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Density and Abundance of *Delphinus delphis* in Waters South of Samos Island, Greece (Eastern Mediterranean Sea)

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Abstract: The Mediterranean subpopulation of short-beaked common dolphin *Delphinus delphis* is ranked as endangered on the IUCN (International Union for Conservation of Nature) Red List because it has sharply declined during the last decades, resulting in sparse and decreasing populations. Monitoring the conservation status of this endangered dolphin species is particularly relevant to fulfil targets under the range of several international agreements. Moreover, estimating the abundance of *D. delphis* is essential to verify the effectiveness of conservation action to maintain safe population levels in the Mediterranean Sea and to suggest appropriate modifications to limit potential threats. In this regard, a monitoring program of the short-beaked common dolphin in Samos Island (Greece) was carried out from 2016 to 2019, adopting a random line transect sampling method. The overall density and abundance estimates of *D. delphis*, obtained by applying conventional distance sampling (CDS) on sighting data, were 0.15 individuals/km^2 (CV = 13.27%; 95% CI = 0.11–0.19 individuals/km^2) and 51 individuals (CV = 13.27%; 95% CI = 40-66 individuals), respectively. Although, a longer time series of sighting data should be collected and a larger area should be investigated to better understand the population trend of *D. delphis* and its residency pattern, the results contribute to setting up a baseline reference for future assessment of its population in the Eastern Aegean Sea.

Keywords: cetacean; conservation; conventional distance sampling; endangered species; short-beaked common dolphin

1. Introduction

The short-beaked common dolphin *Delphinus delphis* (hereafter, common dolphin) is one of the cetacean species that regularly occurs in both the coastal and pelagic domains of the Mediterranean Sea as well as in other oceanic areas [1,2], with its spatiotemporal occurrence linked to seasonal fluctuations in sea-surface temperature and upwelling currents [3,4]. In the Mediterranean Sea, the common dolphin may occasionally form mixed groups with other cetacean species. In shallower waters, it can be observed in mixed groups with the common bottlenose dolphin *Tursiops truncatus* [5,6]. In offshore waters over the continental slope it can be observed in mixed groups with the striped dolphin *Stenella*

coeruleoalba [3,7–14]. A specific case exists in the Gulf of Corinth where *D. delphis* has usually been recorded in mixed groups with the striped dolphin and the Risso's dolphin *Grampus griseus* [15–19].

The common dolphin was one of the most abundant species in the Mediterranean basin, but in recent decades it has sharply declined due to multifactorial and increasing anthropogenic threats (e.g., climate change, habitat loss and degradation, prey depletion, as well as underwater noise and chemical pollution) [6]. Consequently, the Mediterranean subpopulation of common dolphin was declared endangered by the IUCN [20], and recently, the local population of *D. delphis* in the Gulf of Corinth was proposed as critically endangered [19]. In this regard, monitoring the conservation status of this endangered dolphin species at both the local and Mediterranean regional scale is particularly relevant to fulfil targets under the range of several international agreements such as the Habitats Directive (Annex IV), the Barcelona Convention (Annex II), the Convention on Biological Diversity, and the ACCOBAMS agreement. Moreover, *D. delphis* and other cetacean species represent key taxa in the marine food web, as they are highly responsive to anthropogenic impacts, assuming a significant role in addressing a Good Environmental Status (GES) for EU marine ecosystems according to the Marine Strategy Framework Directive (MSFD) [21–23]. Therefore, providing information on the occurrence and abundance estimates of *D. delphis* is essential to support the implementation of effective conservation measures to maintain safe population levels and to suggest appropriate modifications to limit potential threats.

Currently, records of this species are documented in the Pelagos Sanctuary, near Lampedusa Island and in the Messina Strait [13], off western Sardinia [24], in the Cap Bon area (northern Tunisia) [25], in the eastern Ionian Sea [15], in the Aegean Sea [26–28], and in the Levantine Sea [29,30]. Local abundance estimates of this species have only been provided for long-term monitored areas such as the Alborán Sea [4,11], the waters off Malta [31], the Inner Ionian Sea Archipelago [6,32,33], the Gulf of Corinth [17,18,34], and the Thracian Sea [35]. Recently, an attempt to estimate abundance of a local population of common dolphin inhabiting waters near Lipsi and Samos islands, in the Eastern Aegean Sea, was carried out by the authors of [36]. However, the abundance estimates were provided only using photo-identification data collected during 2015 and 2017, whereas the density estimate was carried out by statistical tests including sighting data collected during 2016 and 2017 along pre-determined transects [36]. Against that background, some of the previous studies are very preliminary and often represent qualitative assessments of the species trend. Moreover, to date, no overall abundance estimate has been provided for *D. delphis* in the ACCOBAMS area [37].

This study aims to update information on the occurrence of *D. delphis* in the waters of Samos Island (Greece) and to provide estimates of density and abundance by applying the conventional distance sampling (CDS) method on sighting data collected through the study period from 2016 to 2019. This research could represent a baseline reference for future assessment of this species in an area already proposed as a Cetacean Critical Habitat [38,39], but for which insufficient knowledge on the population status as well as on the main anthropogenic pressures have limited the implementation of specific management actions that may ensure conservation benefits [40].

2. Materials and Methods

2.1. Study Area

The study area is located to the south of Samos Island (Greece) covering an area of approximately 351 km^2, on a shallow plateau with depths that rarely exceed 100 m (Figure 1). The surrounding area is characterized by a steep valley formation reaching approximately 1500m in depth. A small-scale artisanal fishery is active in the area. Trammel and gill-netters, bottom trawlers, and long-liners are distributed in several fishing harbors along the coast of Samos and neighboring islands [41–44]. Marked shipping traffic providing underwater noise affects the area, and floating plastic debris has been increasingly recorded, probably due to the presence of different marine thoroughfares from

the Dardanelles Straits towards Athens, the Suez Canal (via the Dodecanese Archipelago), and Turkey/Cyprus via Rhodes [44].

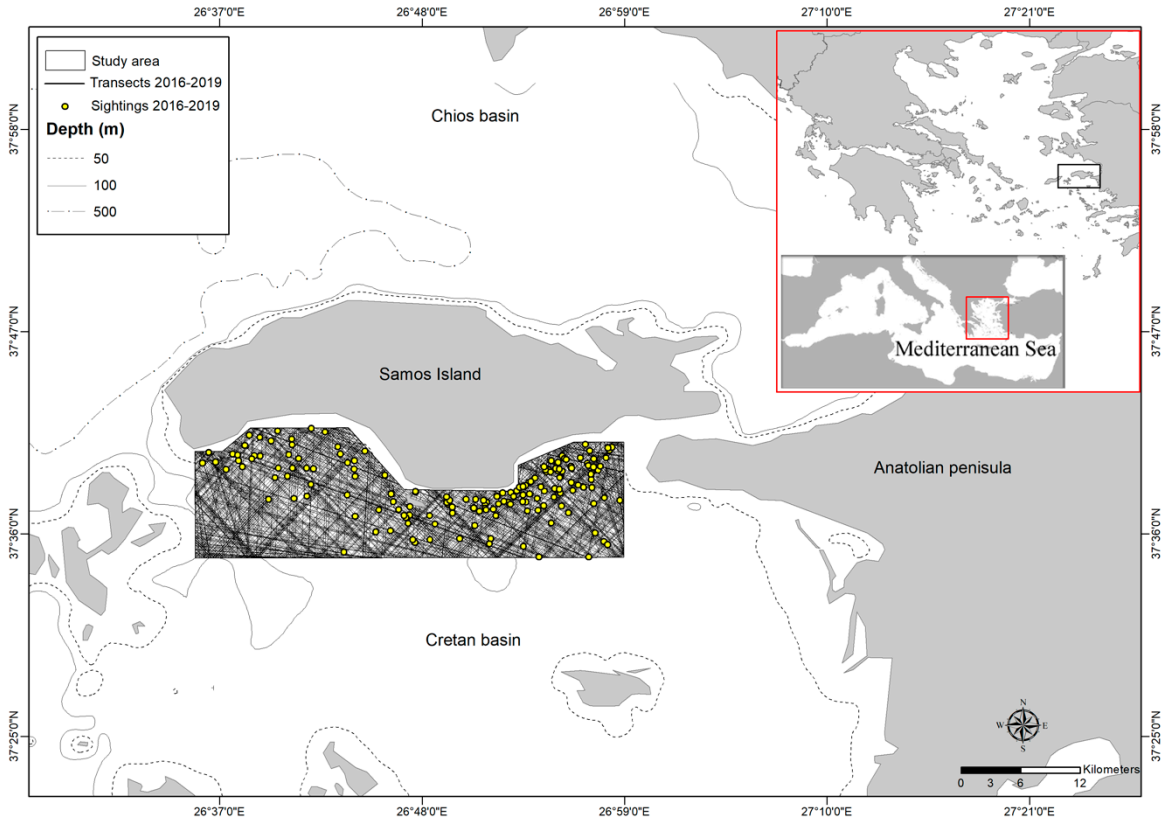

Figure 1. Map of the study area south of Samos Island in the Eastern Aegean Sea (Eastern Mediterranean Sea) with indication of sampling transect lines carried out from 2016 to 2019.

2.2. Data Collection

Sighting data were collected during daily-standardized line-transect surveys carried out from February 2016 to September 2019 on board of a 50-foot sailing boat. According to [45], a systematic equal spaced zigzag survey design with a random start was adopted to afford better spatial coverage of the study area [46] and to reduce effective costs and off-effort navigation time [47]. Random transects of 50 km were generated daily with an angle of 0° to the x-axis using the Distance 7.3 software. The sampling effort was set at approximately 5 h/day with a boat speed of 6 knots. Trips were carried out only in favorable weather conditions (Douglas scale ≤ 3 and Beaufort scale ≤ 4) to avoid the underestimate of dolphin's abundance due to the loss of possible sighting data [48]. Observations were made by four observers of whom two were always trained experts, investigating a sector from the track line to 90° on the starboard and the port sides. Observers rotated their positions after 30 min of observation. Once a target (an individual or a group of dolphins) was detected, the geographic position of the boat, the angle at first contact and the radial distance were measured using an on-board compass and a marine reticule binocular, assuming the dolphins position did not change during measurement [49]. In addition, the date, sea and weather conditions, depth, species, and group size (number of individuals) were also recorded.

2.3. Data Analysis

Analysis of sighting data to estimate density and abundance of *D. delphis* in the study area was performed using conventional distance sampling in the Distance 7.3 software [46]. Different configuration setting values were previously tested to adopt the correct truncation value. The value of

750 m proved to be the best solution because it assures that the probability of detection stays close to 1 for some distance from the line, and that the probability of detection has a wide shoulder (shape criterion) [45]. In addition, this value also corresponds to half the width of the strip (line transect sampling), which is consistent with the indication provided in [50]. The model of detection function and the encounter rate (ER) were estimated, stratifying for each sampling year (representing the stratum), and the selection of the best detection function model was made using the Akaike information criteria (AIC) [51]. The possible effect of the change of the effort applied and of the group size recorded through the study period was tested by means of the non-parametric Mann–Whitney test (U test) with Bonferroni's correction [52] (PAST 3.05 Software, [53]). The expected value of group size was assessed using a size-biased regression method if the regression was significant with an α of 0.05, otherwise the mean of group size was used. Estimates of the encounter rate, the expected value of group size, the effective strip width (ESW), the abundance, and density of the common dolphin throughout the study period were provided for each sampling year, reporting the coefficient of variation (CV).

3. Results

A total effort of 214 daily surveys was applied in the study area during the investigated period (2016–2019) (Table 1). Approximately 1070 h of observations were carried out covering 10,700 km and providing 128 *D. delphis* sightings. Sightings of common dolphin occurred in waters with depths ranging between 12 and 100 m with a mean of 60 ± 22 m (Table 1). The results of the CDS analysis are summarized in Table 2. Based on the lower AIC values, the half-normal key function with no cosine adjustment term proved to be the best model of the detection function, fitting sighting data of *D. delphis* recorded in each stratum (Figure 2). The ER values ranged between 0.009 (CV = 25.33%) in 2018 and 0.017 sightings/km in 2019 (CV = 19.17%). The estimated ESW ranged from 229.85 m (CV = 20.93%) in 2018 to 449.46m (CV = 15.86%) in 2019. The expected value of group size, representing the mean group size estimated by CDS, ranged from 6 individuals (CV = 19.42%) in 2018 to 10 individuals (CV = 17.28%) in 2019. Density and abundance values ranged, respectively, between 0.11 individuals/km^2 and 39 individuals (CV = 38.17%) in 2018 and 0.18 individuals/km^2 and 67 individuals (CV = 30.29%) in 2019. No significant differences were observed in the effort applied or the group size recorded through the sampling period (U-test, $p > 0.05$). Therefore, the overall density and abundance estimates of common dolphin in the study area, obtained by pooling data by year, were 0.15 individuals/km^2 (CV = 13.27%; 95% CI = 0.11–0.19 individuals/km^2) and 51 individuals (CV = 13.27%; 95% CI = 40–66 individuals), respectively.

Table 1. Sampling period, number of daily surveys, effort (hours and kilometers), range and mean of investigated depth (m), and number of sightings of *D. delphis* that occurred in waters south of Samos Island from 2016 to 2019.

Sampling Period	N. Daily Surveys	Effort		Depth Range (m)	Mean Depth	N. of Sightings
		Hours	Kilometers			
Feb–Dec 2016	77	385	3850	18–86	54 ± 19	34
Jan–Dec 2017	60	300	3000	30–100	62 ± 23	48
Jan–Dec 2018	45	225	2250	47–90	71 ± 14	17
Jan–Sep 2019	32	160	1600	12–93	54 ± 24	29
Total	214	1070	10700	12–100	60 ± 22	128

Table 2. Estimates by year of the encounter rate, effective strip width (ESW), group size, density, and abundance of *D. delphis* obtained by conventional distance sampling (CDS) analysis.

Year	Encounter Rate	ESW	Group Size	Density	Abundance
2016	0.009 (16.32)	278.45 (13.15)	9 (11.29)	0.14 (23.81)	53 (23.81)
2017	0.014 (12.73)	354.17 (11.89)	7 (10.01)	0.14 (20.09)	48 (20.09)
2018	0.009 (25.33)	229.85 (20.93)	6 (19.42)	0.11 (38.17)	39 (38.17)
2019	0.017 (19.17)	449.46 (15.86)	10 (17.28)	0.19 (30.29)	67 (30.29)

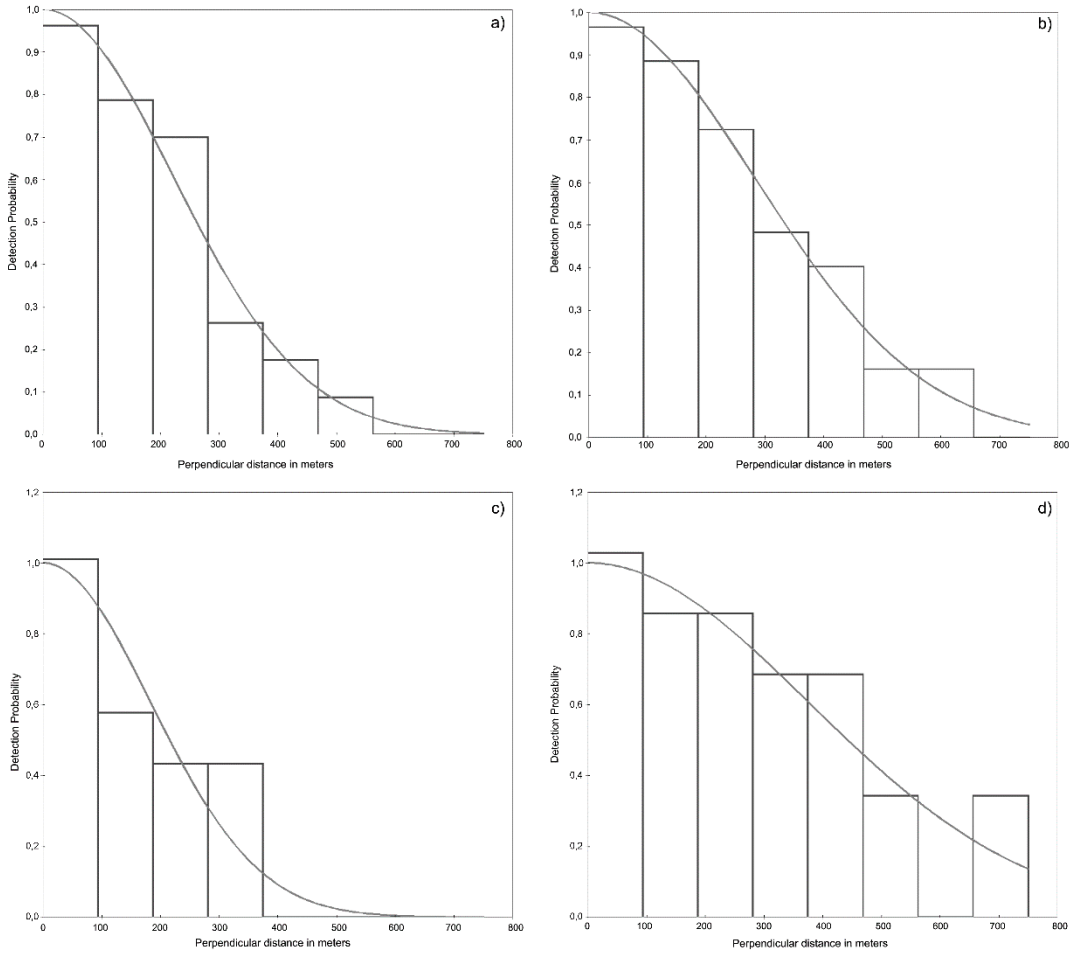

Figure 2. Detection functions modelled for *D. delphis* in (**a**) 2016, (**b**) 2017, (**c**) 2018, and (**d**) 2019.

4. Discussion

Estimations of encounter rate, group size, density, and abundance values of *D. delphis* were made by the application of CDS analysis to sighting data collected during standardized surveys carried out near Samos Island, Greece (Eastern Aegean Sea), providing a comparison with analogous values estimated in similar studies carried out in other Mediterranean areas (Table 3). The encounter rates estimated in the study area were higher than values reported for the Alborán Sea [4], in waters off Ischia Island [14], in the Inner Ionian Sea Archipelago [6,32], and in the Thracian Sea [35], indicating that the waters off the south of Samos Island are an eligible habitat for *D. delphis*. The estimated ER values could be used as an effective baseline for future assessment of the common dolphin conservation status in the area, where an increasing trend in small-scale fishery exploitation and tourist flow have been recorded in the last few years, representing potential harmful threats for the species. The mean group size estimated for the waters south of Samos Island confirmed the pattern observed for the species in the Inner Ionian Sea Archipelago [6,32] and the Thracian Sea [35]. The small-sized aggregation of

common dolphin groups is probably due to a behavioral feeding strategy caused by the distribution of prey (small pelagic fish) over many small patches in the study area [5,28,54], which leads dolphins to split into smaller groups for more efficient predation [55]. On the other hand, the presence of highly productive marine areas and the high seasonal abundance of prey leads to the formation of larger groups of *D. delphis* as observed in the western Alborán and southern Almeria [4,11], in the Tyrrhenian Sea [8,13,14] and in waters off Malta Island [31]. Indeed, the presence of small pelagic fish such as sardine and anchovy resulted in an important explanatory variable in the modelling of the distribution of the common dolphin as reported by the authors of [28] in the Aegean Sea. However, both the presence and distribution of these small pelagic fish can fluctuate with the seasons depending on environmental factors such as sea surface temperature and chlorophyll concentration, causing a variation in the presence of the common dolphin, both in its group size and spatial distribution. In effect, during warmer months, the common dolphin shows a preference for coastal waters due to the movement to epipelagic areas by small pelagic fish both in the western [3,11] and eastern Mediterranean areas [35,56]. During the colder season, the species seems to move in offshore waters in the western Mediterranean areas, whereas in the Greek seas it seems to remain relatively close to the coast (not exceeding 400 m) also thanks to the presence of Levantine Intermediate Water. The overall density estimate of the common dolphin in the study area is generally in line with the corresponding values reported in both the western and central-eastern Mediterranean regions (Table 3). The overall abundance estimated in the waters south of Samos Island is lower than the values reported for the Thracian Sea [35] and for the Eastern Aegean Sea [36] as well as for the Alborán Sea [4,11]. In contrast, abundance is higher than the latest estimates reported for the Inner Ionian Sea Archipelago [33] and the Gulf of Corinth [17,34]. However, caution in any further comparative consideration is required given the different extensions of the study areas, platforms of observation, sampling designs, and the estimation methods applied. The abundance estimates for the common dolphin provided in the waters south of Samos Island confirmed the importance of this area as a suitable habitat for the species [36]. Nevertheless, a longer time series of sighting and photo-identification data in the investigated area as well as in the larger area should be implemented for a better understanding of the population trend, its residency pattern, and its possible movements throughout the Aegean Sea [35,57,58]. Further research studies aimed at clarifying environmental and anthropogenic variables shaping the critical habitat of *D. delphis* are necessary, mostly because the knowledge on this species is still fragmentary and incomplete [27,59]. In particular, very little is known on the genetic exchange between local aggregations of this species within the Aegean Sea and with other neighboring or even more distant areas. Moreover, the direction of the genic flow for *D. delphis* between the western and eastern Mediterranean regions should be very accurately investigated. In that regard, a common survey plan extended to different local areas of the Mediterranean Sea could address appropriate action for conservation of this species. The Central Aegean Sea including the Cyclades and Dodecanese Archipelagos, as well as the islands of Samos and Ikaria, have recently been declared an Important Marine Mammal Area (IMMA) for the occurrence of Mediterranean monk seal *Monachus monachus* and different species of cetaceans, including the common dolphin [60]. Unfortunately, the presence of this endangered species appears not be enough to meet criteria for the setting up of an IMMA. Conversely, increasing human use of the Aegean basin by fishing vessels and maritime traffic, which produce high sound pressure levels, has been well documented [27,36]. This situation requires the urgent establishment of a comprehensive strategy for maintaining these potentially harmful activities within acceptable levels according to the EU Marine Strategy Framework Directive and Maritime Spatial Planning Directive.

Table 3. Encounter rate (ER groups/100km), density (D), and abundance (N) values with coefficient of variation (% CV) and mean group size estimated for *D. delphis* in the Mediterranean Sea. Indication of the investigated area and years, extension of the study area (km^2), platform of observation, estimation method, and references are reported.

Region	Investigated Area	Years	Study Area	Observation Platform	Estimation Method	ER	D (%CV)	N (%CV)	Mean Group Size
Western Mediterranean region	Alborán Sea, Spain [4]	1991	90670	Boat	CDS	2.11	0.160 (40)	14736 (40)	38.4
		1992	-	-	-	0.75	-	-	10.0
	Ischia Island, Italy [8]	1997–2001	-	Boat	Photo-ID	-	-	-	65.5
	Southern Almeria and westernmost Alborán Sea, Spain [11]	2000–2004	19189	Boat	MCDS	-	1.010 (10.7–18.0)	19428 (10.7–18.0)	-
	Pelagos Sanctuary, Italy [13]	2000–2014	-	Different boats	Visual surveys	-	-	-	5.9
	Central Tyrrhenian Sea, mainly Ischia Island [13]	-				-	-	-	33.5
	Southern Tyrrhenian Sea, mainly Strait of Messina [13]	-				-	-	-	13.9
	Sicily Channel, mainly Lampedusa Island [13]	-				-	-	-	-
	Western Ionian Sea [13]	-				-	-	-	-
	Waters off Ischia Island (Gulf of Naples, Italy) [14]	2000–2015	8800	Boat	Visual surveys	0.12	-	-	43.6
Central-eastern Mediterranean region	Malta Island [31]	1997–2003	28000	Boat + aerial	-	-	0.140 (29.5)	-	25.0
	Kalamos Island, Greece [6]	1993–2002	500	Boat	Photo-ID	1.60 (1993–2000) 0.70 (2001–2002)	-	-	12.0–7.0
	Inner Ionian Sea Archipelago, Greece [32]	1993–2003	480	Boat	Photo-ID	2.18 (1997) 0.40 (2003)	-	-	13.1–9.2
							-	-	
	Inner Ionian Sea Archipelago, Greece [33]	1996	1050	Boat	Mark-recapture	-	0.140 (-)	150 (-)	-
		2007				-	0.014 (-)	15 (-)	-
	Gulf of Corinth, Greece [34]	2009	2400	Boat	Mark-recapture	-	0.012 (-)	28 (-)	-
	Gulf of Corinth, Greece [17]	2011–2015	2400	Boat	Mark-recapture	-	0.009 (-)	22 (17.0)	45.0
	Thracian Sea, North Aegean Sea [35]	2005–2013	2000	Boat	CDS	0.24	0.021 (22.6)	1482 (22.6)	6.9
	Lipsi and Samos Island, Eastern Aegean Sea [36]	2017	-	Boat	Mark–recapture	-	-	180 (-)	-
	Samos Island, Eastern Aegean Sea (Present study)	2016–2019	351	Boat	CDS	0.88 (2018)–1.70 (2019)	0.146 (13.27)	51 (13.27)	7.0

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