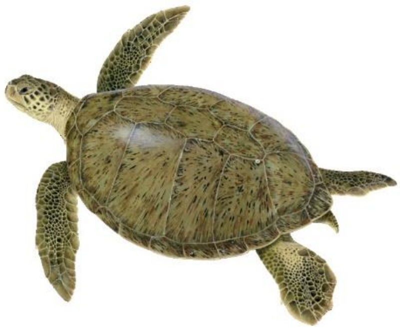

Figure 2-14. Green turtle (Chelonia mydas)

The green turtle (*Chelonia mydas*) is a migratory oceanic turtle with a global distribution. Their nesting sites in the Mediterranean are located mostly in Turkey, Cyprus and Syria (Figure 2-12) with an average of 1500 nests per year. No regular nesting areas are in Greece. They use mostly marine areas in the Levantine basin, but also forage in Greece and Libya, as well as occasionally in the Adriatic Sea and the western Mediterranean basin (Figure 2-13). In Greece local concentration have been found in Lakonikos Bay, southern Peloponnese. Stranding data indicate that there is a more frequent presence of adult green turtles in southern Aegean (Casale & Margaritoulis 2010). The species has been recorded in the Wider Project Area.

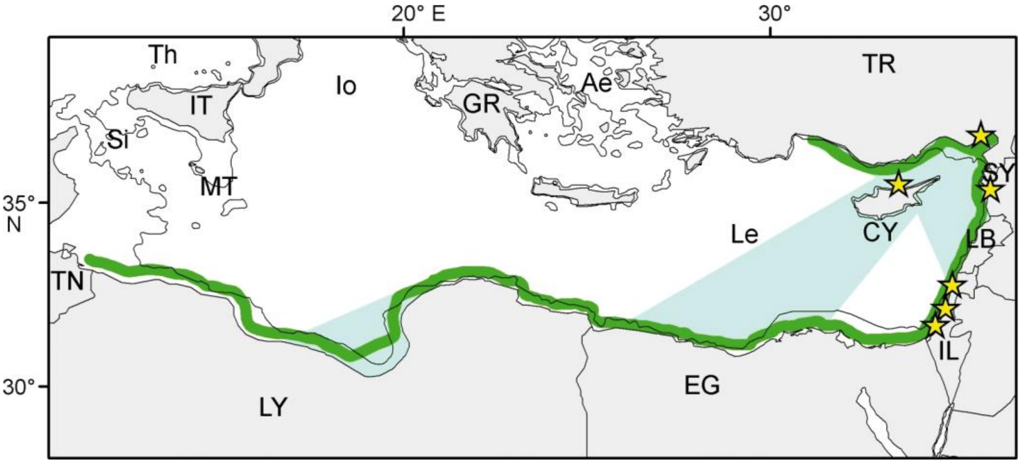

Figure 2-15. Main known migration corridors for adult female green turtles during reproductive migrations from the breeding sites (stars) (adopted from Casale et al. 2018).

2.1.3 Seabirds

To the present study, only those seabird species which are exclusively associated with the marine environment and the pelagic area, that have been recorded in the Ionian Sea in the past and their presence in the wider Project area has been confirmed. These species include pelagic seabird species**: Scopoli's Shearwater (*Calonectris diomedea*), Yelkouan Shearwater (*Puffinus yelkouan*)** and **European Storm-petrel (*Hydrobates pelagicus*)**, as well as coastal seabird species which could be present in the pelagic areas due to shallow waters in the Project area or due to human activities, i.e. **Yellow-legged Gull (*Larus michahellis*) and the Mediterranean Shag (*Phalacrocorax aristotelis desmarestii*).**

2.1.3.1 Scopoli's Shearwater (Calonectris diomedea)

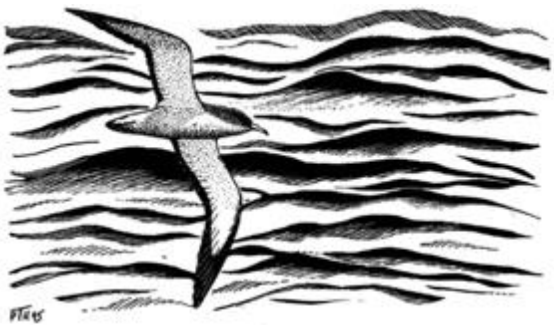

Figure 2-16. Scopoli's Shearwater (Calonectris diomedea) (© Paul Hirst)

Scopoli's Shearwater (C*alonectris diomedea*) breeds across Mediterranean with most of the population spending the non-breeding season in the Atlantic. In the past it was considered conspecific with the Cory's Shearwater (C*alonectris borealis*) which breeds in the Atlantic. In Greece the species breeding in the Aegean and Ionian Sea with the largest known colony being located at Strofades Islets (within the Project Area), south of the Zakynthos Island in the Ionian

Sea, with an estimated breeding population of 5,550 pairs (Karris et al. 2017). Other large colonies occur mainly in the southern, central and eastern Aegean Sea although breeding has also been confirmed in the northern Aegean Sea (Fric et al. 2012). The only other known breeding area in the Ionian Sea is at Diapontia islands at Kerkyra with much smaller breeding population of 60-100 pairs (Fric et al. 2012).

2.1.3.2 Yelkouan Shearwater (*Puffinus yelkouan*)

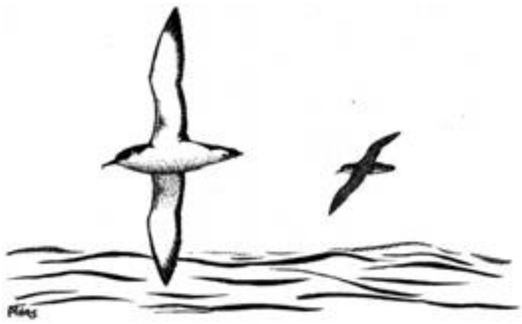

Figure 2-17. Yelkouan Shearwater (Puffinus yelkouan) (© Paul Hirst)

Yelkouan Shearwater is an endemic species to the Mediterranean and the Black Sea. The known species colonies in Greece are in the Aegean Sea, while no colonies have been found so far in the Ionian Sea. The main known colonies are located the North, East and Central Aegean Sea (Fric et al. 2012), with the largest being on Gyaros island in the Northern Cyclades (Fric & Portolou 2016). During the non-breeding season Yelkouan Shearwaters disperse widely within the Mediterranean Sea (mainly Adriatic and Aegean Seas) and the Black Sea. Additionally, 4,000-6,000 individuals are estimated to overwinter in the Aegean Sea the main foraging areas of the Yelkouan Shearwaters are rich coastal and pelagic fishing grounds in the North, Central and East Aegean Sea, while the species is less common in the South Aegean and Ionian Seas (Fric et la. 2012).

The global species population is estimated at 15,337-30,519 pairs with a decreasing population trend (30% in the next 54 years i.e., three generations). Ten colonies in the Mediterranean Sea have disappeared during the last 60 years (Derhe 2012B, BirdLife International 2015, Birdlife International 2018B). The national population is estimated at 4,000-7,000 pairs (without the inclusion of the Gyaros colony which is estimated at 3,090-7,450 pairs), equivalent to 22% percent of the global population (more than 38% with the inclusion of the Gyaros population). The national population trend is estimated to be stable.

2.1.3.3 European Storm-petrel (Hydrobates pelagicus)

Figure 2-18. European Storm-petrel (Hydrobates pelagicus) (© Paul Hirst)

European Storm-petrel is the smallest seabird species in the Western Palaearctic. Its distribution is limited mainly to the Northeast Atlantic Ocean and the West Mediterranean Sea, while the Aegean Sea comprises the easternmost part of its range. The Mediterranean subspecies *Hydrobates pelagicus melitensis* comprises less than 5% of the overall global population (i.e., 12,000-17,500 breeding pairs) with the main colonies located in Malta, Sicily and the Balearic Islands. The species occurs in all Greek seas mainly in spring and summer during the breeding period. Up to date only two colonies have been located, one in the Central Aegean Sea and another in the Cyclades. Storm-petrels, usually individual birds, or very small groups, are regularly observed in the Cyclades, Dodecanese, Central and southwest Aegean Sea and the Karpathian Sea suggesting potential existence of other breeding colonies (Fric et al. 2012).

2.1.3.4 Mediterranean Shag (Phalacrocorax aristotelis desmarestii)

Figure 2-19. Mediterranean Shag (Phalacrocorax aristotelis desmarestii) (© Jens Overgaard Christensen)

Mediterranean Shag is a cormorant species, resident and widely spread in Greece which usually occurs in coastal waters. Shags breed colonially, forming small, loose (rarely dense) colonies, on cliff ledges or small caves or even under thick vegetation. Nesting sites are re-used in successive years by the same birds. They often roost in large groups (Fric et al. 2012). It is a good swimmer and a foot-propelled diver which feed on benthic and pelagic fish in waters with depths up to 80 m which are usually located in coastal zones within a 20 km radius around their colony or roosting sites (Wanless *et al.* 1991; Velando and Friere 1999).

The Greek national population size is 1,300 -1,450 pairs (Fric et al. 2012), equivalent to 2% of the species European population (BirdLife International 2015, BirdLife International 2018D). The population in Greece is stable (Fric et al. 2012). The island of Zakynthos hosts an important population of the Mediterranean Shag (i.e., 44-46 adult and juvenile individuals) (Portolou et al. 2009, Fric et al.2012). The species breeds along the western coast of the Zakynthos and forages in coastal waters along the western and eastern coast, including the Bay of Laganas. Therefore, the major breeding and foraging areas of the Mediterranean Shag around Zakynthos Island are located outside the Project Area and within the Wider Project Area.

2.1.3.5 Yellow-legged Gull (Larus michahellis)

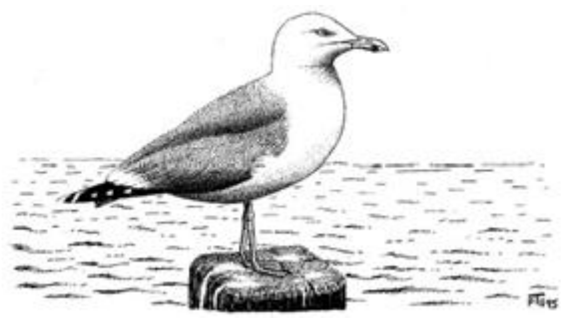

Figure 2-20. Yellow-legged Gull (Larus michahellis) (© Paul Hirst)

The Yellow-legged Gull is the most common gull species in Greece. It is widely distributed around the southern regions of the Palaearctic, from the western part of the Black Sea across to the Mediterranean, Iberian Peninsula, and reaching the Macaronesian region. Breeding grounds are centred mainly around the Mediterranean but reach also the Black Sea, Caspian Sea, and eastern Atlantic. In Greece, the species is resident and widespread all along the coastline of mainland Greece and of the islands of the Aegean and Ionian Seas.

In Greece, the largest breeding colonies are located on uninhabited islets of the Evoikos and Saronikos Gulfs that surround Attica, the most urbanised area in the country, although colonies occur on most Greek islets (Fric et al. 2012). Wintering grounds include the coast of southwest Asia, most of the European coast up to Denmark and the coast of Africa from Western Sahara through the eastern Mediterranean (del Hoyo *et al.* 1996).

3 Methodology

3.1 Pelagic surveys

Pelagic surveys for cetaceans, sea turtles and seabirds are carried out using i) the 15m sailing boat ARTINA, ii) a 7,5m RIB boat and iii) a high wing, ultralight aircraft.

3.1.1 Boat surveys

Visual-based surveys

The method applied for visual surveying seabirds, cetaceans and sea turtles in the Pelagic surveys area is the **European Seabirds at Sea (ESAS)**, based on Tasker *et.al* 1984 and Champhuysen & Garthe 2004 and adopted to Greek/Mediterranean conditions through the LIFE-Nature project for the Identification of Marine Important Bird Areas (marine IBAs) in Greece, entitled "Concrete Conservation Actions for the Mediterranean Shag and Audouin's Gull in Greece, including the Inventory of Relevant Marine IBAs", LIFE07 NAT/GR/000285, (http://www.ornithologiki.gr/en/seabirds), as described in Fric & Gaganis 2009.

In summary, the method is aimed at systematically recording seabirds, cetaceans and sea turtles as well as human activities in the survey area, in transects by trained observers, from a boat which is moving at a constant low speed (<15 knots). Swimming seabirds, cetacean, fish and sea turtles are recorded continuously in a 300m wide strip transect in **5-minute intervals**, while flying birds are recorded with **1-min snapshot**. Scanning angle is 180° (*i.e. in front of the survey vessel*). The perpendicular distance of swimming fauna is recorded relative to the transect line ahead of the ship: **A = 0-50m, B = 50-100m, C = 100-200m, D = 200-300m, E = >300m, W = within 300m, but no distance recorded**. For flying birds, coded with **F**, there is no distance indication. Boat position (**poskey**), namely geographical longitude and latitude, are recorded every 5 min. The marine species are spotted by a naked eye or binoculars and are identified by binoculars.

A method described by Heinemann (1981) is used to determine the distances at sea and more particularly the distance of 300*m* from the observing platform which determines the width of the line transect by using a calliper or a ruler. During ESAS surveys data is recorded regarding (A) boat route, (B) marine species and (C) human activities in the survey area, which may influence the presence and behaviour of the marine species.

Survey boat data include start and end location date, time and geographical location of each line transect, sea state, visibility and floating matter (including fishing vessels). Species data recorded include species, number of individuals, age (if applicable), distance from the observation vessel, location within or outside 300m line transect, flight direction (for birds), behaviour and association with human activities or other species. Datasheets for species data are provided in Annex I.

Figure 3-1. Visual boat surveys

The **survey design for cetaceans** is based on the established methodology design for such surveys, used over the past 4 decades (Buckland et al. 2001, Buckland et al. 2004), and uses a grid of line transects, which provided comprehensive coverage of the study area.

The transect lines acted as the basis for the daily track line, followed by the vessel providing roughly uniform coverage of the study area. Attempts were made when selecting the orientation of the transect lines to have them move across (at an angle to) the depth gradient in the area as opposed to moving along (parallel to) the depth gradient. This was done to allow for the coverage of different depth levels during navigation of each transect, to minimize detection bias on individual transect lines when mapping sighting data.

When a group of cetaceans is sighted (group defined 'dolphins observed in apparent association, moving in the same direction and often, but not always, engaged in the same activity' (Bearzi et al. 2005) by any of the on-effort observers, the systematic search effort is interrupted while the vessel diverted from the track line toward the sighted animals to achieve more accurate determinations of the species, the group size, group age class composition and group activity of the group sighted. In addition to basic environmental data (e.g., Beaufort sea state, visibility conditions etc.) collected at regular 1 hour intervals as well as at the start and the end of each transect line, data collected for each sighting includes the time, GPS coordinates, initial bearing and radial distance to the cetacean group (used to calculate the perpendicular distance of the sighting to the track line), species identity, group size, group age class composition (3 age classes: Calf < 1/2 length of adult, Juvenile < 2/3 length of adult and adult) and the general activity in which the group is engaged in at the time of approach (e.g. foraging, travelling, milling). For the correct identification of the species as well as the correct recording of group size and group age class composition, attempts are made to approach the animals to obtain photographs. Where possible the photographs taken are also used for the photo-identification of individuals. This is being done to ensure the same group of animals was not counted twice during the same survey day.

The navigation schedule coincided with the Visual boat-based surveys.

In case a group of cetaceans or seabirds was spotted, a drone was used to more accurately identify the species and assess the number of the individuals, record their behaviour and gather the relevant photographic evidence.

Acoustic surveys

The acoustics detection team works in cooperation with the visual observers, detecting cetacean vocalizations by using a hydrophone array towed behind the sailing boat. The hydrophone array system consisting of High Frequency Magrec HP03 hydrophone elements, comprising a HP03 preamp (Low cut filter set at 2kHz) with a nominal sensitivity of 1.5kHz – 150kHz along with a topside Magrec HP/27ST Amplifier along with a Lenovo Thinkpad Laptop using the PAMGUARD acoustic analysis software specifically developed for cetacean monitoring, covering the range of possible vocalizations for species likely to be encountered during our surveys. The towed hydrophone system is submerged and active, and a Passive Acoustic Monitoring (PAM) operator is active on the equipment during all "On Effort" times during the survey. The hydrophone system consists of 4 hydrophones, which record on 4 different channels. The visual observers and PAM operator rotate every 1.5 hours to minimize fatigue.

The PAM operator immediately informs the visual observer team of any acoustic detection.

The hydrophone recordings are analysed real-time during the survey by PAMGUARD software using the "*whistle and moan detector*" and the *"Click Detector"* modules.

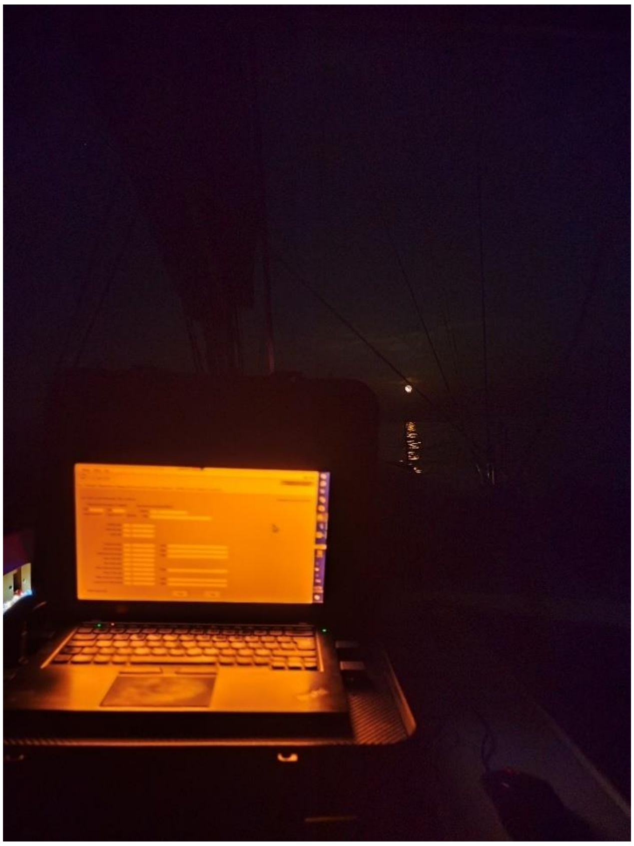

Figure 3-2. Night PAM boat survey.

Figure 3-3. Deployment of the towed hydrophone array behind the sailing boat

Photo – Identification

Photo-identification (photo-ID) is one of the most reliable non-invasive methods for identifying individual marine mammals. It relies on the unique natural characteristics of each animal, including the shape, scars, and pigmentation patterns on the tail fluke or dorsal fin, which act as a biological “fingerprint” for individual recognition.

Photo-identification is widely applied across different species of marine mammals such as dolphins, seals, and whales by using permanent external traits (scars, pigmentation patterns, and notches) that remain stable over time. This approach enables the estimation of population trends, spatial distribution, and individual movement patterns. In the case of the sperm whale (*Physeter macrocephalus*), the technique focuses primarily on the tail fluke, whose morphology is distinct for each individual and represents a highly reliable feature for identification. The shape of the fluke, the pattern of its trailing edge, notches, scars, and pigmentation marks remain consistent over time and can be used as diagnostic characteristics for individual recognition. Through this approach, it is possible to estimate the minimum number of individuals observed, detect potential re-sightings, and assess the spatial and temporal distribution of sperm whales within the study area.

During field surveys, photographs were taken whenever sperm whales were sighted, focusing particularly on moments of deep diving when the tail fluke was fully raised above the water surface (fluke-up). For each encounter, the date and time of the first and last observation, the group size and composition, and the general behaviour of the animals were recorded. From the total number of photographs, only those meeting the quality criteria for identification clear focus, full fluke exposure, and near-perpendicular angle were selected for further analysis. The selected images were organized by encounter and uploaded to the Flukebook platform, which applies an automated algorithm for pattern matching. The system-generated matches are not considered final; each proposed match is visually reviewed by the analyst to confirm specific morphological traits such as the outline of the fluke, notches, and scars. Each identified individual is assigned a unique code (e.g. SW1, SW2) and archived in a dedicated reference folder containing one or two representative photographs. All individual codes (SW1–SW14) correspond to entries in the NCC Flukebook database (Project: Ionian_2025_PhotoID).

The results of algorithmic matching are always interpreted with caution, as similar scores alone do not constitute definitive evidence of identification. The final confirmation relies on expert visual assessment of morphological features to ensure that every identification is scientifically valid and well-documented. Photo-identification metadata are compiled in a dedicated Excel database, which includes, for each individual, the corresponding photo codes, observation times, group composition, behavioral notes, and key morphological characteristics. This database serves both as a validation record and as a reference for future cross-comparison of observations.

Photo quality control is conducted at two stages: initial field selection (sharpness, angle, full fluke exposure) and subsequent post-processing review to ensure temporal and spatial consistency across identifications. Potential limitations of the method include environmental and behavioral factors such as lack of full fluke-up, distance from the observer, sea state, or lighting conditions which can reduce the reliability of individual recognition. Despite these limitations, photo-identification remains a fundamental and effective tool for documenting the number, composition, and behaviour of sperm whales observed during the surveys.

3.1.2 Aerial surveys

For the aerial surveys, a high-wing, light aircraft Cessna C172R Skyhawk was used, powered with a Lycoming IO-360-L2A, 160 Hp. This four-seater aircraft offers an excellent view from its cockpit and is considered suitable, reliable, and cost-effective for such a mission. Messolonghi Airport (ICAO designator GR-0008) was used as a base for the aerial expeditions to the Northern Ionian Project Area. The flight was performed along the Project Area at an altitude of 1000 ft MSL and an average Speed Over Ground of 85 knots. The flights were performed under ideal weather conditions (wind speed less than 10 knots, clear sky, and visibility more than 8 km). In every case where an "object/s of interest" was spotted, the airplane left its track and performed one or more circles over the object/s to visually identify it. Furthermore, the object was photographed so that a proper record of its observation and identification is kept. The photographic operation was performed using a full frame DSLR (Nikon D750) with a 70-200mm F/2.8 Tamron SP lens. All photographs were georeferenced since the camera was equipped with a GPS Unit (Nikon GP-1A). The flights were monitored and recorded with the use of two specialized applications, namely the GARMIN-Pilot and the Fore-Flight.

Figure 3-4. The aircraft used for the aerial surveys spotting a group of Sperm whales

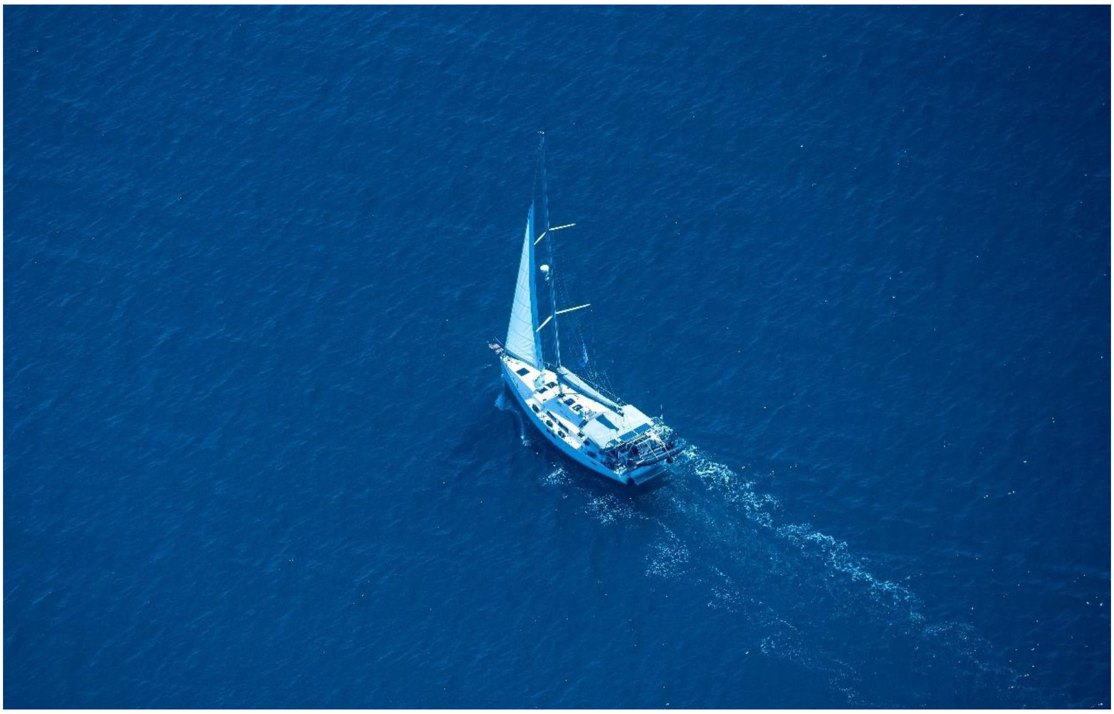

Figure 3-5. ARTINA sailboat from the aircraft's cockpit

In the following example, the staged photographic identification process of an initially "object of interest" located on the shore is clearly shown.

Figure 3-6. A: Recording an "object of interest", B: Approaching, C: Identifying

3.2 Coastal surveys

3.2.1 Coastal surveys and cave monitoring for the Mediterranean Monk Seal

Coastline surveys will be conducted across southwest Zakynthos Island, the Strofades Islands, the Kyparissiakos Gulf, and the southwestern Peloponnese to identify and monitor marine caves that may serve as suitable pupping sites for the Mediterranean monk seal (*Monachus monachus*). Surveys will be carried out using a Rigid Inflatable Boat (RIB), enabling efficient coverage of extensive and complex coastal areas to ensure that no potential pupping site is overlooked.

In addition, infrared (IR) trap cameras will be installed in selected caves to collect data that will support further assessment of monk seal breeding activity. Depending on the monitoring objective, cameras will either operate in timelapse mode capturing images at regular intervals (e.g., every 1 or 2.5 hours) for continuous observation of known breeding sites, or in motion-triggered mode to record presence-absence data of the species.

Lastly, records of seal observations are collected through the operation of Rescue and Information Network (RINT).

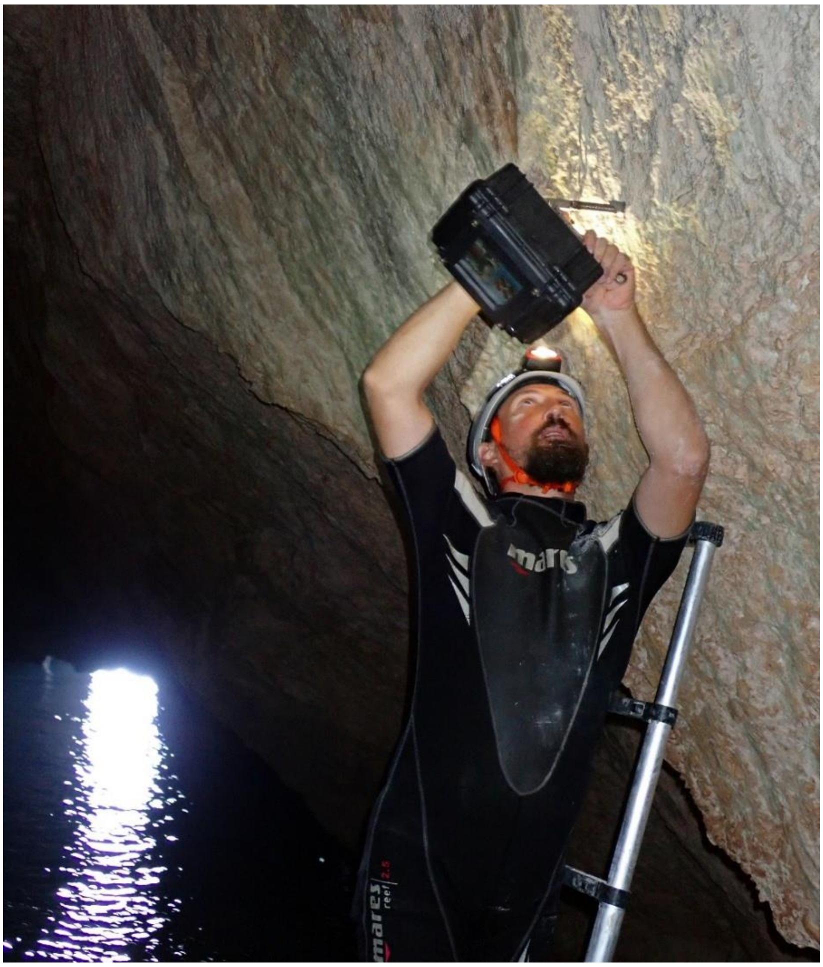

Figure 3-7. Installation of infrared camera systems in a monk seal shelter

3.3 Colony surveys - Telemetry

3.3.1 Colony surveys of Scopoli’s Shearwater at the Strofades islets SPA with nest cameras

The internationally significant colony of Scopoli’s Shearwater (*Calonectris diomedea*) at the Strofades Islets SPA, and the surrounding project area, will be monitored using GSM-enabled stationary nest cameras and audio recordings. These systems will document the breeding activity, assess the presence and behavior of ground predators, and detect potential anthropogenic disturbances to the colony.

Cameras will be deployed throughout the breeding season. All visual and acoustic data collected will undergo systematic analysis. The cameras are equipped with PTZ (pan-tilt-zoom) capabilities, allowing for adjustable fields of view and enhanced monitoring coverage compared to fixed-angle systems. Furthermore, their integrated audio recording functionality enables dual use of data for both visual and acoustic analysis, providing a comprehensive assessment of the colony's status and threats.

3.3.2 Telemetry of Scopoli’s Shearwater at the Strofades islets SPA with satellite transmitters

10 GPS/GSM tags will be deployed to Scopoli’s shearwater fledglings on September-early October 2025, to record the maiden journeys of the fledged birds and identify possible threats and mortality factors during this high-risk period.

By processing the data through Artificial Intelligence and machine learning software, the bird populations, movements, patterns of space use by the species for foraging in the “Kyparissiakos block” lease area will be further explored.

4 Results

4.1 Pelagic surveys

4.1.1 Boat surveys

A total of **950 nautical miles** of boat-based visual and acoustic surveys using both the sailing boat as well as the RIB vessel were carried out from 10/6/2025 to 16/6/2025 and from 19/9/2025 to 1/10/2025 in the Project Area, as well as in the Wider Project Area and the surrounding areas, to assess the presence, abundance and distribution of the cetacean, sea turtle and seabird species of interest.

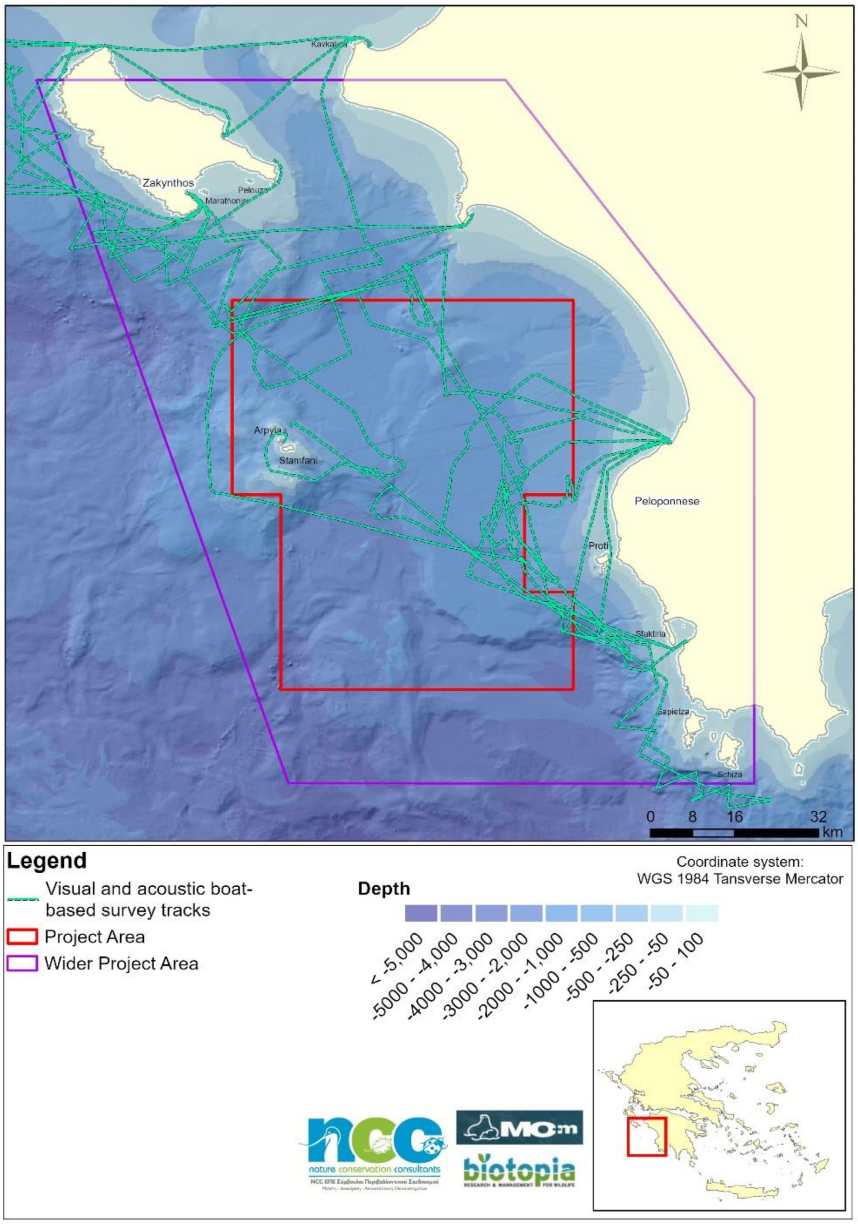

Figure 4-1. Visual and acoustic boat-based survey tracks

During the visual surveys the following species were recorded inside the Project Area:

- 3 cetacean species: **sperm whale** (*Physeter macrocephalus*), **Cuvier's beaked whale** (*Ziphius cavirostris)*, and **striped dolphin** (*Stenella coeruleoalba*),
- 2 seabird species: **Scopoli's shearwater** (*Calonectris diomedea*) and **Yelkouan shearwater** (*Puffinus yelkouan*)
- 1 raptor bird species: An unidentified buzzard species (*Buteo* sp.)
- 1 sea turtle species: **loggerhead turtle** (*Caretta caretta*)

Table 4-1. Species visually recorded in the Wider Project Area

Species	Common name	Number of individuals
Physeter macrocephalus	sperm whale	17
Ziphius cavirostris	Cuvier's beaked whale	24
Stenella coeruleoalba	striped dolphin	105
Calonectris diomedea	Scopoli's Shearwater	43
Buteo sp.	buzzard species	1
Puffinus yelkouan	Yelkouan shearwater	1

Moreover, during the visual surveys, the following target species were observed outside the Wider Project Area:

- **3 loggerhead turtles**,
- **7 sperm whales** NW of Zakynthos Island,
- **70 striped dolphins**, S of the SE border of the wider project area,
- **5 bottlenose dolphins** (*Tursiops truncatus*) NW of Zakynthos Island,
- **9 Scopoli's shearwaters** NW of Zakynthos Island.

During the surveys conducted with the RIB vessel, covering **93 nautical miles, 2 detections of Cuvier's beaked whale**, **1 detection of 2 sperm whales** were recorded, as well as **1 detection of striped dolphins** in the Wider Project Area.

During the **acoustic surveys with the towed hydrophone**, covering 857 nautical miles, **8 detections of Cuvier's beaked whale**, **4 independent detections of sperm whales** (two of which ended up successfully tracking the animals) were recorded, as well as **28 detections of dolphins** (species identification is not possible for dolphin species with the acoustic data) in the Wider Project Area.

Additionally, another **1 acoustic detection of sperm whales** (which ended up successfully tracking a group of 7 animals), **3 detections of Cuvier's beaked whale** and **13 detections of dolphins** were recorded outside the Wider Project Area (NW of Zakynthos and S of the SW border of the Wider Project Area).

It is noteworthy that during the visual and acoustic surveys conducted in June 2025, a total of **20 to 21 sperm whales** (*Physeter macrocephalus*) were recorded within the wider project area and its surroundings. This represents an exceptionally high number of individuals, considering the estimated population in Greek waters is between 180 and 280 animals. Among those encountered, two social groups of females accompanied by calves were identified, as well as an undetermined number of males—with at least one confirmed.

Additionally, an encounter involving 14 individuals, also documented via aerial survey imagery, presents a particularly intriguing case. The animals remained at the surface for several hours, displaying close social interactions, without diving behaviour which is typically observed (e.g., no fluking). The NCC vessel remained with the group from midday until dusk, yet no foraging activity or deep dives were recorded.

The results of the boat visual and acoustic surveys are presented in the following figures.

4.1.1.1 Cetaceans' visual records

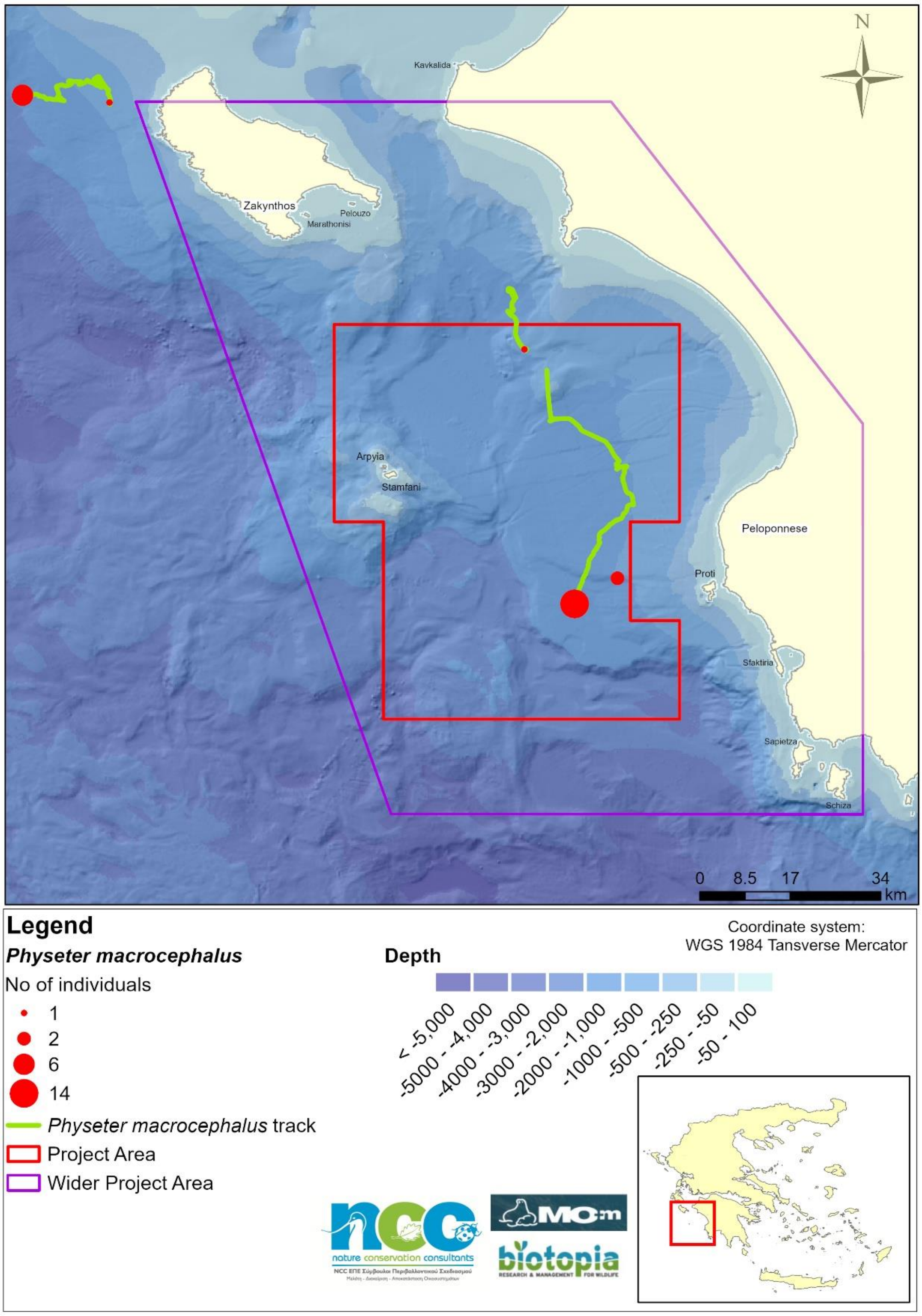

Figure 4-2. Locations of encounters and tracks following sperm whales.

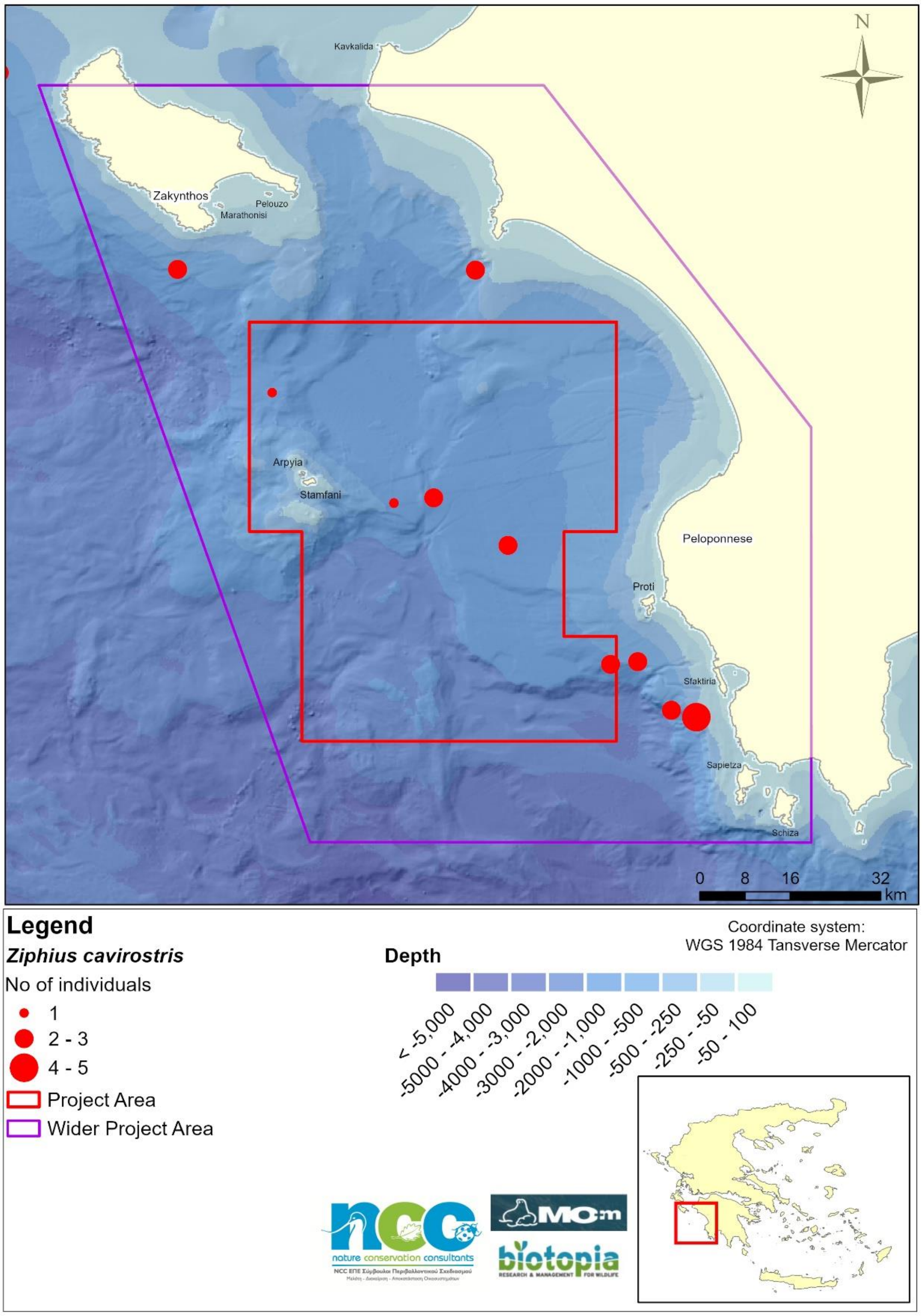

Figure 4-3. Locations of Cuvier's beaked whale visual records.

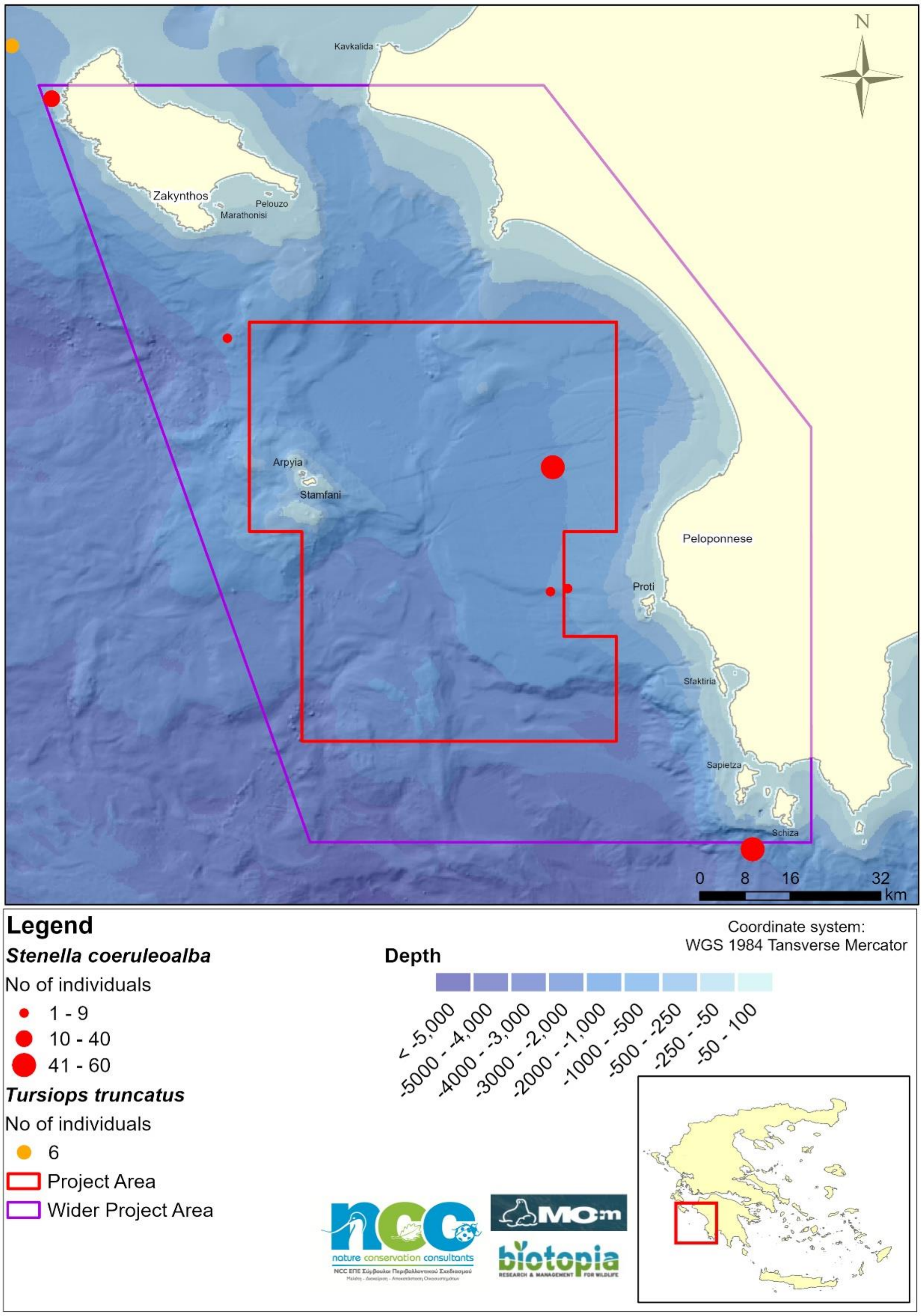

Figure 4-4. Locations of dolphin species visual records.

4.1.1.2 Sperm Whale Photo – Identification

The present section covers the photo-identification analysis carried out between 8 and 16 June 2025. Sperm whales were visually recorded on 13, 14, and 16 June; therefore, all photographic material and corresponding results derive from these three survey days. Processing and visual validation of the images in Flukebook (https://www.flukebook.org/).

<u>13 June 2025</u>

During this survey day, a total of six distinct sperm whale individuals were identified (*Ionio_SW1, SW2, SW3, SW5, SW7,* and *SW12*). The first sighting occurred at 09:17, involving a single individual (SW1) that remained at the surface for approximately one hour and performed a fluke-up at 10:12, providing the first full photographic documentation of the day.

Table 4-2. Summary of sperm whale (Physeter macrocephalus) sightings and behavioural events on 13 June 2025 in the Kyparissiakos Gulf.

Time	Individual ID	Behaviour / Event	Notes
9:17	SW1	First sighting	Whale observed at surface for ~1h
10:12	SW1	Fluke-up	First complete documentation
10:04	-	First sighting	Second encounter – different morphology from SW1
10:05	-	Additional individual sighted	Increasing group size
11:02	-	Group formation	At least four whales are present in same area
13:50	SW2	Fluke-up	Feeding dive
13:53	SW3	Fluke-up	Feeding dive
13:54	SW1	Re-sighting – Fluke up	Surfacing between dives
14:43	SW3	Re-sighting	Resting at surface
15:34	SW1	Re-sighting	Resting at surface
17:19	SW2	Re-sighting	Resting at surface

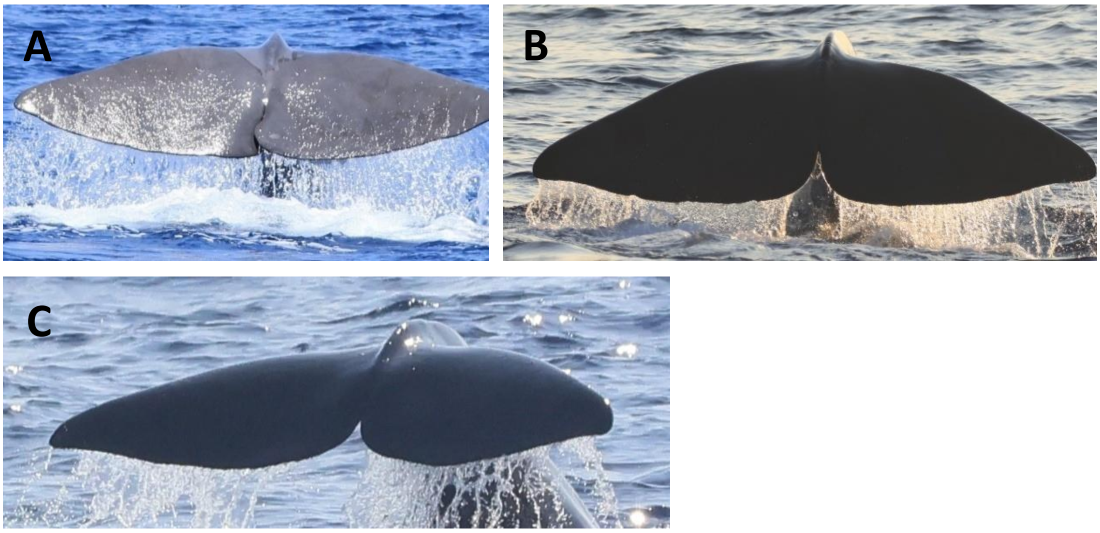

Figure 4-5. Image A shows individual SW1, Image B individual SW2, and Image C individual SW12, all displaying the dorsal (upper) surface of the tail fluke during full extension at the initiation of a deep dive.

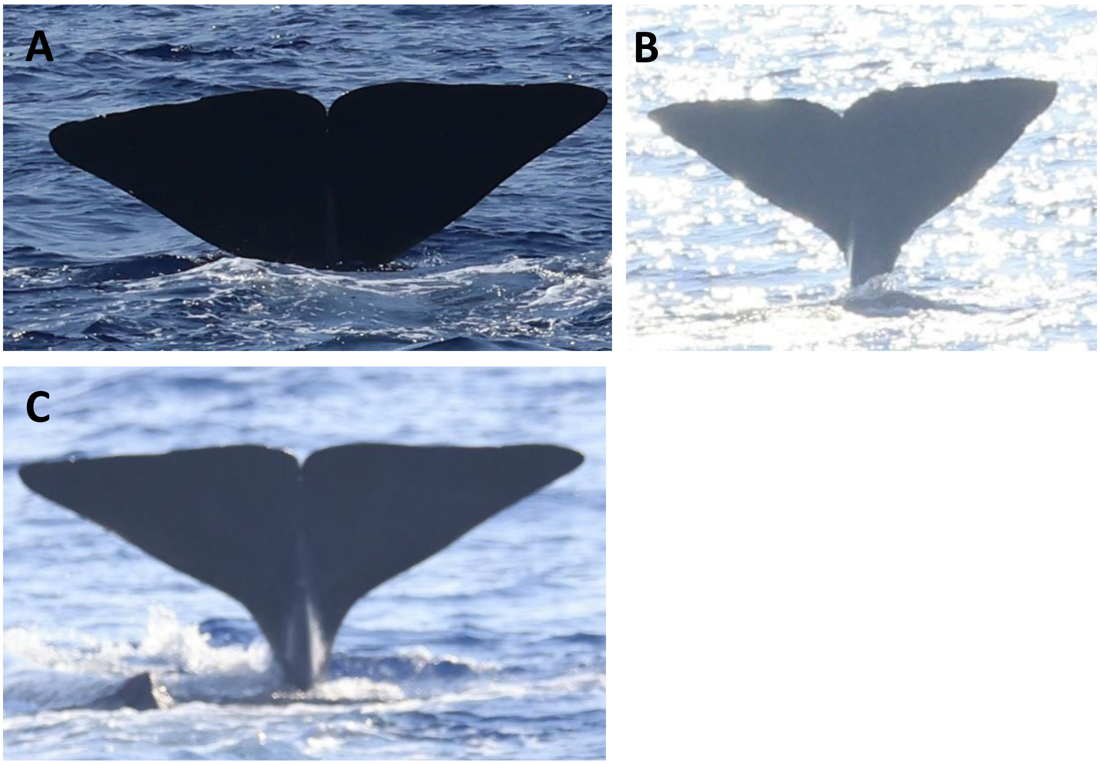

Figure 4-6. Image A shows individual SW3, Image B individual SW5, and Image C individual SW7, all displaying the ventral (underside) surface of the tail fluke during full extension at the initiation of a deep dive.

A second encounter began at 10:43 with the sighting of an individual showing no morphological similarities to SW1. As the survey progressed, the number of whales gradually increased, with a second individual appearing at 10:45, a third at 11:12, and a fourth at 11:15. This steady increase of the sightings indicates that multiple individuals were present within the same general area during the morning hours, with the group eventually reaching a total of seven whales seen simultaneously but only six of them photographed by the end of the observation period (Figure 4-5, Figure 4-6).

Photo analysis and Flukebook results confirmed that certain individuals (SW1, SW2, and SW3) were re-sighted multiple times within the same day (Table 4-2). These repeated detections are consistent with feeding behaviour, as the same whales appeared to perform successive deep dives interspersed with short surface-resting intervals.

Figure 4-7. Five of the six identified Physeter macrocephalus individuals observed on 13 June 2025, forming the cohesive group monitored during the survey in the Kyparissiakos Gulf.

At 13:50, individuals SW2, SW3, and SW1 performed near-simultaneous deep dives, resulting in three consecutive fluke-up sequences. Figure 4-8 illustrates the three whales that remained at the surface during this event.

Figure 4-8. Three Physeter macrocephalus individuals observed remaining at the surface while the other three group members commenced deep diving activity, as evidenced by consecutive fluke-up events.

In total, six distinct individuals were confirmed through photographic analysis. Overall, 13 June 2025 represented the day with the highest photographic coverage and analytical precision of the entire monitoring period.

<u>14 June 2025</u>

During the 14 June survey, a new sperm whale individual (SW13) was recorded, identified through the Flukebook platform and classified as a probable male. The first visual sighting occurred at 07:55, followed by the first complete fluke exposure at 08:02 (Figure 4-9A).

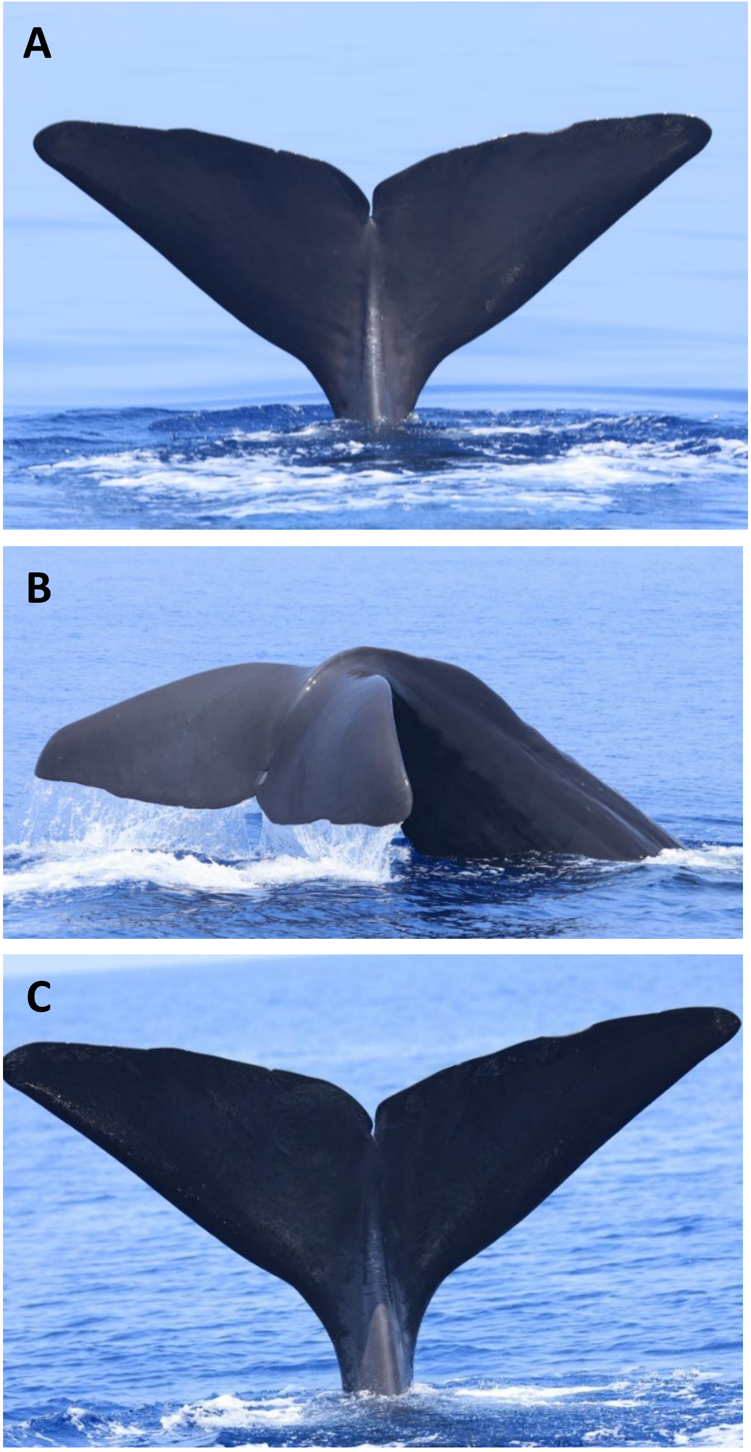

Figure 4-9. Fluke-up photographs of individual Physeter macrocephalus (SW13) captured on 14 June 2025. Images A–C depict the three consecutive deep-diving events of the same whale, recorded at 08:02, 10:07, and 11:05, respectively. Frames A and C show the tail fluke during full extension prior to submersion.

At 10:07, a second fluke-up sequence was documented (Figure 4-9B), followed by a third re-sighting shortly before 11:00, when the whale initiated another deep dive at 11:05 (Figure 4-9C). Multiple photographs confirmed that this was the same individual, maintaining consistent movement and behaviour throughout the observation period.

Individual SW13 remained in the area for approximately three hours, performing three successive deep dives separated by short surface intervals. Its behaviour was calm and steady, characterized by slow directional movement and the absence of other whales in the vicinity. Neither visual nor acoustic detections of additional sperm whales were recorded, indicating solitary foraging activity.

The photographic material obtained was of high quality, providing clear documentation of both the fluke and dorsal fin, with well-defined markings that render individual SW13 fully recognizable for future comparisons.

<u>16 June 2025</u>

On 16 June, the most extensive and prolonged encounter of the survey period was documented. The day commenced at 10:35 with the sight of a single sperm whale; however, within minutes the number of observed individuals increased to three. At 11:28, three whales were recorded travelling southward at a consistent bearing and relatively high speed, maintaining parallel spacing and coordinated surface intervals.

Between 11:45 and 12:40, the aggregation expanded to six individuals, comprising both adult and juvenile individuals. The whales moved in a loosely structured yet synchronized formation, remaining in proximity and exhibiting short, regular surfacings. From that time onward, the group remained continuously visible until approximately 21:30, maintaining a steady southbound trajectory.

Despite the extended duration of the encounter, estimated at approximately ten hours, only a single fluke-up event was successfully documented at 10:46 (Figure 4-10). Consequently, individual photo-identification through Flukebook was not feasible. Nevertheless, continuous visual tracking and supplementary aerial imagery confirmed the presence of at least eleven whales, with up to fourteen individuals observed simultaneously in the vessel’s forward sector.

Although the absence of fluke-up sequences restricted definitive individual identification, the prolonged observation of a large, cohesive group, including juveniles, and their coordinated directional movement strongly suggest social cohesion or collective travelling behaviour within this region of the Kyparissiakos Gulf.

Figure 4-10. Single fluke-up event documented on 16 June 2025, corresponding to individual Physeter macrocephalus SW14. The image captures the full extension of the tail fluke during descent, representing the only complete identification-quality photograph obtained during this survey day.

Figure 4-11. Aggregation of Physeter macrocephalus individuals recorded on 16 June 2025. The image shows at least nine whales travelling in coordinated formation at the surface, part of the larger group of up to fourteen individuals observed during this encounter.

The analysis of photographic data collected in the Kyparissiakos Gulf during June 2025 confirmed the presence of eight distinct Physeter macrocephalus individuals, all recorded between 13 and 16 June. The observations from 13 and 14 June documented repeated sightings of the same individuals within the same day, suggesting foraging activity concentrated in a localized area likely rich in prey resources. In contrast, the 16 June survey was characterized by the presence of a large social aggregation, with at least eleven to fourteen individuals, including juveniles, but no evidence of deep-diving or feeding behaviour. This event is most likely associated with social interaction or collective movement of sperm whales within the area.

The assessment of photographic material demonstrated that the photo-identification method provided consistent and reliable data for both identification and re-sighting, despite constraints related to the limited number of complete fluke-up sequences and variable environmental conditions.

Overall, the June results suggest that the Kyparissiakos Gulf functions as an active habitat for sperm whales during the early summer period, showing evidence of both individual foraging and social aggregation. However, the low sighting rates in September cannot yet be confidently attributed to seasonal variability. The Ionian Sea is an extensive basin with a highly variable bathymetry exceeding 1,000 meters, and the lack of sightings may simply reflect a temporary absence of whales from the specific survey area during that time.

Further data collection and increased monitoring frequency are required to develop more robust, evidence-based conclusions regarding the potential seasonality and habitat use of sperm whales in the Ionian Sea.

Table 4-3. Summary of sperm whale (Physeter macrocephalus) sightings and photo-identification results during the June and September 2025 surveys in the Kyparissiakos Gulf. The table includes observation periods, estimated number of individuals, identified whales, behavioural notes, and photo-ID quality assessment.

Date	Observation period (local time)	Estimated number of individuals	Identified individuals (Flukebook IDs)	Behavioural notes	Photo-ID quality / remarks
13 June 2025	09:17 – 17:20	6	SW1, SW2, SW3, SW5, SW7, SW12	Repeated re-sightings of same individuals; multiple feeding dives	Excellent visibility; multiple fluke-ups (10:12, 13:54, 15:34)
14 June 2025	07:55 – 11:05	1	SW13	Solitary adult male; three successive deep dives (~08:00, 10:07, 11:05); no other whales observed.	High-quality images of fluke and dorsal fin; individual fully identifiable.
16 June 2025	10:35 – 21:30	11–14 (visual & aerial count)	SW14	Large social aggregation including juveniles; steady southward movement; no feeding behaviour observed.	One complete fluke-up (10:46); insufficient data for ID; valuable behavioural documentation.
September 2025 expedition	Two-week period	0 visual (2 acoustic detections)	—	No visual sightings: only two distant acoustic detections recorded.	Indicates possible seasonal movement; further monitoring required.

4.1.1.3 Seabirds visual records

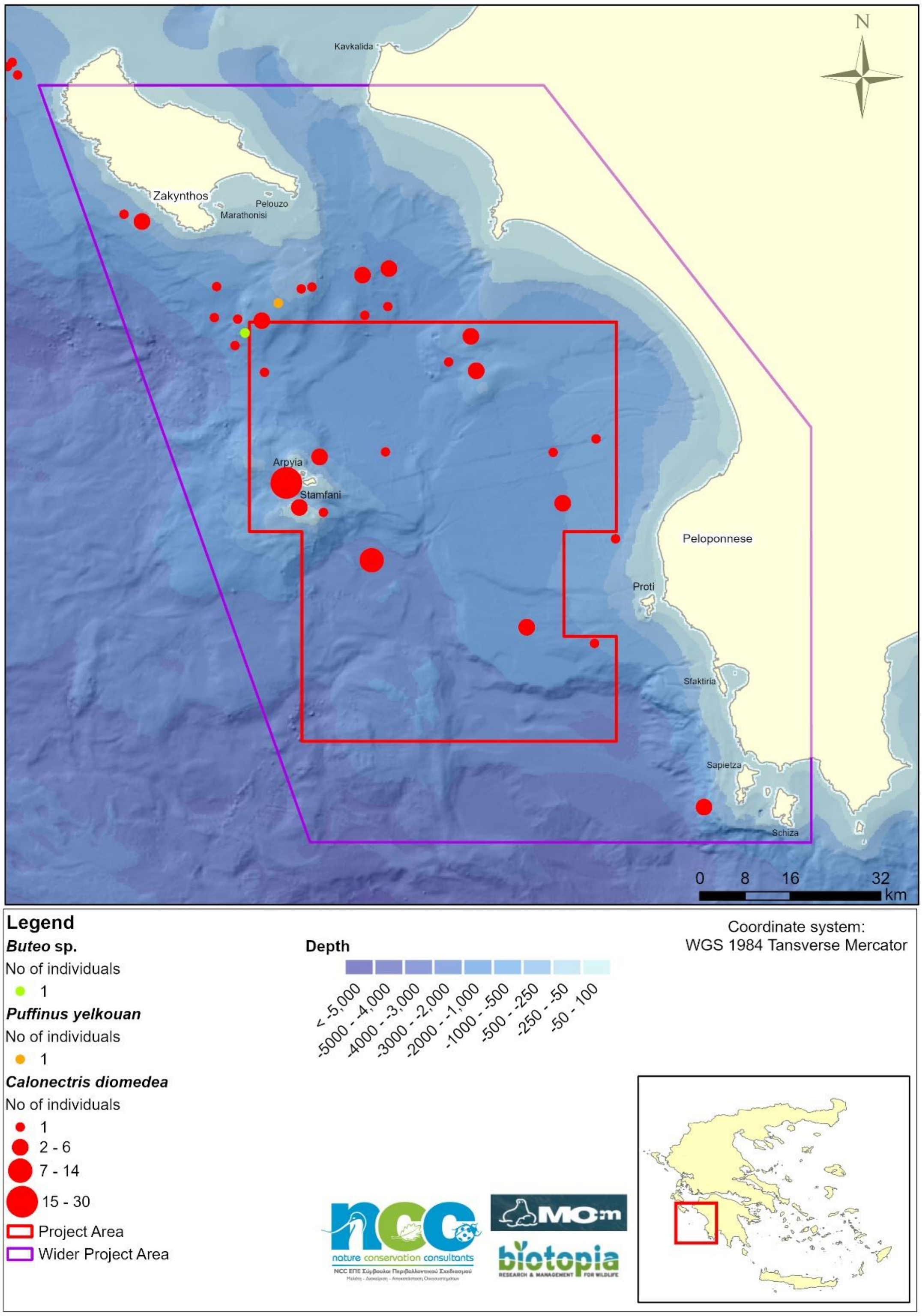

Figure 4-12. Locations of bird species visual records.

4.1.1.4 Cetaceans acoustic records

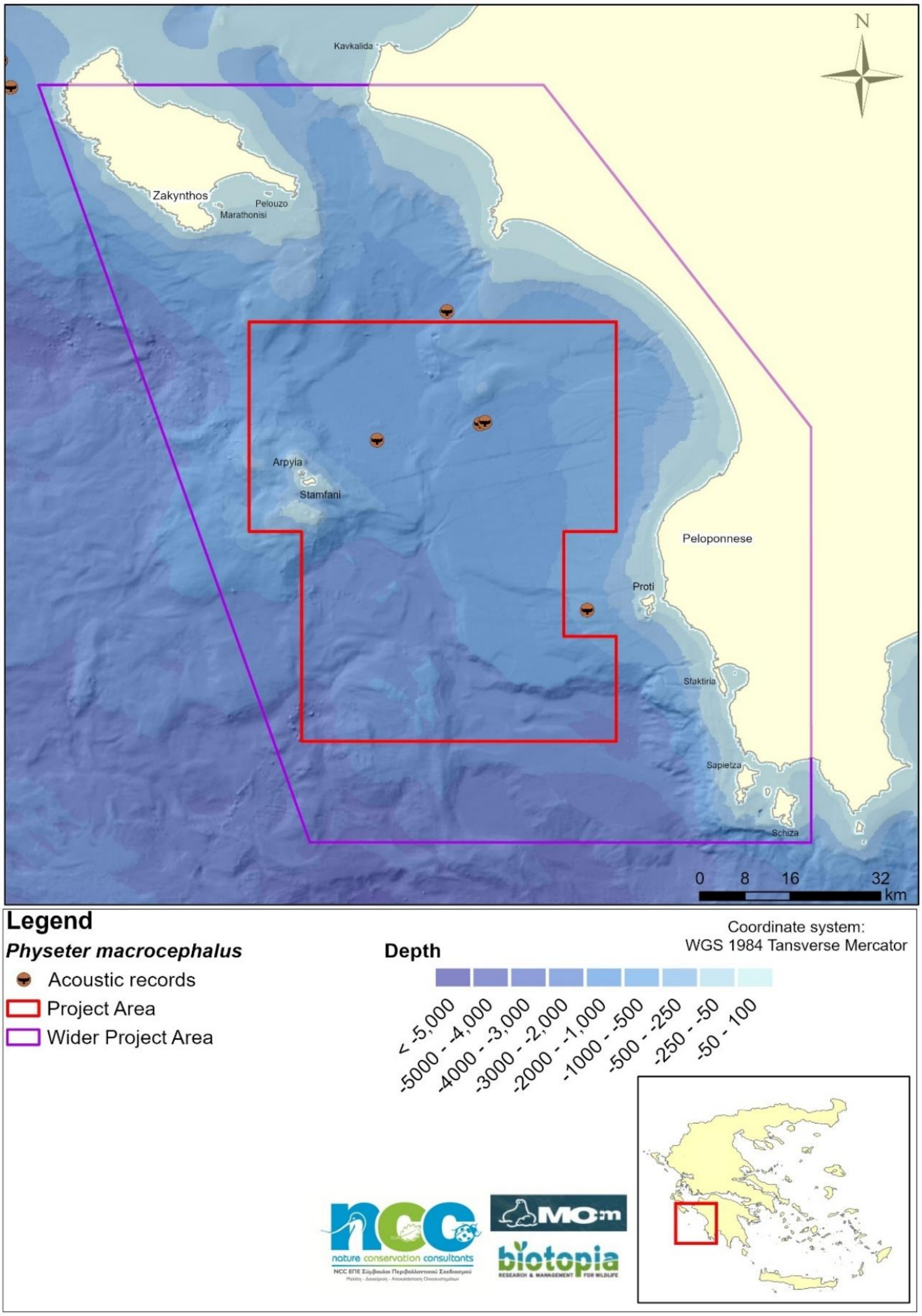

Figure 4-13. Locations of sperm whale acoustic records.

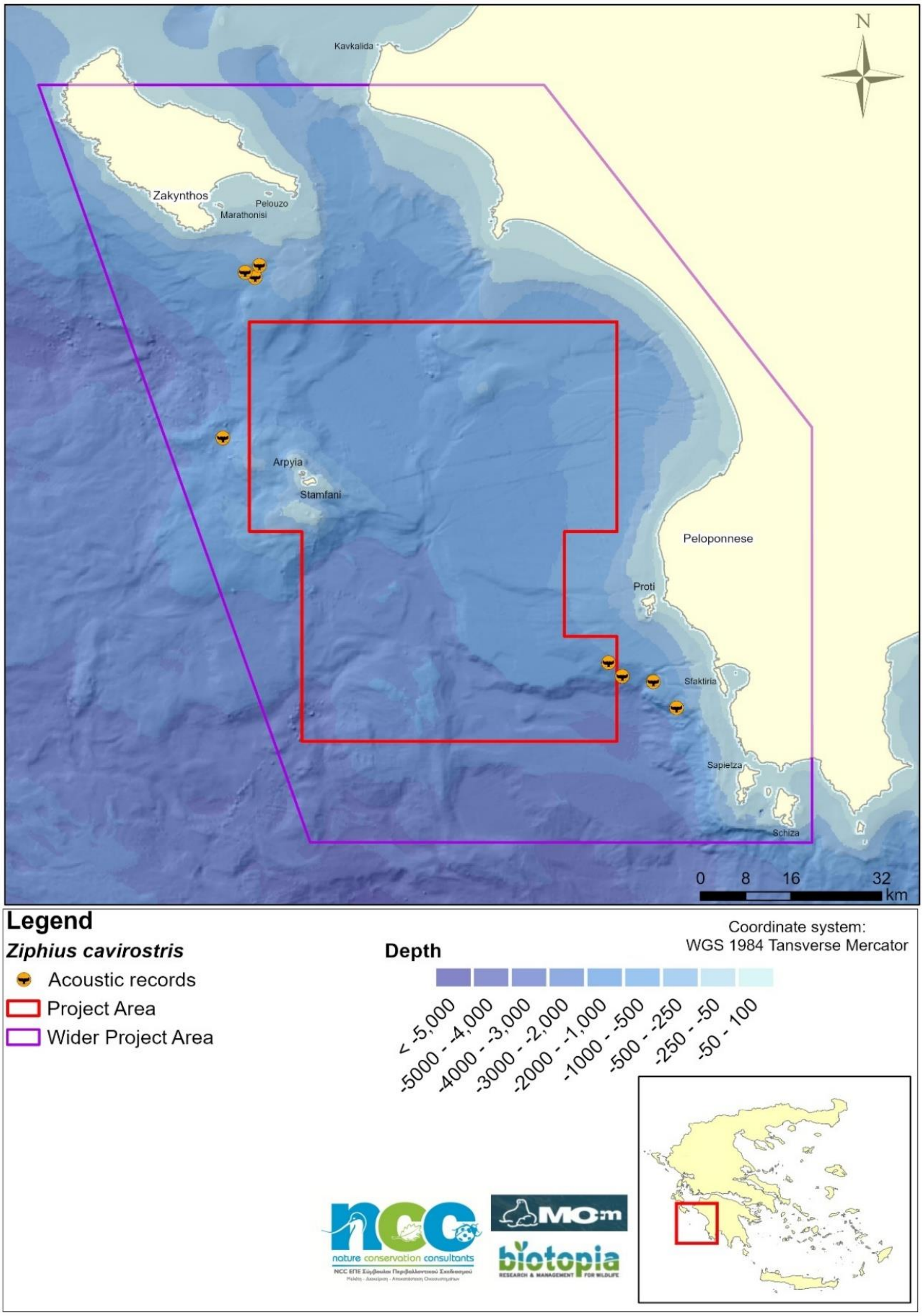

Figure 4-14. Locations of Cuvier's beaked whale acoustic records.

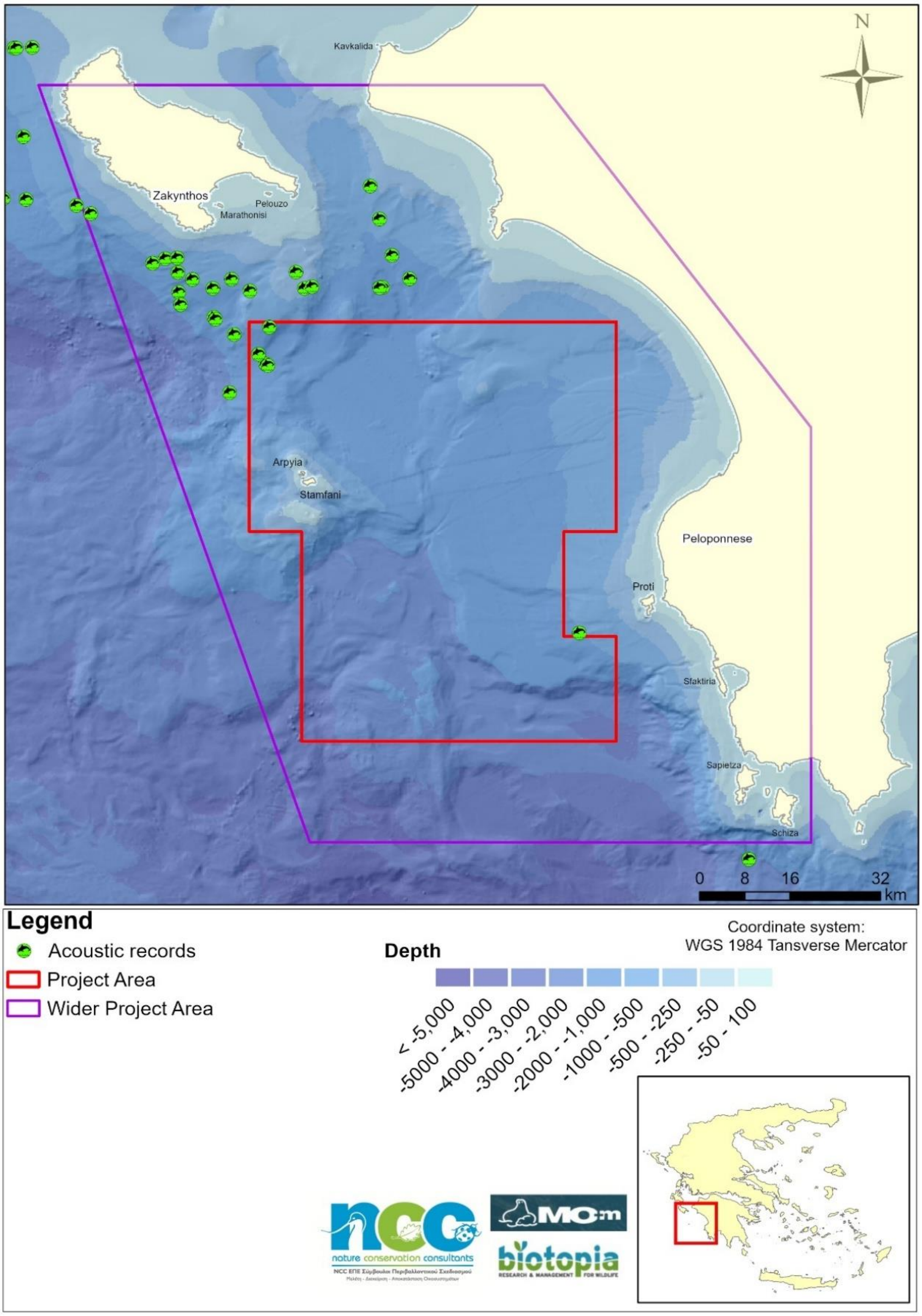

Figure 4-15. Locations of dolphin species acoustic records.

Figure 4-16. Sperm whales during the boat surveys.

Figure 4-17. Cuvier's Beaked whales during the boat surveys

Figure 4-18. Group of Sperm whales with a sailing boat (above) and Scopoli's Shearwater (below).

Figure 4-19. Big group of Striped Dolphins porpoising

Figure 4-20. Striped Dolphins travelling

4.1.2 Aerial surveys

The aerial surveys have been conducted on the 16th and 17th of June 2025 and the 14th and 15th of October 2025. A total of **1850 km** has been inspected, covering the Wider Project Area and the surrounding areas.

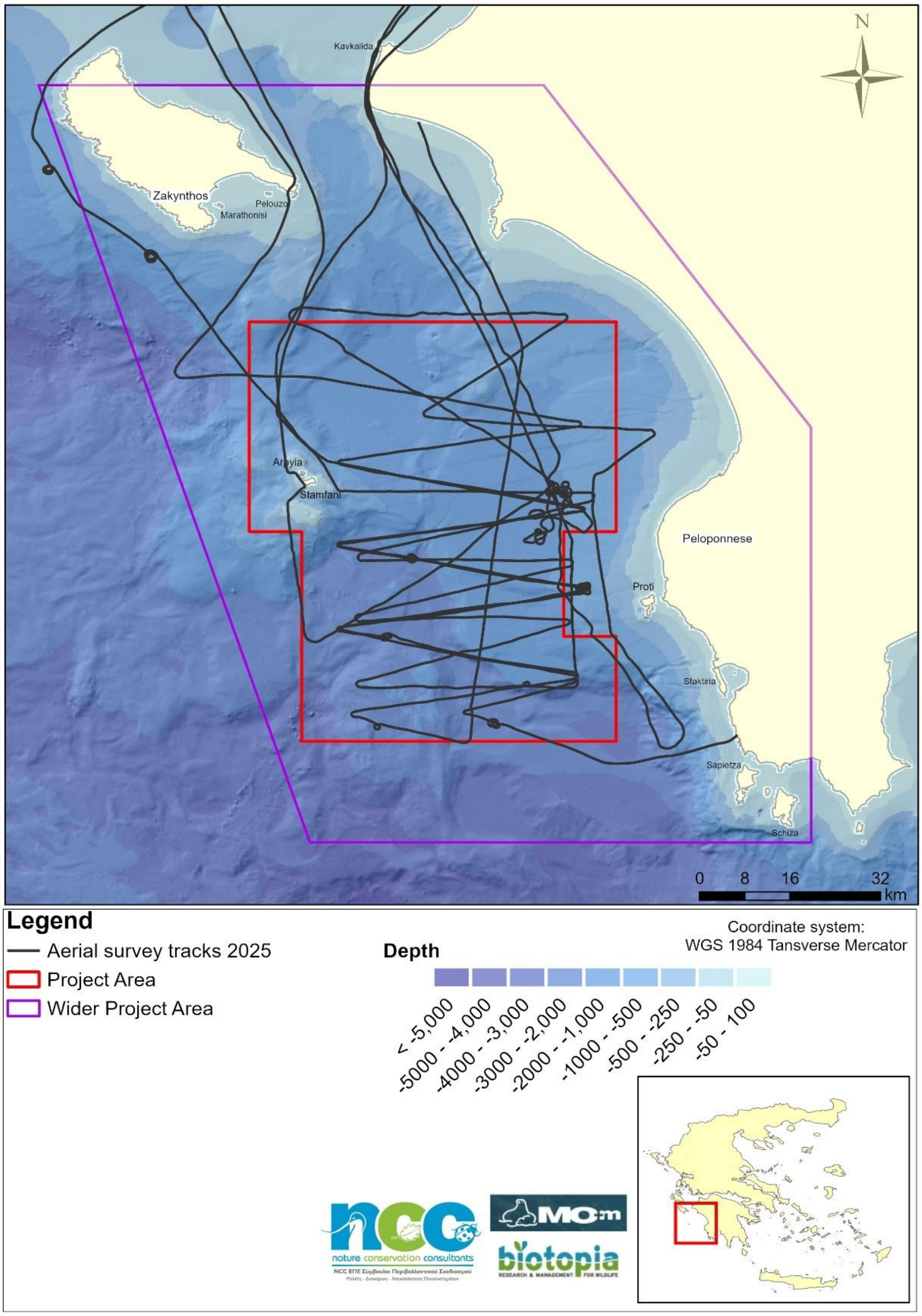

Figure 4-21. Aerial survey tracks

During the aerial surveys the following species were recorded visually inside the Project Area:

- 4 cetacean species: **sperm whale** (*Physeter macrocephalus*), **Cuvier's beaked whale** (*Ziphius cavirostris)*, **striped dolphin** (*Stenella coeruleoalba*) and **Risso's dolphin** (*Grampus griseus*)
- 1 sea turtle species: **loggerhead turtle** (*Caretta caretta*)

Table 4-4. Species recorded during the aerial surveys in the Wider Project Area

Species	**Common name**	**Number of individuals**
Physeter macrocephalus	sperm whale	14
Ziphius cavirostris	Cuvier's beaked whale	1
Stenella coeruleoalba	striped dolphin	18
Grampus griseus	Risso's dolphin	10
Caretta caretta	Loggerhead turtle	2

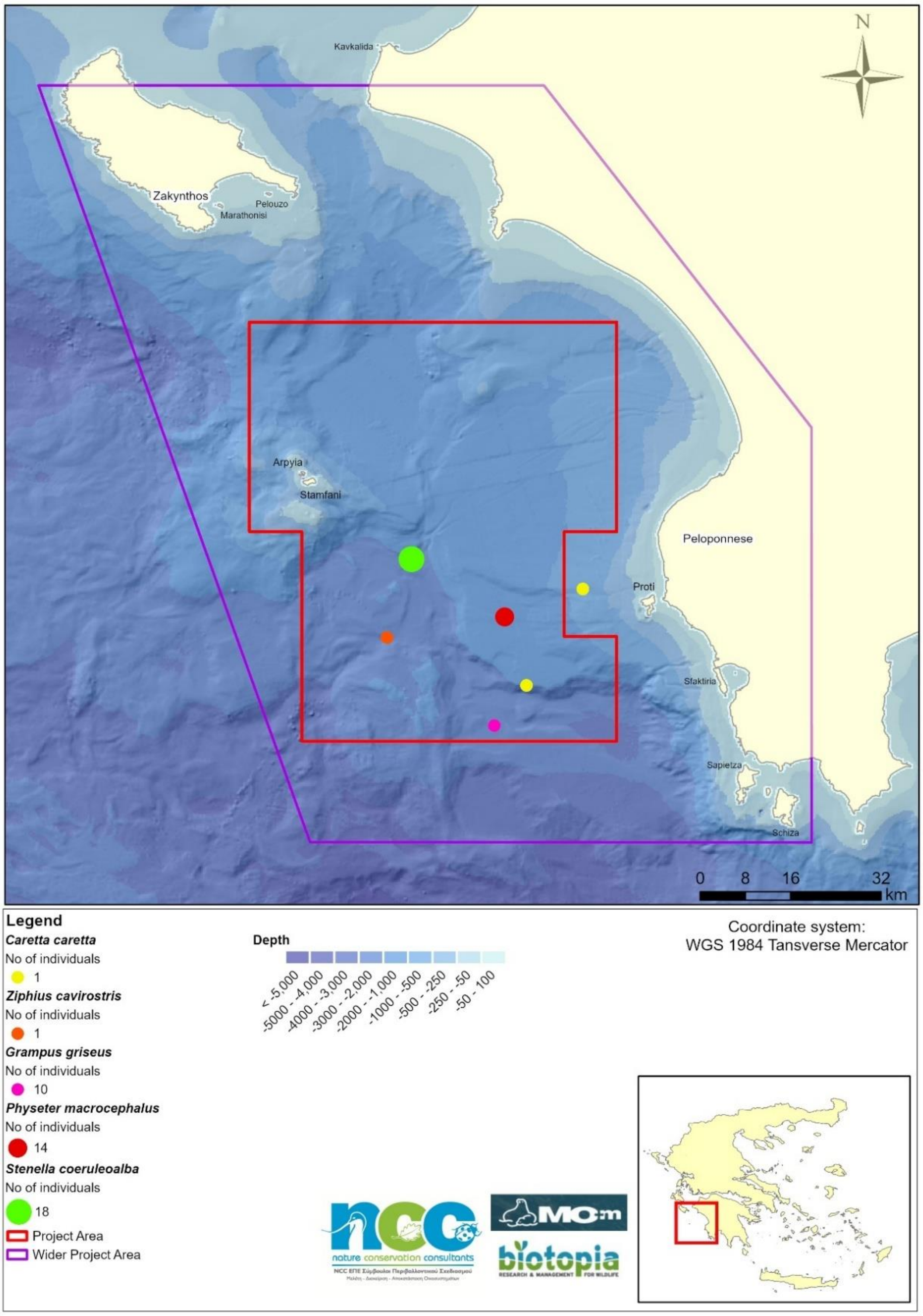

Figure 4-22. Aerial surveys records

Figure 4-23.Group of 14 Sperm whales observed on the 16th of June 2025

Figure 4-24. Cuvier's beaked whale photographed on the 14th of October 2025

Figure 4-25. Loggerhead turtle photographed on the 14th of October 2025

Figure 4-26. Striped dolphins photographed on the 14th of October 2025

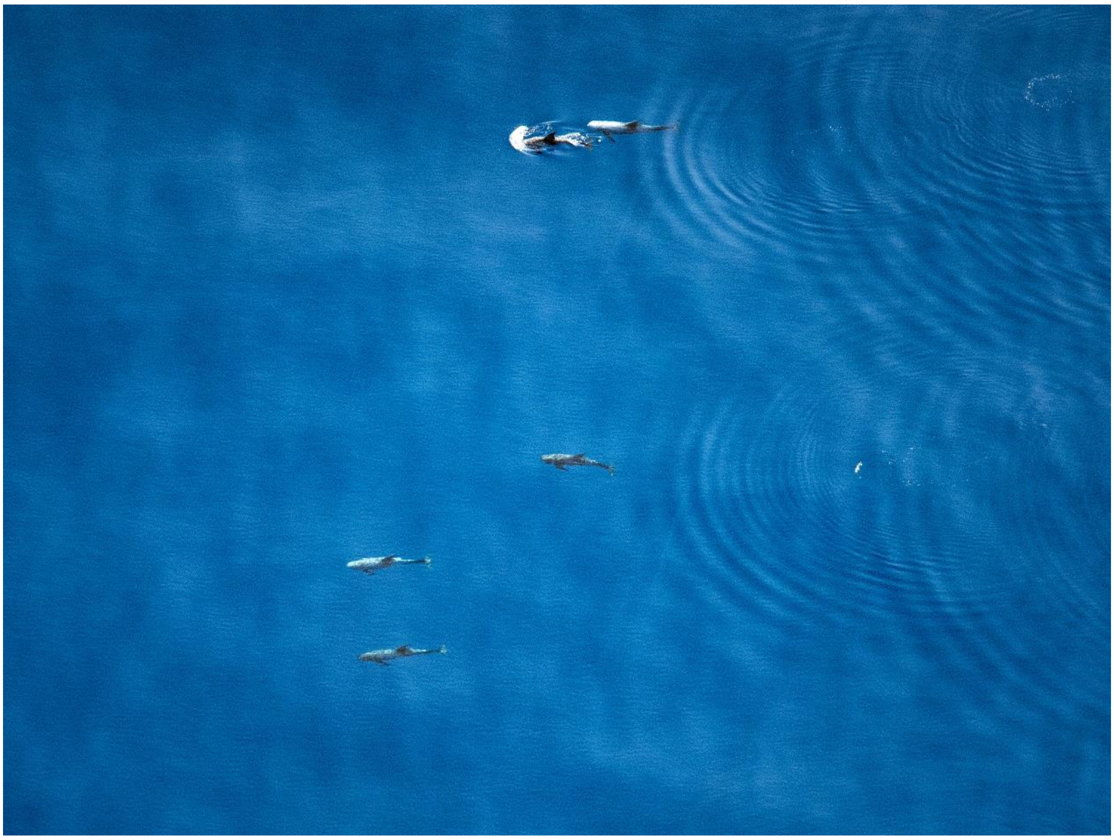

Figure 4-27.Group of 10 Risso's dolphins photographed on the 15th of October 2025

4.2 Coastal surveys

4.2.1 Coastal surveys and cave monitoring for the Mediterranean Monk Seal

During the 2024–2025 monitoring period, systematic monitoring of the Mediterranean monk seal population continued within the framework of the National Rescue and Information Network (RINT), with a particular focus on the southwestern coast of Zakynthos—an area already identified as critically important for the species' reproduction in the Ionian Sea. Moreover, six infrared Camera Traps have been placed in 2 caves on the southwest coast of Zakynthos island, located in the Wider project area. Four of the cameras were scheduled to work in Time Lapse configuration (every 1 hour or every 2.5 hours) while the two others were set in Motion detection configuration. The cameras were placed on the rocky walls of the caves and were positioned in such a way to maximize the coverage of the terrestrial components of the caves (internal beaches).

Through the RINT, a total of 19 monk seal sightings were recorded between 1 July 2024 and 22 October 2025, including 16 live animals and 3 dead. Age classification of the observed individuals comprised of 12adults, 1 subadult, 4 pups, and 2 of unknown age. Sex classification indicated 5 males, 6 females, and 7 individuals of undetermined sex.

The updated data confirms the species' consistently high presence and reproductive activity in the wider Zakynthos area, where an estimate of six pups are born annually. In contrast, the species appears to be only sporadically present in the Kyparissiakos Gulf. Most sightings are concentrated along the southwest coast of Zakynthos, with their spatial distribution presented in Figure 4-28. The specific locations of pup sightings are depicted separately in Figure 4-29, highlighting the core pupping zone.

Two significant negative incidents have been also documented: the deliberate killing of two adult male monk seals as depicted in Figure 4-33 and Figure 4-34.

Given the breeding season of the species is in October, the infrared cameras haven't been retrieved yet. The retrieval of the camera traps is scheduled to take place later in the year after the completion of the yearly pupping period. It should be noted that the data available to date has already documented the importance of one cave as a breeding site, while for the second cave, where cameras were installed for the first time, researchers have assessed from indirect evidence (scats and tracks) that it is frequently used by the monk seals.

These findings reinforce the ecological significance of Zakynthos as a key reproductive hotspot for the Mediterranean monk seal in the southern Ionian Sea. In the upcoming study period, the planned retrieval and data analysis of infrared camera systems in marine caves of southwestern Zakynthos will further support documentation of the area's importance for the species' reproductive activity.

Table 4-5. RINT records within the wider project area classified by age classes and sex.

Date	Longitude	Latitude	Location	Age	Sex	State
8/12/2024	20.72822	37.71731	Zakynthos	Unknown	Unknown	Alive
8/18/2024	20.70467	37.92958	Zakynthos	Adult	Male	Alive
8/19/2024	20.8809	37.81725	Zakynthos	Subadult	Unknown	Alive
9/5/2024	20.75883	37.70097	Zakynthos	Adult	Female	Alive
9/5/2024	20.75883	37.70097	Zakynthos	Adult	Female	Alive
9/5/2024	20.75883	37.70097	Zakynthos	Adult	Female	Alive
9/5/2024	20.75883	37.70097	Zakynthos	Adult	Female	Alive
9/5/2024	20.75883	37.70097	Zakynthos	Pup	Unknown	Alive
9/5/2024	20.75883	37.70097	Zakynthos	Pup	Unknown	Alive
9/5/2024	20.75883	37.70097	Zakynthos	Pup	Unknown	Alive
9/27/2024	20.75883	37.70097	Zakynthos	Adult	Female	Alive
9/27/2024	20.75883	37.70097	Zakynthos	Adult	Female	Alive
9/27/2024	20.75883	37.70097	Zakynthos	Pup	Unknown	Alive
1/30/2025	20.90062	37.73606	Zakynthos	Adult	Male	Dead
4/1/2025	20.89257	37.73418	Zakynthos	Adult	Male	Dead
4/7/2025	20.86824	37.81798	Zakynthos	Adult	Male	Dead
7/8/2025	20.70528	37.93107	Zakynthos	Unknown	Unknown	Alive
9/17/2025	20.7087	37.72813	Zakynthos	Adult	Male	Alive
9/24/2025	20.70533	37.93026	Zakynthos	Adult	Unknown	Alive

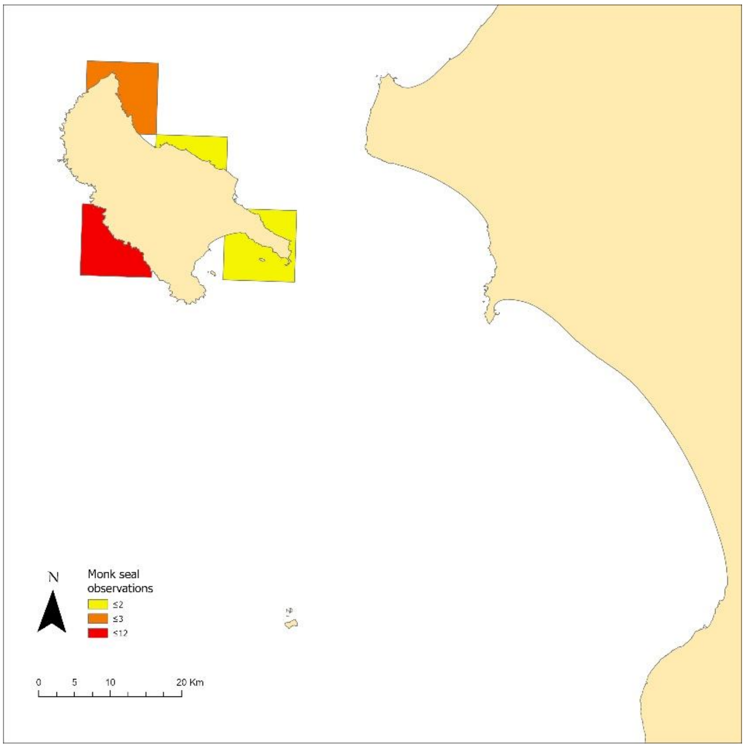

Figure 4-28. Geographic distribution of sightings during the period 1/6/2024-22/10/2025 within the wider project area.

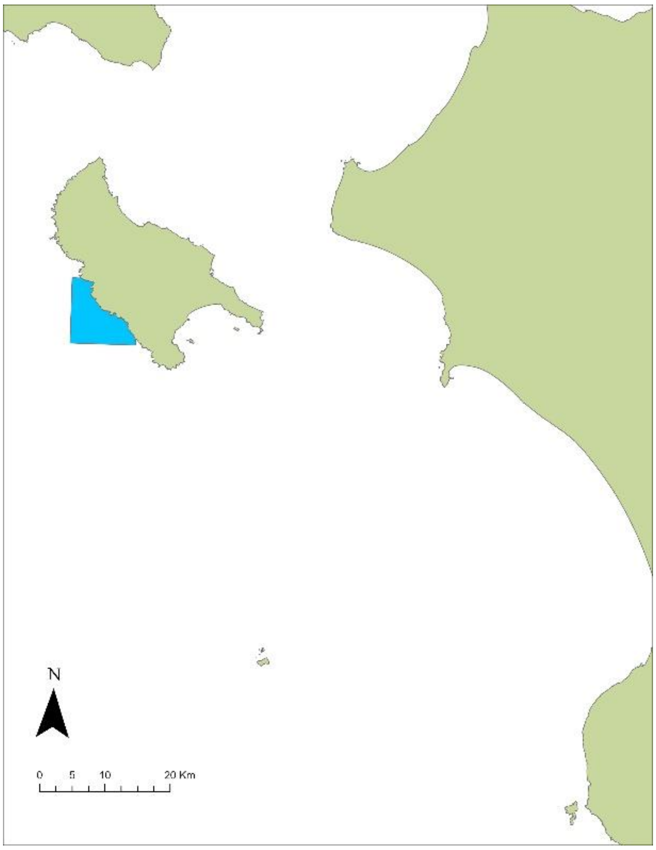

Figure 4-29. Geographic distribution of pup sightings(N=4) during the period 1/6/2024-22/10/2025 within the wider project area.

Figure 4-30. General view of the SW coast of Zakynthos was significant monk seal pupping activity has been recorded.

Figure 4-31. A monk seal pup resting on the beach in a marine cave at the SW coast of Zakynthos

Figure 4-32. A group of seven monk seals in a cave at the SW of Zakynthos island

Figure 4-33. Deliberately killed adult male monk seal that was found washed ashore within the National Marine Park of Zakynthos in February 2025.

Figure 4-34. Deliberately killed adult male monk seal found in Zakynthos on the 30th of January 2025

Figure 4-35. Adult male monk seal found dead in Zakynthos on the 1st April 2025

4.3 Colony surveys - Telemetry

4.3.1 Colony surveys of Scopoli's Shearwater at the Strofades islets SPA

Two GSM-enabled stationary nest cameras were deployed on June 26, 2024, and retrieved on October 3, 2024, at two Scopoli's Shearwater (*Calonectris diomedea*) nests located on the Strofades islets. These cameras operated continuously throughout the entire breeding season, providing a comprehensive dataset that includes high-resolution images, video recordings, and ambient audio. This dataset offers valuable insights into key aspects of the species' breeding behavior, chick development, and potential disturbances from natural predators or human activity.

The two cameras recorded the condition and activity of each nest on a daily basis, from 11/07/2024 to 02/10/2024. The audiovisual material was stored on OneDrive and subsequently analyzed separately for each nest. Based on the recordings, an ethogram was created in which the behaviors of the individuals (parents) were coded.

The factors considered during the analysis were:

(a) the recording date,

(b) the time of behavior occurrence,

(c) the type of behavior,

(d) the number of individuals inside and outside the nest, and

(e) the sex of the individual (where it was possible to identify).

Sex identification was based on the frequency range of the individuals' vocal calls, as the species exhibits vocal sexual dimorphism, with males producing calls of a higher fundamental frequency compared to females. Specifically, for parental care behavior through feeding, the number of feeding events per day and the duration of each feeding event inside the nest were additionally recorded.

The purpose of this study was to:

(a) calculate the feeding rate per nest during the breeding period,

(b) determine the temporal distribution of feeding events throughout the night,

(c) estimate the duration and frequency of the parents' absence from the nest, and

(d) identify potential differences between males and females in feeding rate and feeding duration.

Figure 4-36. Footage from Scopoli's Shearwater nests from the GSM cameras

The data from the two nests showed variation both in the duration and in the frequency of feeding events during the breeding season (from early July to early October) (Figure 4-37). Specifically, feeding duration exhibited higher values and greater dispersion during the first weeks of July, followed by a gradual decrease toward the middle of the period (August) and lower or sporadic values toward the end (September).

Furthermore, the number of feeding events per day was also higher in July, progressively decreasing over the following months, following a similar downward trend to that of feeding duration. In general, both the total time the parent remained inside the nest and the number of nest visits tended to decline toward the end of the breeding season.

Between the two nests, quantitative differences were observed in the magnitude of the values; however, in both cases, the temporal pattern of change remained similar, with high parental activity at the beginning and a marked reduction toward the end.

It should be mentioned that the presence of rats was confirmed in Nest A (5 days of presence in total), while no rats were recorded in Nest B.

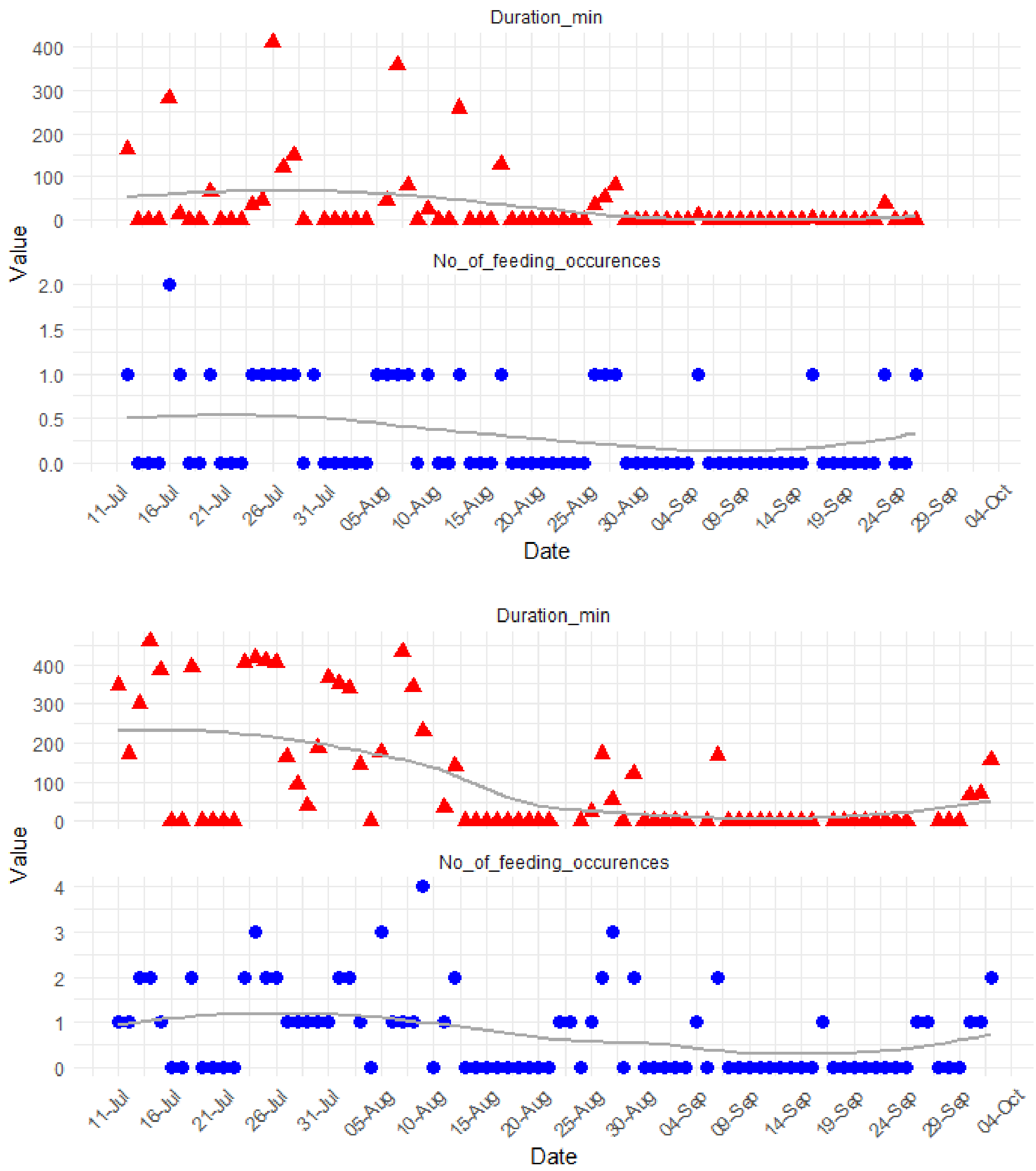

Figure 4-37. Duration and frequency of feeding events during the breeding season in nest A (above) and B (below)

The analysis of the nocturnal temporal distribution of feeding events (20:00–06:00) showed that parental activity follows a non-uniform pattern and tends to cluster within distinct time intervals (Figure 4-38). In Nest B, the majority of feedings occurred between 22:00 and 02:00, with the highest activity observed between 22:00 and 23:00, gradually decreasing during the early morning hours. In Nest A, feeding events were also concentrated between 22:00 and 01:00; however, secondary peaks were recorded around 02:00 and 04:00, indicating the presence of two distinct periods of increased feeding activity.

A differentiation in the temporal pattern of parental arrivals was observed between the two nests (Figure 4-39). In Nest A, entries into the nest were recorded mainly around midnight, whereas in Nest B, parental presence peaked between 21:00 and 23:00, indicating different temporal strategies of nocturnal activity. However, the considerably smaller number of recordings in Nest A (N = 8) compared to Nest B (N = 78) substantially limits the statistical lower of the analysis rendering the comparison between the two activity profiles indicative rather than reliably comparable.

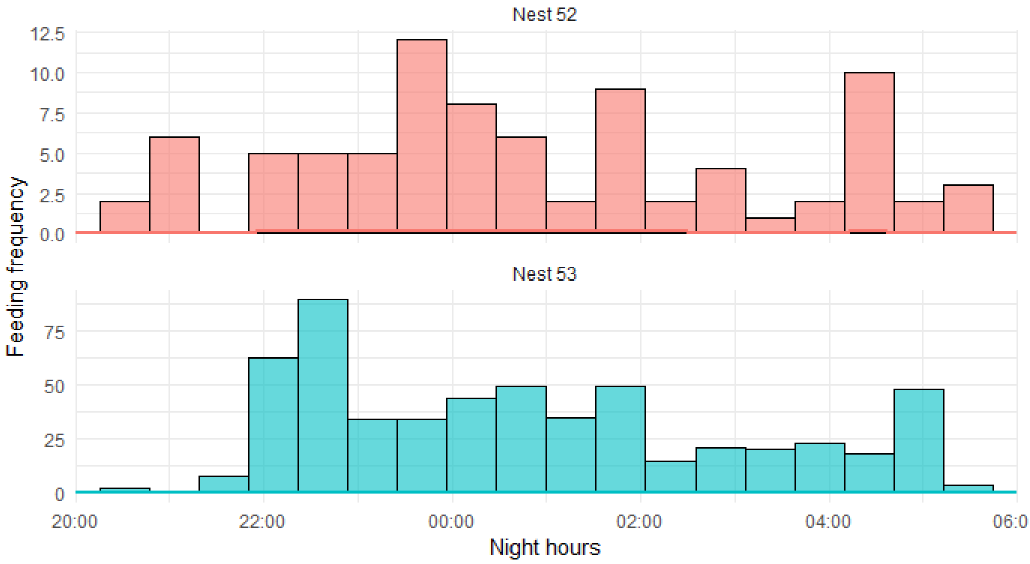

Figure 4-38. Night-time feeding activity (Nest 52=nest A and Nest 53=nest B)

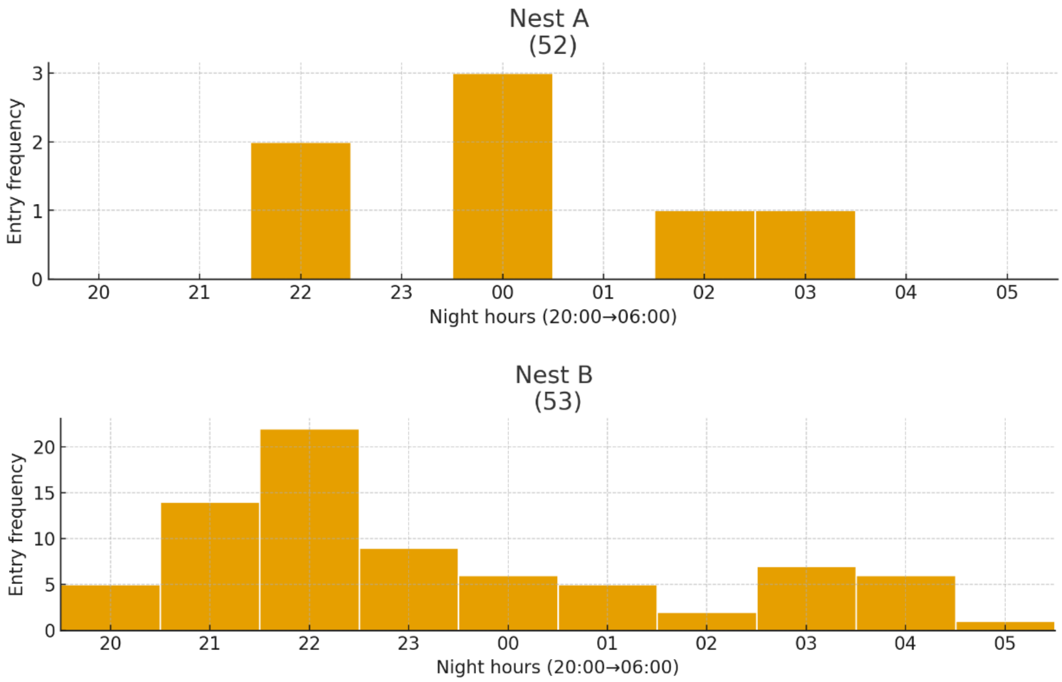

Figure 4-39. Arrival time of parents in nests A and B

According to the data presented in Table 4-6 and Table 4-7, both pairs exhibited extended periods of absence from their nests, being away for more than half of the days during the breeding season. The longest absence was recorded at Nest A, lasting for 10 consecutive days in September, while at Nest B the longest absence occurred in mid-August and lasted for 9 days. In contrast, the lowest daily absence values were observed in early July in both nests, a period that coincides with the initial stages of chick development. This finding is expected, as the increased demands for thermoregulation, feeding, and protection during this phase require greater parental presence in the nest, significantly limiting the possibility of prolonged absences.

Table 4-6. Absence of parents from the nests

Nest	Streak #	Start Date	End Date	Length (days)
A	1	2024-07-13	2024-07-15	3
A	2	2024-07-18	2024-07-19	2
A	3	2024-07-21	2024-07-23	3
A	4	2024-07-29	2024-07-29	1
A	5	2024-07-31	2024-08-04	5
A	6	2024-08-09	2024-08-09	1
A	7	2024-08-11	2024-08-12	2
A	8	2024-08-14	2024-08-16	3
A	9	2024-08-18	2024-08-25	8
A	10	2024-08-29	2024-09-04	7
A	11	2024-09-06	2024-09-15	10
A	12	2024-09-17	2024-09-22	6
A	13	2024-09-24	2024-09-25	2
B	1	2024-07-16	2024-07-17	2
B	2	2024-07-19	2024-07-22	4
B	3	2024-08-04	2024-08-04	1
B	4	2024-08-10	2024-08-10	1
B	5	2024-08-13	2024-08-21	9
B	6	2024-08-24	2024-08-24	1
B	7	2024-08-28	2024-08-28	1
B	8	2024-08-30	2024-09-03	5
B	9	2024-09-05	2024-09-05	1
B	10	2024-09-07	2024-09-15	9

Nest	Streak #	Start Date	End Date	Length (days)
B	11	2024-09-17	2024-09-24	8
B	12	2024-09-27	2024-09-29	3

Table 4-7. Max and min days of parents' absence from the nests

	Nest A	Nest B
% of days absent	68.8	53.6
Maximum consecutive number of days absent (days)	10	9
Mean consecutive number of days absent (days)	4.08	3.75
Minimum consecutive number of days absent (days)	1	1
Total number of days absent	53	45
Total number of nest monitoring days	77	84

The days of recording and identifying the female and male individuals were 4 for Nest A and 16 for Nest B.

In Nest A, the male shows a wide temporal spread, indicating inconsistent presence at the nest, while the female displays a narrower distribution, with her activity concentrated later in the night, just before dawn (03:00–05:00) (Figure 5).

In Nest B, both sexes exhibit a more compact temporal distribution; however, the female shows later median feeding times compared to the male.

Overall, the results indicate sex-specific temporal strategies, with females remaining active later into the night.

Furthermore, according to the Mann–Whitney U test, there is a significant difference in feeding times between males and females in Nest A ($U = 32.0$, $p = 0.018$), indicating that the two sexes do not follow a common temporal activity pattern. A similar but stronger effect was observed in Nest B ($U = 1838.0$, $p < 0.00001$), demonstrating pronounced differentiation between sexes. These findings confirm the presence of sex-specific temporal strategies in both nests, with females entering the nest significantly later in the night than males.

However, it is important to note that in Nest B, there were several days ($N = 12$) during which both the male and female were simultaneously present in the nest or in its immediate vicinity.

It should also be considered that the available sample per nest is limited, which reduces the statistical power of the analyses and limits the ability to draw robust conclusions. Collecting additional data is therefore necessary to strengthen the reliability of the results and to allow for more well-supported interpretations.

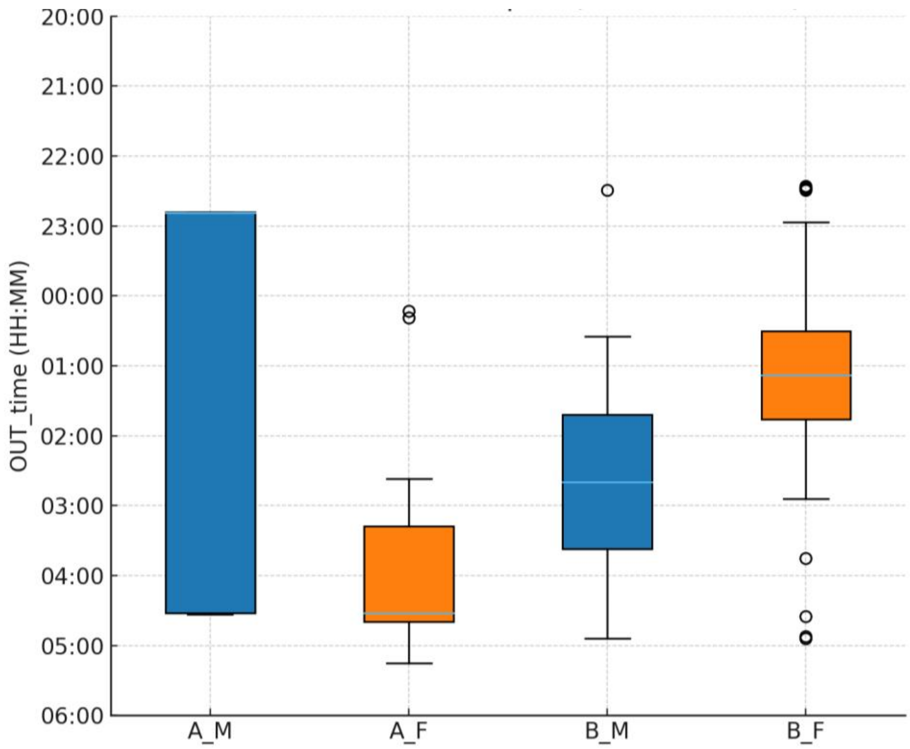

Figure 4-40. Boxplot of feeding time for male and female individuals in both nests

The analysis of the nocturnal behavior of the two pairs in Nests A and B revealed patterns of parental activity, with high feeding rates and frequent nest attendance during the early stages of the breeding season, which gradually declined toward the end. High parental activity in the initial phases reflects the increased need for thermoregulation, protection, and frequent feeding of the chicks, which have limited thermoregulatory capacity.

At the same time, the temporal distribution of feedings and nest visits during the night showed clustering in specific time windows (22:00–02:00), suggesting non-random and possibly energetically optimized behavior. Significant differences were observed between sexes, with females showing later nest attendance times. However, additional data collection is required to support these findings with greater reliability.

Finally, both nests exhibited extended periods of absence, with duration and frequency varying according to the stage of the breeding attempt. The species appears to employ a dual foraging strategy, in which parents alternate between short, nearshore foraging trips and longer trips to balance immediate chick provisioning with their own energetic maintenance (Phillips et al., 2009). It has been found that the intensity and frequency of this strategy are regulated by food availability in the broader colony area, resulting in individuals adjusting their behavior in environments with fluctuating food abundance (Burke & Montevecchi, 2009).

Within this context, extended and repeated periods of nest absence likely reflect low local food availability, forcing parents to undertake energetically costly long-range trips to secure sufficient resources for self-maintenance and successful chick rearing. Nevertheless, it should be noted that the available sample per nest is limited, reducing the statistical power of the analyses and constraining the ability to draw robust conclusions. Collecting additional data is therefore essential to strengthen the reliability of the results and to allow for more well-supported interpretations.

Based on the data from the satellite transmitters, there is a clear behavioral difference between adults and juveniles Scopoli's shearwaters during the post-breeding season. The young birds leave the colony and head directly westward to their wintering grounds in the Atlantic, whereas the adults first disperse either to the Adriatic Sea or the Corinthiakos Gulf, where they remain for several days before beginning their migration toward the Atlantic (Figure 4-41).

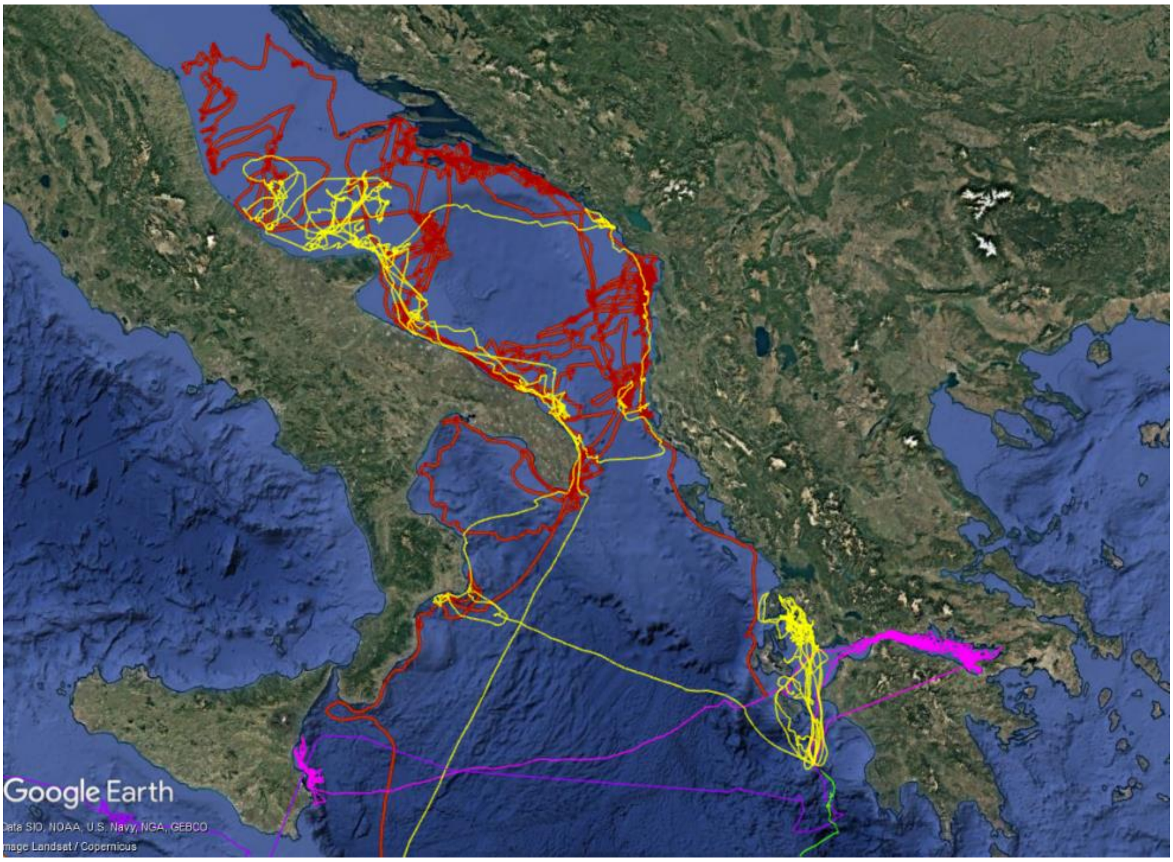

Figure 4-41. Tracks of tagged Scopoli's shearwaters (youngs: green and purple lines), adults: yellow, red and magenta lines)

4.3.2 Sea turtle telemetry data analysis

Following the loggerhead turtle (*Caretta caretta*) satellite and GSM telemetry tagging efforts that have taken place over previous years (from 2019 to 2024), data analysis has led to the publication of two peer-reviewed articles (Rees et al., 2025a, Rees et al., 2025b), with an additional manuscript in preparation.

The first published study (Rees et al., 2025a) focused on Kyparissia Bay, which hosts the largest loggerhead nesting aggregation in the Mediterranean. Using satellite and GSM telemetry in combination with drone surveys, researchers tracked the interesting movements of female turtles during the breeding season, which spans from late May to August.

From the data analyzed till the present date the turtles predominantly remained nearshore, within the 50 m isobath, and within proximity to their nesting sites in the southern section of the bay (from Elaia to Kalo Nero). A notable hotspot was also identified within the sheltered waters of Kyparissia harbor.

The study further updated the estimated clutch frequency for this population, indicating an average of 3.3 to 3.5 clutches per turtle per season, slightly lower than earlier estimates but still among the highest reported in the Mediterranean.

The second study (Rees et al., 2025b) focused on the dispersal and foraging strategies of adult loggerhead sea turtles breeding in Kyparissia Bay. Argos satellite transmitters were deployed in 11 adult individuals in order to study their migratory routes and foraging strategies during the post-breeding period.

End points for the tracked turtles were grouped into four distinct regions: Aegean Sea (end point for 3 turtles), Adriatic Sea (3 turtles), northern Ionian Sea (3 turtles) and Tunisian plateau (2 turtles). Six turtles migrated to restricted area foraging sites, 1 turtle remained nomadic for the entirety of its tracking duration, 2 turtles were semi-nomadic incorporating both restricted area foraging and large-scale movements during their tracking period, and the tracks of the final 2 turtles ceased before their behaviour type could be determined, but sedentary behaviour type was inferred.

The turtles generally moved to locations that had been previously identified by flipper tag recaptures, however the tracking identified routes taken to get there, which were often highly convoluted. These foraging sites, also identified through other tracking studies of loggerhead turtles nesting elsewhere in Greece and from Cyprus, were often sites of high fishing activity and cause for concern for turtles present there.

The full articles are presented in Annex II.

5 Conclusions

During 2025, all planned activities were successfully completed. Both boat-based (visual and acoustic) and aerial surveys were conducted within the project area in June, September and October 2025. Four cetacean species were recorded: the sperm whale (*Physeter macrocephalus*), Cuvier's beaked whale (*Ziphius cavirostris*), Risso's dolphin (*Grampus griseus*) and striped dolphin (*Stenella coeruleoalba*), all typical species of the deep waters in the Project Area.

The most notable finding was the observation of sperm whale groups, both inside and outside the Project Area. Particularly significant was the encounter with a group of 14 individuals in June. This group not only represented an unusually large aggregation but also exhibited atypical behavior, which remains insufficiently understood and warrants further investigation.

By combining the visual and acoustic surveys with the photo-identification analysis during June 2025, it is estimated that a total of 20 to 21 sperm whales were recorded within the wider project area and its surroundings, which is an exceptionally high number of individuals, considering the estimated population in Greek waters is between 180 and 280 animals.

It is worth noting that encounters with sperm whales during autumn were noticeably fewer compared to June. However, it remains unclear whether this difference reflects seasonal changes in the species' distribution or is the result of variations in sampling effort or other non-ecological factors.

In contrast, Cuvier's beaked whales were encountered more frequently in autumn than in early summer, though the factors influencing this pattern are still unknown.

Additionally, Scopoli's Shearwater (*Calonectris diomedea*) was the most abundant seabird during the boat surveys, as the species breeds on the Strofades Islands—home to the largest colony in Greece—and utilizes the broader project area as a feeding habitat.

The installation of GSM cameras at Scopoli's Shearwater nesting sites in July 2024 allowed for continuous monitoring throughout the entire breeding season. Analysis of the collected footage provided valuable insights into the species' breeding ecology, particularly in relation to parental behavior, including feeding rates and their temporal patterns during the critical chick-rearing period.

The analysis of GSM cameras data in two nests of the species revealed that parental activity, including feeding and nest attendance, was highest during the early stages of the breeding season and declined toward the end. Feeding and nest visits clustered between 22:00 and 02:00, suggesting non-random, possibly energetically optimized behavior, with females tended to attend the nest later than males. Both nests showed extended periods of absence, likely reflecting a dual foraging strategy where parents alternate short nearshore trips with longer trips to balance chick provisioning and self-maintenance. Variations in this strategy appear linked to local food availability. However, the limited sample size reduces the statistical power of these findings, emphasizing the need for additional data to support more robust conclusions.

The pilot implementation of the nest camera monitoring has been rather successful, in recording the timing and efficiency of the parental feeding behavior at the colony of Strofades and providing valuable insights for the breeding ecology of the species. A further expansion of the method would be desirable for future research on the species in this important colony.

Coastal surveys focused on the Mediterranean monk seal (*Monachus monachus*) reaffirmed the importance of the southwestern region of Zakynthos Island as a key reproductive site for the species in the South Ionian Sea. Between July 2024 and October 2025, 19 sightings were recorded (16 live, 3 dead), including adults, sub-adults, and pups, confirming high presence and ongoing reproduction, with an estimated six pups born annually. Most sightings were concentrated along the southwest coast of Zakynthos, highlighting core pupping zones, while the species was only sporadically observed in the Kyparissiakos Gulf. Two incidents of deliberate killing of adult males were documented.

Moreover, six infrared cameras were installed in two caves to monitor the terrestrial components of the caves. Data from the cameras, which will be fully retrieved and analysed after the end of the breeding season, already indicates the importance of one cave as a breeding site and suggest frequent use of the second cave. These findings reinforce Zakynthos' ecological significance as a key reproductive hotspot for the Mediterranean monk seal.

Finally, telemetry studies on loggerhead turtles (*Caretta caretta*), conducted during previous phases of the project, have generated significant findings. These results have contributed to peer-reviewed publications, enhancing our knowledge of the species' ecological requirements within the region.

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Annex I: Survey protocols

ESAS protocol datasheet for collection of seabird data

Empty species datasheet

BIRD DATA Ship-based seabird surveys EUROPEAN SAS / Royal NIOZ

Date:	Ship:	Obs.:	Page: of

Distance[1]:
F = in flight
A = swims, 0-50m
B = swims, 50-100m
C = swims, 100-200m
D = swims, 200-300m
E = swims, >300m
W = swims, no distance

Tr[2]: 1 = out, 2 = in transect

Direction of flight[3]:
2
9 N 3
NW NE
8 W 1 E 4
SW SE
7 S 5
6

Associated with[3]:
11 = cetaceans
12/3 = front/line in sea
14/5/6 = wood/litter/oil
18/21 = own/other ship
22/5 = buoy/stick
23/4 = near/on platform
26 = fishing vessel
27/8/9 = ice/land/shallows

Behaviour codes[4]:
30/1 = holding/without fish
32 = feeding chick
33 = "feeding"
34/5 = wading/scooping
36/7 = aerial purs/skimm.
38/9 = hydropl/pattering
40/1 = scavenging/at trawl
42/3 = dipping/surf.seizing
44 = surface pecking
45 = deep plunging
46 = shallow plunging
47 = pursuit plunging
48 = pursuit diving
49 = actively searching
60 = resting/asleep
61/2 = courtship displ/fd
65 = guarding chick
66 = preening/bathing
91 = kleptoparasitised
92/3 =attacked (brd/mm)

MSFAs[3] (Dirn codes)
50 = "participant"
51/2 = joined / joining
53 = scrounger type
54 = solitary diver
55 = beater (e.g. dolphins)
56 = social feeder/diver

Poskey	Time	G	Species	Age	Plum	Number	Dist[1]	Tr[2]	Dirn[3]	Behav.[4]	Prey[5]/notes

Prey examples[5]: 10 = "fish", 11 = small fish (bill length), 12 = medium fish (2-5 bl), 13 = large fish, 14 = sandeel ball, 15 = clupeoid ball, 16 = "fish ball", 21 = clupeoid fish, 22 = sandeel, 23 = gadoid, 24 = flatfish, 25 = regurg. fish, 32 = jellyfish, 34 = worm, 41 = swimming crab, 42 = starfish, 50 = carrion, corpse, 51 = seal carcass, 52 = whale carcass, 53 = bird carcass, 56 = active bird kill, 60 = fishery waste, 61-66 = specified discards

Protocol datasheet for collection of cetacean visual records

Index	GpsIndex	GpsTime	SightingNo	Time	Platform	Angle	Distance	Heading	Cue	Species	Confidence	MinNo	MaxNo	Adults	Juveniles	Calves	Birds	Behaviour1	Behaviour2	Behaviour3	SeenFrom	SeenBy	SightingEffort	Notes	ButtonRef	MagBearing	Reticles	RelBearing	EyeHeight

Protocol datasheet for collection of cetacean acoustic records

Index	GpsIndex	GpsTime	DateTime	Observer	End Time	Notes	SelfBoat	OtherBoat	WaterNoise	DOClicks	DOCNotes	DOWhistle	DOWNotes	DOOther	DONotes	SWClicks	SWCodas	SWOther	SWNotes	BWMoan	BWOther	BWNotes

Annex II: Articles on loggerhead turtle telemetry

Further Evidence Supporting Internesting Habitat Boundaries for Loggerhead Turtles Nesting in Kyparissia Bay, Greece

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Kyparissia Bay in Greece hosts the largest loggerhead turtle (*Caretta caretta*) nesting aggregation in the Mediterranean (Casale et al 2018). The turtle nesting season runs from late May through to August, during which time individual turtles may deposit 1 to 5 clutches of eggs at approximately two-week intervals (Margaritoulis 1983, Omeyer et al. 2019). Turtles may remain in the breeding area for an approximately two-month internesting period – defined as the time in days after deposition of the individuals first clutch of the season until the day of departure, which is normally the day after the deposition of the individual's last clutch of the season (Dujon et al. 2017). The turtles then migrate away to their overwintering and foraging areas which may be up to 1,000km or more away (Margaritoulis et al. 2003; Zbinden et al. 2008; Schofield et al. 2013; Patel et al. 2015; Snape et al. 2016).

Due to the predictable presence, during the summer, of sea turtles in waters off known nesting areas, these sites are often declared protected areas and are subject to specific management measures. For example, the National Marine Park of Zakynthos, largely incorporates the marine habitats of Laganas Bay as protected internesting habitat (Dimopoulos 2001) and the nearshore waters of southern Kyparissia Bay, down to the 25 m isobath, are designated protected as an EU Natura 2000 site (GR2330008).

For these designations to be effective they need to encompass most of the turtles internesting area, over the period the turtles are there, and prohibit activities that might harm the turtles. In Kyparissia Bay a Presidential Decree (PD; Government Gazettes D 391/03-10-2018, D 414/12-10-2018) has stipulated the protection of the integrity of the designated area, including protected species occurring there, such as the loggerhead turtle. The PD provides some protective measures including speed limits for vessels within one nautical mile of the shore, with regulations in place during the breeding period. However, a specific Management Plan, which is legally required for the area, is still being drafted and additional conservation measures may be included therein.

In the context of hydrocarbon exploration in the Ionian Sea, HELLENiQ UPSTREAM S.A., a member of the HELLENiQ ENERGY Group, has undertaken five 2D/3D Marine Seismic Surveys in the Greek territorial waters of the Ionian Sea between 2016 -2023. Especially in Block 10 Lease Area (offshore Kyparissiakos Gulf). HELLENiQ UPSTREAM as the sole operator of the Block, put in place Environmental Monitoring Projects in aim to assess critical habitats of protected species in the wider area of Ionian Sea during the course of the hydrocarbon exploration activities. During the period 2018-2023, HELLENiQ UPSTREAM has established a state-of-the-art Biodiversity Monitoring and Critical Habitats Assessment project, for marine megafauna in the context of the hydrocarbons exploration programs in the Ionian Sea, (Greece). More particularly the project, implemented by the specialised consultancy Nature Conservation Consultants (NCC) Ltd, in collaboration with international biodiversity expert groups BIOTOPIA and MOm (the Hellenic Society for the study and protection of the Monk Seal; https://www.mom.gr/) has conducted extensive field surveys, to assess and map the spatiotemporal distribution, abundance and conservation status of sea turtles, marine mammals (cetaceans and monk seals), and seabirds, in the wider area of Ionian Sea.

Recent studies carried out in southern Kyparissia Bay, using telemetry and drone surveys were able to identify at sea hot spot areas of high use by turtles during the summer months (Rees et al. 2023). Results suggested that the 25 m isobath boundary for the marine protected area may not sufficiently encompass the turtles internesting habitat.

This present study, which was contemporaneous with the published work (Rees et al. 2023) uses satellite telemetry to determine equivalent and comparable data that can be used to further support adapting and updating conservation and management plans, verify any overlap between Block 10 Lease Area, designated by the Greek State to HELLENiQ Upstream S.A. for hydrocarbon exploration and internesting habitat of breeding turtles thus resulting in the most effective protection of this regionally important breeding population.

We located turtles for the study along southern section of the 9.5 km core loggerhead turtle nesting area at the south of Kyparissia Bay (37.3399°N, 21.6952°E; Margaritoulis & Rees 2001). We patrolled the beach between 23:00 and 03:00 to locate nesting turtles. Turtles were selected for study upon completion of a nesting emergence, confirmed through the observation of egg laying. Eight satellite transmitters (Model SPOT-375; Wildlife Computers, Redmond, Washington, USA) were attached to a subset of observed flipper-tagged turtles to track them using the Argos system (www.argos-system.org). Turtles were moved into a large plastic box to retain them on the beach during transmitter deployment that took ~2 h. Transmitters were attached to the turtles' carapaces, centred over the second vertebral scute, using the Wildlife Computers attachment kit and their recommended methods (www.wildlifecomputers.com).

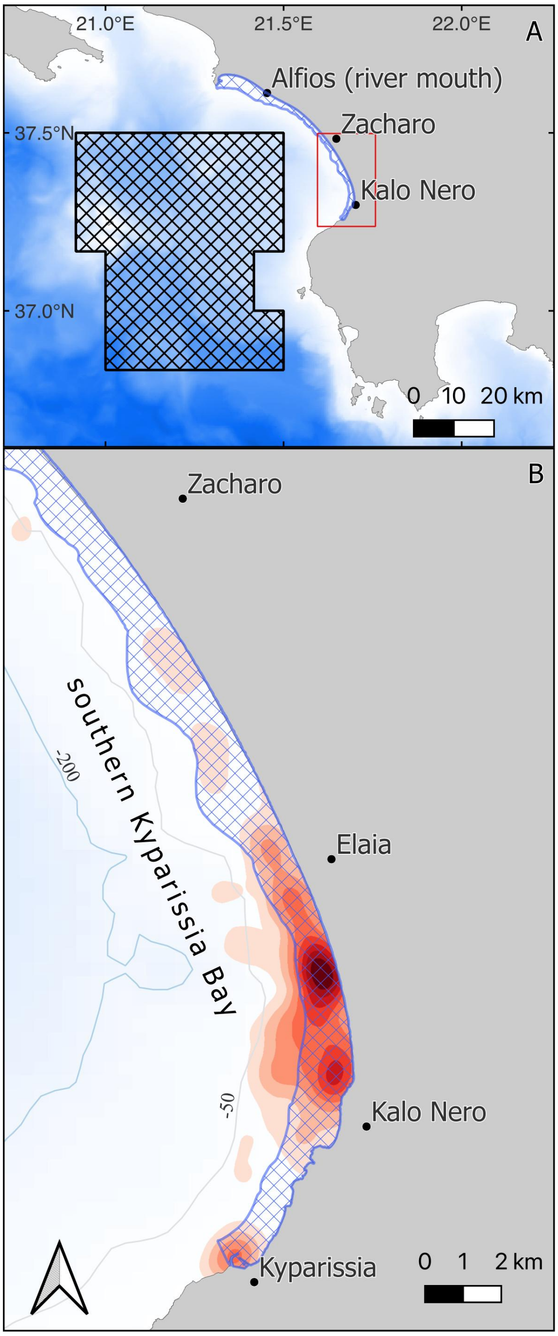

Figure 1. Hotspots during the internesting period for loggerhead turtles in Kyparissia Bay, Greece. (A) southwestern Peloponnese, showing the marine Natura 2000 site relating to sea turtles in blue hatching (GR2330008: *Thalassia Periochi Kolpou Kyparissias* (Marine Area Kyparissia Bay)) and Block 10 Lease Area (black hatching) an area of marine habitat leased for petrochemical exploration and potential extraction. (B) Heatmap density distribution with darker reds representing higher kernel densities. Isobaths are derived from global GEBCO bathymetry dataset (www.gebco.net/)

Data were processed as per Rees et al. (2023) to simplify comparison with the published dataset. Wildlife Computers' data portal (www.wildlifecomputers.com) was used to retrieve and archive Argos location data. From the downloaded data, we used the first best location per day from Argos Location Classes 3, 2, 1 (Class 3 assumed better than Class 2, better than Class 1 etc.; www.argos-system.org) to register turtle positions and movement, with expected accuracy of no better than 250 m. Inland locations were retained to avoid skewing average position data offshore. Maps were created in QGIS (v3.40; www.qgis.org). Turtle high-use areas were determined using the integrated Heatmap (Kernel Density Estimation) symbology function (https://docs.qgis.org/3.28/en/docs/user_manual/processing_algs/qgis/interpolation.html#heatmap-kernel-density-estimation) with 1,000 m at scale entered as the radius and automatic selected for Maximum Value.

We deployed the first three satellite transmitters between 29 June 2021 and 04 July 2021 and a further five transmitters between 09 and 13 June 2022 (Table 1).

After data filtering, we retained 268 daily internesting locations. We retained an average of 33.5±13.7 (SD) locations per turtle (range, 13-50, n = 8). All eight turtles remained within Kyparissia Bay, nearshore in shallow water generally < 50 m deep (Fig. 1). The main cluster of locations ranged along the shore for about 10 km from Kalo Nero in the south to just past Elaia in the north, adjacent to the main nesting beach. An additional distinct hotspot of locations was present south of the nesting beach, centred on Kyparissia harbour (Fig. 1). This hotspot was mainly created by the repeated presence of one turtle from the 2021 cohort, but three other turtles provided locations near to the harbour.

It is clear from the results presented above that the findings of this study, very closely reflect and therefore support those of the previously published work (Rees et al. 2023). The internesting habitat used by the turtles generally reflects the core nesting habitat located between Elaia and Kalo Nero (Fig. 1) but extends a short way to the south and includes the very specific habitat created in Kyparissia harbour, as was previously found (Rees et al. 2023). Likewise, turtle locations range further than the 25 m isobath and are generally confined to the 50 m isobath. Overall, the turtles resided in nearshore shallow habitats as reported for other breeding populations within Greece (Zbinden et al. 2007, Panagopoulou 2015, Schofield et al. 2007, 2010) and elsewhere in the Mediterranean such as southwest Turkey (Cerritelli et al. 2022) and Alagadi, Cyprus (Snape et al. 2018). During the internesting period no turtle locations were recorded within or near to the designated hydrocarbon exploration Block 10 Lease Area. However, at least some turtles travelling to and from Kyparissia Bay

Table 1. Dates of satellite tag deployment and turtle departure (onset of a turtle's permanent migration away from the nesting area) from Kyparissia Bay during 2021 and 2022.

Turtle	Tag Deployment	Turtle Departure	Internesting Period (days)
2021-01	29 June 2021	21 July 2021	22
2021-02	03 July 2021	23 July 2021	20
2021-03	04 July 2021	17 July 2021	13
2022-01	9 June 2022	30 July 2022	51
2022-02	12 June 2022	21 July 2022	39
2022-03	12 June 2022	25 July 2022	43
2022-04	13 June 2022	28 July 2022	45
2022-05	13 June 2022	19 July 2022	36

migrate through the area (manuscript in preparation). HELLENiQ Upstream S.A., following the requirements of the Greek state and based on the results of its monitoring programs, carries out all of its exploration activities between November and March, which is outside the breeding and nesting season.

In conclusion, as per previous publications, our results show that the marine Natura 2000 site in Kyparissia Bay covers a large portion of the key summer habitat used by internesting turtles. However, extending the seaward boundary to the 50 m isobath (ca. 1 km) would incorporate the majority of internesting turtle locations and the protection measures established therein would further benefit turtles. We can now add context to these data regarding the spatial distribution of internesting locations and their lack of proximity to the leased petrochemical exploration area.

Acknowledgments

Satellite tracking was funded by NCC in the context of the Biodiversity Monitoring and Critical Habitats Assessment project. The authors wish to thank ARCHELON, the Sea Turtle Protection Society of Greece, for field support, using personnel from their on-going sea turtle nest monitoring and conservation program in the area to assist with locating turtles and deploying transmitters.

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Dispersal and Foraging Strategies of Adult Loggerhead Sea Turtles (*Caretta caretta*) Breeding in Kyparissia Bay, Greece: Implications for Conservation

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Sea turtles are long-lived wide-ranging animals undertaking long-distance breeding migrations showing fidelity to both foraging and breeding sites. This fidelity has led to population structuring with regional management units defined for globally distributed species. Loggerhead sea turtles (*Caretta caretta*) have established such a management unit in the Mediterranean, with the greatest number of turtles breeding in Greece. Kyparissia Bay, Greece, has been identified as the location with largest nesting aggregation of loggerhead turtles in the Mediterranean. Determining where this aggregation of turtle migrates to outside the breeding season is important for its continued conservation. Long-distance flipper tag recaptures have identified certain high use areas for these turtles but lack route data and certainty that recaptured turtles are resident in the area of capture. Satellite tracking has been used to validate such tag return data and generate insights into turtle migrations patterns and their relationship with phenological and fecundity metrics. Here we recorded turtles' curved carapace lengths as a metric for general body size and deployed Argos satellite transmitters on 11 adult loggerhead sea turtles (8 females, 3 males) during their breeding period in Kyparissia Bay, to examine the implications of their selected migratory routes and foraging strategies. Average carapace length (±SD) was 82.0 cm (±4.6 cm) for the 8 female turtles and 86.0 cm (±5.5 cm) for the 3 males. Turtles were tracked for an average of 326.9 days. End points for the tracked turtles were grouped into four distinct regions The Aegean Sea was the end point for 3 turtles, and the Adriatic Sea was the end point for another 3 turtles with one turtle spending an extended period in the northern Ionian. The northern Ionian Sea was the end point for a further 3 turtles and the Tunisian plateau was the end point for final 2 turtles. Six turtles migrated to restricted area foraging sites, 1 turtle remained nomadic for the entirety of its tracking duration, 2 turtles were semi-nomadic incorporating both restricted area foraging and large-scale movements during their tracking period, and the tracks of the final 2 turtles ceased before their behaviour type could be determined, but sedentary behaviour type was inferred. Notably the one turtle that remained nomadic was 6 cm shorter than the next shortest turtles, suggesting carry-over effects of the nomadic life-history. The turtles generally moved to locations that had been identified by flipper tag recaptures, however the tracking identified routes taken to get there, which were often highly convoluted. These foraging sites, also identified through other tracking studies of loggerhead turtles nesting elsewhere in Greece and from Cyprus, were often sites of high fishing activity and cause for concern for turtles present there. Given that up to around 2,000 turtles may nest in Kyparissia Bay during a single summer, we conclude that a larger number of turtles, over multiple years, should be tracked to obtain a more robust assessment of post-breeding migrations, foraging strategy adoption and their carry-over effects, which can then be used to better inform conservation and management actions.

Key words: marine turtle migration, foraging sites, tracking male sea turtles, fisheries threats, Mediterranean Sea

BACKGROUND

Sea turtles long lived slow to mature creatures inhabiting wide expanses of marine habitats over their lifetime (Musick and Limpus 1997). As adults they perform regular breeding migrations from foraging sites to breeding sites showing strong fidelity over successive reproductive periods (Broderick et al. 2007, Schofield et al. 2010, Shimada et al. 2019). These foraging sites host mixed stocks of turtles, which means that individuals from different rookeries congregate in the same foraging areas (Bowen and Karl 2007). Through these characteristics of natal homing (the propensity for sea turtles to return to breed on beaches they were themselves hatched) and site fidelity (where sea turtles nest in the same vicinity for each breeding season) global sea turtle metapopulations can be divided into regional management units (RMUs, Wallace et al. 2023) each with their own conservation status and needs (Wallace et al. 2025). Larger turtles from the onset of sexual maturity are considered to have higher reproductive value than smaller, younger turtles (Wallace et al. 2008). Consequently, determining the whereabouts of these biologically important adult turtles means targeted conservation and management measures can be set, which are likely to have disproportionate conservation benefit on threatened populations.

Flipper tagging capture-mark-recapture programmes on nesting beaches have existed for decades and are a somewhat effective way of determining the distribution of turtles away from their breeding sites (e.g. Mortimer and Carr 1987, Limpus et al. 1992, Margaritoulis et al. 2007). However, tag returns only give point locations of turtle observations and single observations and do not give indication if a turtle is resident at the capture site or migrating through. They also depend on the turtles being observed and may therefore show bias in observation distributions. However, at least in the Mediterranean, distribution of nesting turtles tracked using satellite tags has been shown to support long-distance tag recapture data (Zbinden et al. 2008, Baldi et al. 2023).

Since the 1990s, satellite telemetry of sea turtles has become increasingly common (Godley et al. 2008, Hays et al. 2016) and complements tag return data through identifying migration routes and foraging locations of turtles after nesting (e.g. Schofield et al. 2013a, Pilcher et al. 2014, Whittock et al. 2016). Tracking durations for individuals are such that sometimes even two-year remigrations back to the original nesting areas can be followed (e.g. Rees et al. 2010, Schofield et al. 2010, Mingozzi et al 2016), providing remarkable insights into individual turtles' spatial movements, albeit at low sample sizes.

Attempts have been made to upscale tracking results to more population level sample sizes using differential stable isotope signatures of turtle tissues (generally for Carbon and Nitrogen) to define broadscale spatially explicit foraging locations. The benefit of stable isotope analyses (SIA) being the cost per individual to gather the relevant data is far less than for telemetry. This technique has proven moderately effective for certain turtle species in certain global locations (e.g. Bradshaw et al. 2017, Ceriani et al. 2012) but not always so (Coffee et al. 2020).

Two species of sea turtle nest in the Mediterranean, the loggerhead turtle (*Caretta caretta*) and the green turtle (*Chelonia mydas*) and have both established their own endemic RMUs (Wallace et al. 2023). The loggerhead is the most numerous species and most commonly nests in Greece, Turkey, Cyprus and Libya (Casale et al. 2018). In Greece, the two most important nesting areas are Laganas Bay, Zakynthos Island and Kyparissia Bay, on the west coast of the Peloponnese (Casale et al. 2018). Flipper tag recaptures from both nesting areas revealed the most common foraging areas for turtles nesting at these locations are the Adriatic Sea and the Tunisian Shelf (Margaritoulis et al. 2007) and satellite tracking over 70 turtles from the Laganas Bay nesting site confirmed these findings for both adult female and male turtles (Zbinden et al. 2008, Schofield et al. 2013a).

Kyparissia Bay, which has recently overtaken Laganas Bay to host annually the most loggerhead nests in the Mediterranean region (Margaritoulis et al. 2025), has relatively less information published on migrations of the turtles breeding there. In addition to the reported flipper tag returns of Margaritoulis et al. (2007), Haywood et al. (2021) provide generalised foraging locations for 20 nesting females tracked after nesting there. The authors attempted to use SIA to determine similar scale foraging locations for a further 80 sampled turtles, however lack of isotopically distinct foraging regions for the population meant that untracked females could not be assigned to putative foraging grounds (Haywood et al. 2021).

In this study we aimed to identify migratory routes and foraging strategies for both adult male and female loggerhead turtles breeding in Kyparissia Bay. We also sought to determine other biologically relevant observations based on the behaviours of the tracked individuals with the goal of highlighting the conservation implications of their selected behaviours in the context of heterogenous regional fishing pressure.

MATERIALS AND METHODS

Transmitters

We used Wildlife Computers' (Wildlife Computers, Redmond, WA, USA) SPOT-375 Argos-linked satellite tags (https://www.argos-system.org/) to track female loggerhead turtles and Wildlife Computers' SPLASH10-385 to track male loggerheads on their post-breeding migrations. The tags were programmed with a 15 s transmission repetition rate, with no duty cycling but transmissions were limited to 250 day^{-1}. The Argos system provides locations classified to have different levels of accuracy, depending on the number of transmissions received during the satellite pass, and other factors (CLS 2016).

Turtles

We deployed satellite tags on 3 nesting turtles in 2021, 5 nesting females in 2022 and 3 breeding males in 2023. Nesting turtles were located at random on the southern core nesting area of the Kyparissia Bay nesting site (Margaritoulis et al. 2025). Full transmitter deployment methods have been previously described (Rees et al. 2023), in short, turtles were moved into a large plastic container after they had finished laying a clutch of eggs and completed the covering stage of their nesting behaviour. The carapace was cleaned and transmitter attached with epoxy and fibreglass sheets using the Wildlife Computers attachment kit (or equivalent) following the company's methods (wildlifecomputers.com).

Male turtles were captured at sea using the turtle rodeo technique (Ehrhart and Ogren 1999) in Kyparissia harbour, a location previously identified as hosting high densities of turtles during the breeding period (Rees et al. 2023, 2025). To ensure these turtles were adult males in breeding condition we randomly targeted males that were mounted upon- or attempting to mount other turtles. Captured turtles were taken ashore and retained in a plastic container and we attached transmitters to them using the same methods as for nesting females.

We recorded the turtles' curved carapace lengths, notch to tip (CCL; see Bolten 1999) and the male turtles' tail lengths measured from the inner part of the notch between the supracaudal scutes to the tip of the outstretched tail. Both types of measurement were recorded to the nearest 0.5 cm. After measuring and transmitter attachment the turtles were released at the location they were obtained, generally within two hours of capture.

Data processing and presentation

Argos location data were automatically downloaded and archived in the Wildlife Computers' data portal (my.wildlifecomputers.com) for the lifespan of the tags. The data were pre-cleaned prior to state space modelling. Irrespective of Argos location class, we removed all extreme visual outliers (hundreds of km from the main data cluster) and for records with duplicate time stamps we removed the worse quality locations. We also removed all but the last location when the turtle was resident in the breeding area, as previously determined in Rees et al. (2025). We then performed state space modelling (SSM) on the pre-cleaned data in R (R Core Team 2024) using the package aniMotum (Jonsen et al. 2023). In aniMotum we set vmax (maximum travel speed) to 1.39 m s^{-1} (5 km h^{-1}) and selected the "rw" (random walk) model with a 12-hr time step.

To produce the final dataset, we removed all grossly outlying locations produced by the SSM together with multiple consecutive interpolated locations that were produced by the SSM when there was a gap greater than 7 days in the original Argos location data for any individual.

Mapping and post-SSM spatial data processing were undertaken in the Free and Open Source QGIS v3.40.4 (www.qgis.org). All summary statistics are presented as mean ± standard deviation.

Classification of movements and behaviours

Turtle behaviour was classified as migrating/remigrating, foraging or mixed behaviour based on sustained speed of travel and track tortuosity. Foraging periods were defined by slow rates of travel (<1 km h^{-1}) with multidirectional movement. Migration/Remigration periods were defined by faster travel (>1 km h^{-1}) with directed movement (i.e. sections of track with low tortuosity) and mixed behaviour periods were defined by slow rates of travel (≤1 km h^{-1}) combined with directed movements and generally occurred in offshore locations. Short periods (≤3 d) of any one behaviour type during a protracted period of another behaviour type (e.g. faster travel speeds in a period of mixed behaviour movement) were incorporated in the main behaviour type. Periods of foraging of 7 d or less during initial migrations were considered stopovers (see Cerritelli et al. 2022) and were not interpreted as the end of post-breeding migration.

If a turtle migrated to a spatially restricted identifiable foraging location it was classified as sedentary. If a turtle undertook long-term movements without establishing a clear restricted foraging location it was classified as Nomadic. Turtles that exhibited both behaviours were classified as semi-nomadic.

Analysis of the influence of foraging area and behaviour on turtle body size

To gain insight into the influence of foraging area (Adriatic, Aegean, Ionian/northern Libyan Sea and Tunisian shelf; see results) and foraging strategy (sedentary, semi-nomadic, nomadic) on body size we compared the mean CCL for each variable. Statistical comparisons were not undertaken due to small sample size.

Determining threat levels from fisheries

To examine the relative potential impact of fisheries on the turtles over their tracked range we obtained twelve months of contemporaneous fishing effort data from the Global Fishing Watch (GFW) web portal (Global Fishing Watch 2025). GFW fisheries effort data were determined from AIS (automatic identification system) data for vessels 15 m or longer with apparent fishing effort and gear type used identified by a neural network model (Kroodsma et al. 2018). Data were downloaded, in 0.1° cells, for the period September 2022 to August 2023; this date range covered a large period of tracking for the adult females and complete tracking of two of the three adult males.

RESULTS

The turtles

Average CCL was 83.1 cm (±4.9, range 73.5–91.5 cm) for all 11 turtles, 82.0 cm (±4.6, range 73.5–89.5 cm) for the 8 female turtles and 86.0 cm (±5.5, range 80.5–91.5 cm) for the 3 males (Table 1). Male turtle tail lengths were on average 22.8 cm (±2.9, range 19.5–25.0 cm, n = 3). We received location data from all 11 turtles tracked between 2021 and 2023. The turtles were tracked for an average of 326.9 d. Females tended to be tracked for longer than males; 351.6±232.9 d (range 69–716 d) and 261.0±248.5 d (range 98–547 d), respectively (Table 2).

Duration and Speed of behaviours, migrations and movements

Females departed the breeding area on average 33.6 days after tagging (±13.6, range 13–51 d, *n* = 8). Males departed 9.7 days after tagging (±13.3, range 1–25 d, n = 3). Average migration duration lasted 17.5 d (±8.0, range 8–29 d, *n* = 8) for female turtles and 21.0 d (±19.3, range 4–42 days, *n* = 3) for males, which included stopovers of 4 and 7 d for two turtles (Table 2). Average mean migration speed for all turtles was 1.7 km h^{-1}. Average mean speed for females was 1.9 km h^{-1} (±0.3, range 1.3–2.4 km h^{-1}, *n* = 8) and 1.3 km h^{-1} (±0.2, range 1.2–1.6 km h^{-1}, *n* = 3) for males (Table 1).

Destinations and groupings

End points of the tracked turtles can be grouped into four distinct regions (Fig. 1, Table 1). The Aegean Sea was the end point for 3 turtles (*1f(A),2m(I,K)*; Fig. 1a), the Adriatic Sea was the end point for 3 turtles (*2f(C,G),1m(J)*; Fig. 1b) with one turtle spending an extended period in the Ionian Sea (J). The Ionian Sea was the end point for a further 3 turtles (*3f(B,E,F)*; Fig. 1c,d) and the Tunisian shelf was the end point for the final 2 turtles (*2f(D,H)*; Fig. 1e).

Foraging strategy (sedentary or nomadic)

The turtles were also grouped by foraging strategy (Table 1). Six of the turtles were classified as sedentary, having established restricted area foraging sites in the Aegean (*1f(A),2m(I,K*), Adriatic (*1f(G)*), Ionian (*1f(F)*), and Tunisian shelf (*1f(H)*). One turtle remained nomadic in the Ionian/northern Libyan Sea region (*1f(B)*). Two turtles were semi-nomadic, with 1 (*1m(J)*) initially being nomadic until settling in the Adriatic, and the other (*1f(C)*) establishing a long-term coastal foraging site in the Adriatic before moving away and behaving nomadically in the same region for its final 20 days of tracking. The remaining two turtles were most likely also sedentary, as their tracks ended in shallow coastal waters, but the track stopped the day after reaching the Libyan coast for one (*1f(D)*) and the other track (*1f(E)*) contained a gap of almost 200 d before the final 7 d of tracking placed the turtle in the same restricted area of coast.

Influence of foraging strategy or region on body size

From the four identified foraging regions, on average the largest turtles were present in the Aegean (mean CCL = 86.5 cm, n = 3) followed by the Tunisian shelf (mean CCL = 83.5 cm, n = 2), and then the Adriatic and Ionian/northern Libyan Sea regions (mean CCL = 81.5cm, n = 2 and mean CCL = 81.3 cm, n = 3, respectively). One turtle was excluded from this assessment as it extensively used both the Adriatic and Ionian regions and could not be assigned to just one of them.

Based on foraging strategy, the largest turtles selected sedentary behaviour (mean CCL = 85.0 cm, n = 8), next largest were the semi-nomadic turtles (mean CCL = 80.3 cm, n = 2) and the only fully nomadic turtle was smallest (CCL = 73.5 cm, n = 1), at over 6 cm smaller than the next smallest turtle.

Fisheries threats

Fishing activity levels in the central Mediterranean, as derived from AIS data by GFW, showed several distinct large-scale hotspots (Fig. 2). Based on apparent fishery activity approaching or exceeding 3,000 hr within the sampled year, we can see that most of the neritic Adriatic Sea and much of the waters between Sicily and Tunisia/Libya were extensive areas of high levels of fishing activity. Other relevant areas included the coastal regions of the northern Ionian Sea and Thermaikos Gulf in the NW of the Aegean Sea (Fig. 2).

DISCUSSION

Travel and speed in context

As expected, the overall migration speed demonstrated by the study turtles (1.7 km h^{-1}), was within the range published for other migrating adult loggerhead turtles in the Mediterranean (Godley et al. 2002, Schofield et al. 2010, Cerritelli et al. 2022). Their travels included 'stop overs' as found with turtles migrating from other Greek and Turkish nesting areas (Dujon et al. 2017, Cerritelli et al. 2022). However, the three male turtles average travel speed (1.3 km h^{-1}) was lower than other tracked turtles (females), even on their slower coastal migratory pathways, which averaged at 1.6 km h^{-1} (Godley et al. 2002, Cerritelli et al. 2022). It could be that adult male loggerheads migrate more slowly than adult females, but more turtles need to be tracked to confirm this difference is not simply an artefact of small sample size. Imprecision in travel speeds may result from the use of SSM generated locations at 12 hourly intervals, rather than raw tracking data over variable time spans to determine speed. This would especially impact periods where turtles were undertaking more than one of the assigned behavioural categories in a 12-hr window. However, we consider the selected method sufficiently robust to provide biologically meaningful results.

Destinations compared to previous findings

The majority of the study turtles migrated to the northern Ionian and Adriatic Seas (Fig. 1, Table 1), which are the highest use adult locations previously identified from tag returns (Margaritoulis et al. 2007) and tracking of Laganas Bay turtles (Zbinden et al. 2011, Schofield et al. 2013a). The Tunisian shelf is underrepresented in this study (n = 2) compared to the previous works focussing on Laganas Bay turtles (Margaritoulis et al 2007, Schofield et al 2013a) that found that region to hold the second largest number of turtles. The final turtles in this study migrated to the Aegean Sea with one more turtle heading there than the Tunisian shelf (n = 3). These results better align with the tag return data of Margaritoulis et al. (2007), which includes Kyparissia Bay tagged turtles, than the tracking results of Laganas Bay turtles (Schofield et al 2013a). Nesting females from Kyparissia have also been reported to migrate into the Western Mediterranean (Backof 2013, Haywood et al. 2021) but none from the current study did so. Separation of tag return data, such as presented by Margaritoulis et al. (2007), per nesting site and increasing the sample size of tracked turtles from Kyparissia Bay can support or refute any differences in the proportions of turtles migrating to the different regions and potentially provide additional evidence for the different conservation status between the two nesting aggregations (Margaritoulis et al. 2025).

There are potentially up to 2,000 nesting turtles in a single year in Kyparissia Bay—based on clutch frequency of ~3.5 (Rees et al. 2023) and 8,019 nests in the updated core nesting area in 2024 (Margaritoulis et al. 2025). In addition, there will be a large cohort of breeding males present in the area. Consequently, the number of turtles tracked here (n = 11) needs to be increased dramatically to provide more conclusive population-level results. Furthermore, tracking turtles from additional seasons may reveal any interannual variation in migratory destinations and overcome limitations of the potentially biased tag return data and the limited temporal spread of the current tracking study.

Increasing the sample of turtles tracked to identify foraging areas and strategies may be achieved through a combination of ways. Emerging alternative technologies, such as transmitters using the Iridium satellite system (Cerritelli et al. 2022, Lamont et al. 2024) or the cellular phone GSM network (Rees et al. 2023), which may result in lower costs per tracked individual, may help stretch funding to track larger numbers of turtles. Furthermore, compilation of all existing tracking data into a single meta-analysis (e.g. Ferreira et al. 2021) would strengthen findings in terms of relative abundance of turtles in the foraging areas and give indication of the diversity of turtles from different breeding populations that utilise these areas.

SIA using carbon, nitrogen and sulphur isotopes present in turtle epidermis tissue, whilst cheaper per individual than typical satellite tracking, has proven to be largely ineffective at differentiating many Mediterranean loggerhead foraging areas (Haywood et al. 2020, 2021). However, the use of other isotopes such as oxygen, in commensal barnacles present on the turtles' carapaces may reveal insights into their spatial origins (Pearson et al. 2019) and should be explored further within the Mediterranean.

Behaviour and the established sedentary foraging paradigm

Three of the study turtles (B,C,J; 27%) did not follow the classic paradigm that post-breeding loggerhead turtles migrate to specific neritic areas and establish spatially distinct foraging sites (see Schofield et al. 2010, 2013a and Mingozzi et al. 2016 for examples) but instead exhibited prolonged periods of nomadic behaviour in both neritic and oceanic waters. The most extreme example of this behaviour pattern was shown by turtle B (Fig. 1d). It moved from near to eastern Sicily, to the southern mainland Italian coast and back to Kyparissia Bay and then once more to the western Ionian, without breeding, for ~700 days. Although apparently rare, this type of behaviour has been reported before from Kyparissia, with adult female turtles remaining nomadic in the western Mediterranean (Haywood et al. 2021). Additionally, a single adult female from 17 (6%) tracked after nesting in southwestern Türkiye undertook wandering movements and established two large-scale foraging areas in the western Ionian and Adriatic Seas (Cerritelli et al. 2022). Two turtles from 37 (5%) tracked from Cyprus also remained nomadic; one also inhabiting the northern Ionian sea and the other spending time over the Tunisian Plateau before covering hundreds of kilometres moving around in oceanic waters of the southern Western Mediterranean (Haywood et al. 2020). These low frequency occurrences of nomadism contrast with a study of sub-adult and adult loggerheads obtained in the Tyrrhenian Sea where 6 of 8 turtles (75%) undertook long-distance circuitous movements in the oceanic environment (Luschi et al. 2017). From the above findings, either a size-based ontogenetic change in behaviour or a temporally evolved behaviour where the nomadic life-history pattern is becoming more prevalent may be inferred.

Area / behaviour influence on body size

The fully nomadic turtle in this study was by far the smallest turtle tracked, and the semi nomadic turtles the next smallest. This suggests a notable carryover effect of a nomadic foraging strategy, possibly in combination with the selected foraging region, as has been shown for loggerhead turtles in the northwest Atlantic (Ceriani et al 2015). For foraging strategy and location to influence body size, a turtle would need to show consistent behaviour over successive years. Though we have only one period for the turtle in this study, other studies show that turtles show fidelity to foraging areas and resulting foraging strategy (Broderick et al. 2007, Schofield et al. 2010, Rees and Margaritoulis 2024) and a persistent long-term nomadic foraging strategy can be assumed for the turtle.

Previous studies on nesting Mediterranean loggerheads have revealed a north-south dichotomy in turtle size, with northern turtles being larger (Zbinden et al. 2011, Cardona et al. 2014, Patel et al. 2015, Haywood et al. 2020) and laying larger clutches (Zbinden et al. 2011, Cardona et al. 2014, Patel et al. 2015). These effects were attributed to better quality benthic forage in the north. Those results contrast with our findings that suggest foraging strategy plays a more important role in body size than foraging location. No reference to a relationship between size and foraging strategy of the nesting females was made in any of the previous Mediterranean studies. Both Zbinden et al. (2011) and Patel et al. (2015) present tracks of turtles that only established restricted benthic foraging areas and lacked any nomadic individuals. The nomadic turtles from Haywood et al. (2020) were of similar small size to other tracked individuals, thus our finding of a small nomadic foraging in the Ionian/northern Libyan Sea is a novel result and worthy of further investigation through tracking other small conspecifics from the area.

Interpretation of the influence of foraging area and strategy on body size may be confounded by the inclusion of both male and female turtles in the analysis, with male turtles in this study being on average larger than their female conspecifics. However, another study in the Mediterranean revealed no sexually dimorphic body size differences (Schofield et al. 2013a), hence the influence of foraging strategy is likely to be the primary driver in differential body size.

Other studies with loggerheads breeding at Cape Verde and Japan have shown that adults turtles residing in oceanic conditions were smaller than their conspecifics feeding in neritic habitats (Hatase et al. 2002, Hawkes et al. 2006), which is reflected in the results of this study. Furthermore, at least for the Cape Verdean turtles, the oceanic residents also remained nomadic for the duration of their tracking, which again is a behaviour presented by the turtles that were either semi-nomadic or nomadic in this study. We would suggest that long-term presentation of a foraging strategy (nomadic vs sedentary) is a result of foraging habitat (benthic or midwater) selection and results in measurable differences in body size between the two categories of animals.

Threat impacts

The factors driving the different turtle behaviour result in individuals being exposed to varying levels of anthropogenic threats. The most insidious marine threat to sea turtles is bycatch in fisheries (Wallace et al. 2025) with the most recent estimate indicating over 120,000 turtles per year end up as bycatch per year in the most important fishery types across the Mediterranean (Lucchetti 2021). Fishing intensity is not uniform across the Mediterranean, with, for example, certain large-scale areas such as the Adriatic Sea, parts of the shelf seas between Sicily and Tunisia and sections of the Aegean Sea experiencing widescale intensive fishing (Fig. 2). These are three of the regions identified here as preferred foraging grounds for loggerhead turtles nesting in Kyparissia and results in the turtles experiencing high fisheries pressure whilst away from their breeding grounds. The smaller nomadic turtle would consequently be least affected by bottom gears but would be affected by other fishing taking place in more offshore oceanic waters.

It should be noted that fishing activity distribution maps derived solely from AIS data (such as shown in Fig. 2) are prone to underreporting vessel presence in certain locations where there are no AIS receivers or when AIS transmitters are muted. In the Mediterranean this occurs most frequently in the south leading to the underreporting of fishing activity, for example, in Tunisian waters (Fig. 2). However, through inclusion of SAR (synthetic aperture radar) data a high presence of fishing vessels is shown in Tunisian coastal waters and shelf sea (Marsaglia et al. 2024; Fig. 3), indicating the entire region poses high risk to turtles foraging there.

Each life history and behavioural variation for loggerheads comes with its own raft of ecological trade-offs that can impact fecundity and survivorship. Conservation measures to reduce bycatch and improve the outcome for bycaught turtles continue to be priority actions away from nesting areas. The greater our knowledge of migratory routes and foraging hotspots, as determined through tracking studies such as this one, the more targeted and impactful such measures may be.

CONCLUSIONS

Although there are alternative ways of determining high-use areas by sea turtles, such as combining analysis of aerial and boat transect data with environmental data (DiMatteo et al. 2022, 2024), satellite telemetry remains the best method. The benefits include determining routes of individual turtle migrations, identifying the origins of turtles in a location where the turtles cannot be accessed to read flipper tags, and revealing nesting-site specific hotspots.

Limited tracking of breeding turtles in this study has confirmed foraging sites that have previously been indicated from flipper tag returns. However, given that SIA is not currently able to distinguish specific foraging regions for Mediterranean loggerheads (Zbinden et al. 2011, Haywood et al. 2020, Haywood et al. 2021) a larger sample of tracked turtles is needed to support population level inferences on foraging hotspot distribution.

Likewise, additional tracking combined with tracked-turtle individual nesting histories should be used to further elucidate the interplay of foraging strategy and location with body size and fecundity as suggested in other studies (Zbinden et al. 2011, Cardona et al. 2014, Patel et al. 2015).

Despite the limited sample size, present data support previous findings as to the distribution of adult loggerhead turtles away from the breeding areas. This strengthens the need for adoption of suitable bycatch reduction measures, such as gear or fishing method modifications or spatial and temporal closures, which will improve the conservation status of turtles in the respective areas.

Acknowledgments: Satellite tracking was funded by NCC in the context of the Biodiversity Monitoring and Critical Habitats Assessment project undertaken for HELLENiQ UPSTREAM S.A. The authors wish to thank ARCHELON, the Sea Turtle Protection Society of Greece, for field support, using personnel from their on-going sea turtle nest monitoring and conservation program in the area to assist with locating nesting turtles and deploying transmitters. We also thank members of BIOTOPIA and Mom (the Hellenic Society for the study and protection of the Monk Seal) who assisted with capture of the male turtles tracked in this study.

Authors' contributions: AFR: Conceived study, undertook fieldwork, curated and analysed data, wrote initial draft of the manuscript. TD: Conceived the study, undertook fieldwork, contributed to drafting the manuscript and approved its final submitted version., YV and GM: Conceived the study, contributed to drafting the manuscript and approved its final submitted version.

Competing interests: HELLENiQ UPSTREAM S.A. funded wildlife research in the Kyparissia Bay region as part of its commitment to conservation while undertaking surveys for potential exploration and exploitation of hydrocarbons in Kyparissiakos Bay.

Availability of data and materials: Raw tracking data analysed in this paper are available from the authors upon reasonable request and can be used with citation of this publication in the resulting documents/outputs.

Ethics approval: Interactions with and tagging the turtles were covered under permit YPEN/DDD/26967/698 from the Ministry of Environment. Tagging and measuring turtles followed internationally accepted standards.

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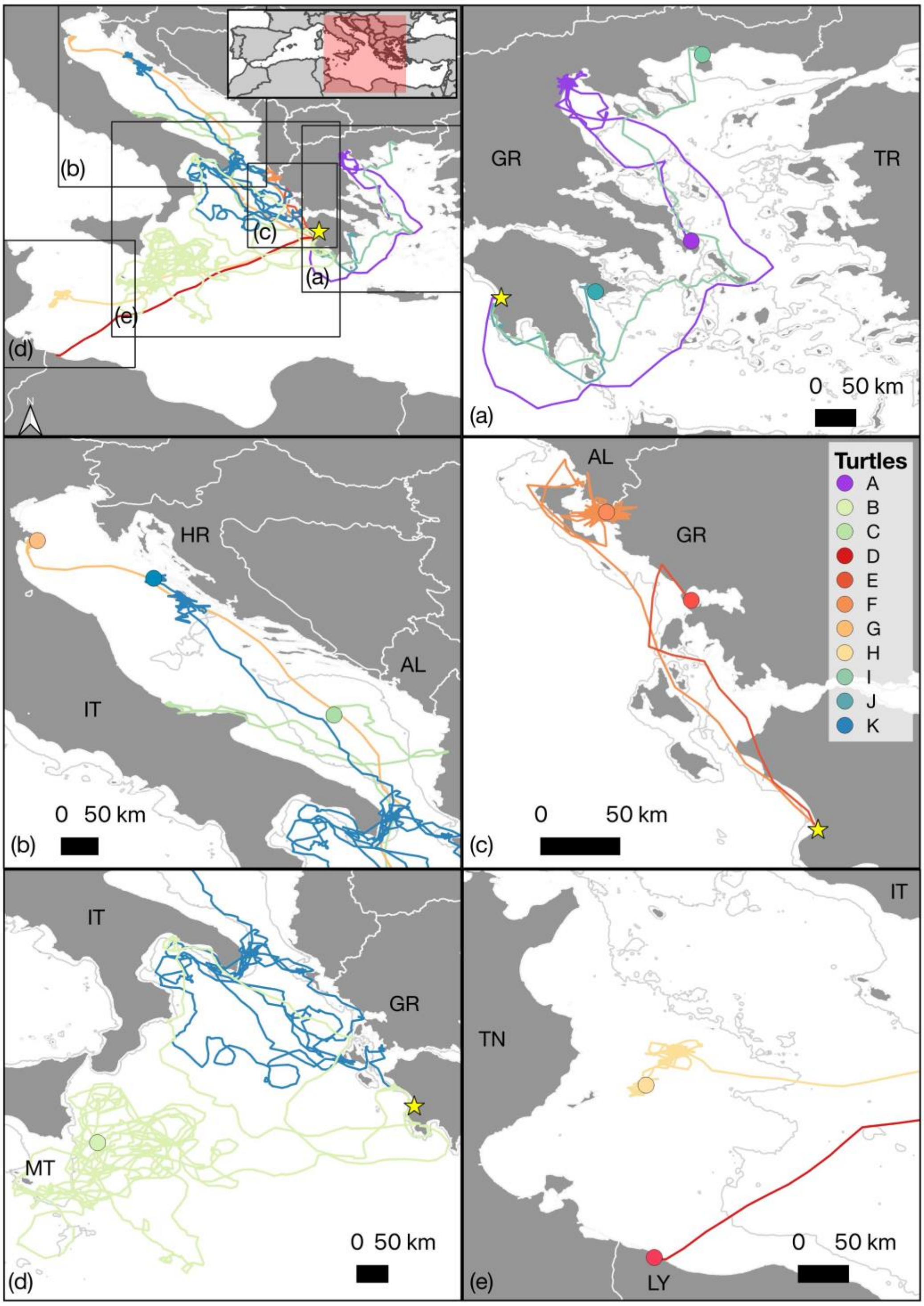

Fig. 1. Post-breeding migrations, movements and end points for the 11 loggerhead turtles tracked from Kyparissia Bay. (a) Aegean Sea, (b) Adriatic Sea, (c) Ionian Sea (sedentary turtles), (d) Ionian Sea/ northern Libyan Sea (nomadic turtles), and (e) Tunisian Shelf. The nomadic portion of the track ending in the Adriatic panel (b) is shown in panel (d). Grey line = 200 m isobath. Bathymetry representation is derived from GEBCO data (https://www.gebco.net/). Yellow star is the tagging site. Coloured circles are end points of each track.

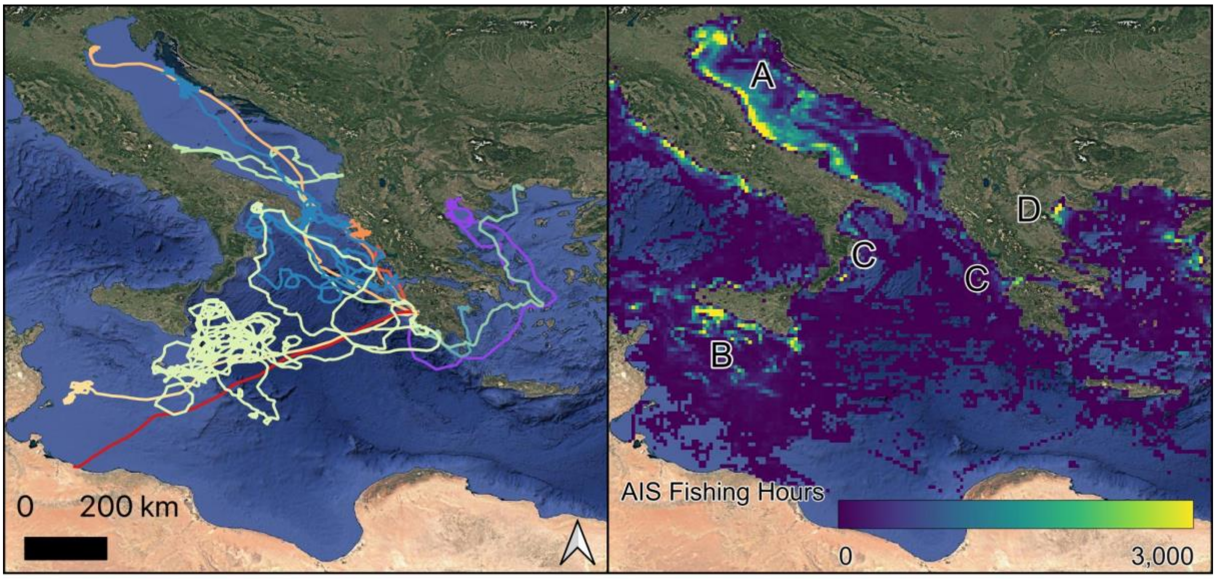

Fig. 2. Potential threat posed by fisheries to the loggerhead turtles tracked from Kyparissia Bay. Left panel: Tracks of the 11 adult loggerhead turtles equipped with Argos satellite transmitters in Kyparissia Bay, Greece. Right panel: Fishing effort in the same location in 0.1° cells, between September 2022 and August 2023. Fishing effort, determined from AIS data, downloaded from Global Fishing Watch (globalfishingwatch.com). Areas with 3,000 or more fishing hours are depicted in the same colour. Areas of high intensity fishing are evident in (A) neritic part of the Adriatic Sea, (B) between Sicily and Tunisia/Libya, (C) coastal regions of the Ionian Sea, and (D) Thermaikos Gulf in the NW of the Aegean Sea, which coincide with the turtle tracks.

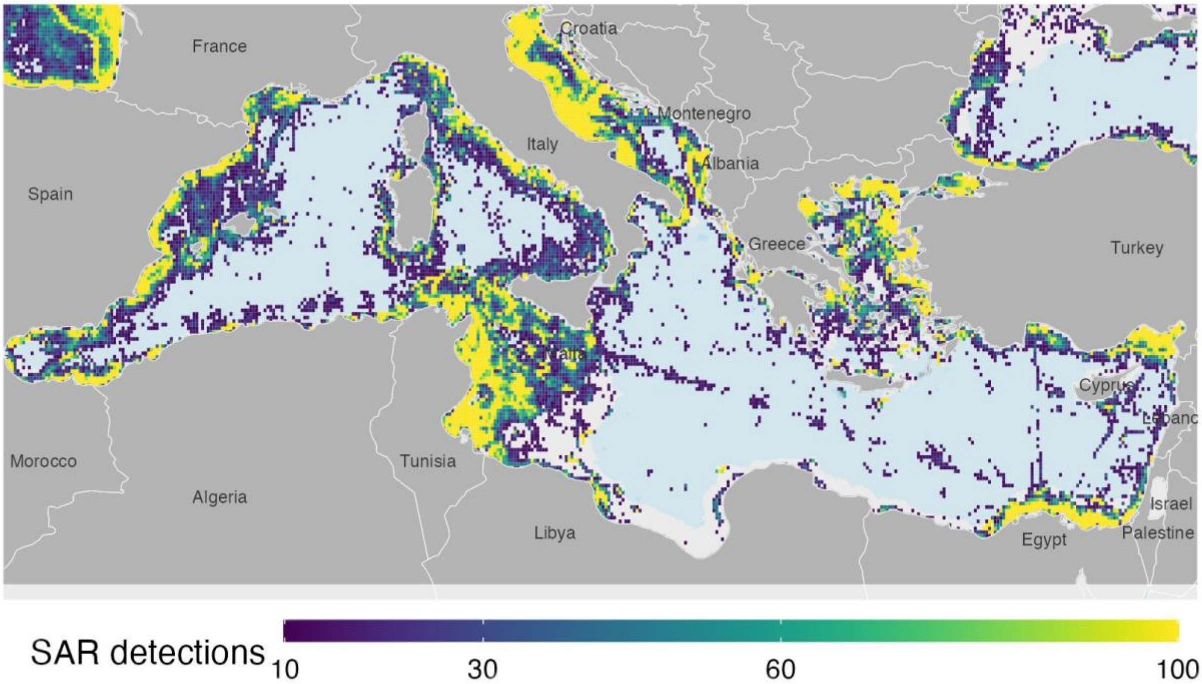

Fig. 3. "SAR fishing vessel presence from Global Fishing Watch SAR data from 2017 to 2021 aggregated by number of fishing vessel detections in 0.1 decimal degrees cells. The light blue shaded area represents the areas with depths greater than 1,000 m". Reproduced from Marsaglia et al. (2024) under Creative Commons Attribution License 4.0.

Table 1. Body size (and tail length of the tracked adult males), migratory speed, and foraging region and strategy for the 11 loggerhead sea turtles tracked after breeding in Kyparissia Bay. CCL = curved carapace length (notch to tip). TL = tail length (from innermost part of the notch between the supracaudal scutes and the tip of the extended tail).

Turtle	Sex	CCL (cm)	TL (cm)	Average migration speed (km h^{-1} ±SD)	Foraging region	Foraging strategy category
A	F	82.0	-	2.0 ±0.7	Aegean	Sedentary
B	F	73.5	-	1.3 ±0.6	Ionian/northern Libyan	Nomadic
C	F	80.0	-	1.6 ±0.4	Adriatic	Semi-nomadic
D	F	85.5	-	2.4 ±0.6	Tunisian shelf	Sedentary[a]
E	F	89.5	-	2.2 ±0.6	Ionian	Sedentary[b]
F	F	81.0	-	2.0 ±0.8	Ionian	Sedentary
G	F	83.0	-	1.8 ±0.6	Adriatic	Sedentary
H	F	81.5	-	1.8 ±0.6	Tunisian shelf	Sedentary
I	M	91.5	24.0	1.2 ±0.6	Aegean	Sedentary
K	M	86.0	25.0	1.6 ±0.5	Aegean	Sedentary
J	M	80.5	19.5	1.3 ±0.5	Ionian / Adriatic	Semi-nomadic

[a]Track stopped the day after the turtle arrived at the Libyan coast. [b]Gap of 194 d in tracking data after turtle reached its foraging area, with locations resuming in the same location afterwards.

Table 2. Summary data of the post-breeding tracking durations of the 11 loggerhead turtles tracked from Kyparissia Bay breeding area,

Turtle	Deploy Date	Depart Date	Breeding duration	Arrival at foraging area	Migration duration	End date	Tracking duration
A	29/06/2021	21/07/2021	22	11/08/2021	21	02/01/2023	552
B	03/07/2021	23/07/2021	20	02/08/2021[a]	10	19/06/2023	716
C	04/07/2021	17/07/2021	13	10/08/2021	24	31/01/2022	211
D	09/06/2022	30/07/2022	51	17/08/2022	18	17/08/2022	69
E	12/06/2022	21/07/2022	39	29/07/2022	8	15/02/2023	248
F	12/06/2022	25/07/2022	43	02/08/2022	8	16/10/2023	491
G	13/06/2022	19/07/2022	36	17/08/2022	29	09/09/2022	88
H	13/06/2022	28/07/2022	45	19/08/2022	22	25/08/2023	438
I	02/05/2023	03/05/2023	1	14/06/2023	42	08/08/2023	98
K	03/05/2023	06/05/2023	3	23/05/2023	17	18/09/2023	138
J	03/05/2023	28/05/2023	25	01/06/2023[b]	4	31/10/2024	547

Turtle behaviour switched from migration to mixed[a] or foraging[b] for a period of 9 days or longer.