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Research Article

Male-biased in-water population of loggerhead turtle (*Caretta caretta*) in Dalyan, Turkey as a possible important marine turtle area in the Mediterranean

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Abstract: In this study, we present the first in-water monitoring results of loggerhead turtles (*Caretta caretta*) in Köyceğiz-Dalyan specially protected area (SPA), Turkey. The capture-mark-recapture (CMR) study encompassed a total of 113 capture events of 88 individuals across two sampling years. The majority of the population was adults (88.6%) with a highly male-biased (70.5%) sex ratio. Our results indicate that some of the overwintering individuals also contribute to the nesting population in the region. Biometric characteristics of captured individuals were also presented. Additionally, we found the population to be under heavy anthropogenic threats with 54.5% of the captured individuals exhibiting results of previous anthropogenically caused injuries. Our results suggest that Köyceğiz-Dalyan SPA is an important overwintering and foraging area for loggerhead turtles, which is currently an indexed nesting site for loggerhead turtles in the Mediterranean. Given the possible feminization effects of climate change on future marine turtle populations, the male-biased population in the study area is of the greatest importance, and together with having an indexed nesting site, the area should therefore be regarded as an important marine turtle area.

Key words: Overwintering area, in-water population, sex ratio, hotspot, anthropogenic impact

1. Introduction

Marine turtle monitoring and conservation studies have been regularly conducted for more than three decades on the major Mediterranean nesting beaches of Cyprus, Greece, and Turkey. In the Mediterranean, the most abundant marine turtle species is the loggerhead turtle (*Caretta caretta*) and the Mediterranean loggerhead turtle population is considered to be one of 10 subpopulations which were defined as regional management units (Wallace et al., 2010). Loggerhead turtle nesting occurs mainly in Greece, Turkey, Cyprus and Libya (Kasparek et al., 2001; Margaritoulis et al., 2003; Canbolat, 2004; Casale and Margaritoulis 2010). Due to a general increase in the number of nests deposited annually, the Mediterranean subpopulation of the loggerhead turtle has been recategorized from Endangered to Least Concern (LC) under the International Union for Conservation of Nature (IUCN) Red List criteria (Casale, 2015).

Despite the downgrading of the threat status for Mediterranean loggerhead turtle, anthropogenic effects such as entanglement in fishing gear (Casale and Margaritoulis 2010; Snape et al., 2013; Başkale et al., 2018a), collision with marine vehicles (Casale and Margaritoulis 2010; Başkale et al., 2018a), macro debris entanglement and plastic ingestion (Tomás et al., 2002; Camedda et al., 2014; Nelms et al., 2015) still remain a significant threat to the Mediterranean loggerhead turtles in marine habitats. Another factor threatening all marine turtle species is global climate change, with marine turtle nesting beaches, coastal and oceanic areas expected to be heavily affected in the future (Hamann et al., 2013). Marine turtles also display temperature-depended sex determination (TSD) (Mrosovsky and Yntema 1980; Wibbels 2003), and it is considered that the warming effect of climate change could present a possible conservation issue that may result in the feminization of future populations (Hamann et al., 2007; Hawkes et al., 2009). The Mediterranean loggerhead turtle population is therefore considered as a conservation-dependent species (Casale, 2015).

Over the last 30 years, various researches have documented for nesting of loggerhead turtle at different nesting beaches in Turkey (Kasparek and Baran, 1989; Türkozan et al., 2003; Canbolat, 2004; Ilgaz et al., 2007; Yalçın-Özdilek, 2007; Kaska et al., 2010; Başkale et al., 2016). Conversely, there is a significant gap in the knowledge of in-water populations, population dynamics and foraging areas in Turkey. Marine turtles spend almost their entire lives at sea (Musick and Limpus 1997), however, our knowledge is mainly restricted to nest counts and nesting females; little is known about their life history, mainly for males and juveniles due to the inaccessibility at sea, this is particularly the case for those inhabiting the Mediterranean region. Casale et al. (2014) briefly explained the need for a good sampling of the natural sex ratio and demographic parameters of marine turtles as a species with TSD to accurately calculate their population size and reproductive outputs.

To date, female-biased hatchling sex ratios have been reported for most loggerhead turtle nesting beaches in Turkey (Kaska et al., 1998; Öz et al., 2004; Kaska et al., 2006; Uçar et al., 2012; Candan, 2014; Sarı and Kaska, 2015). This is also the case for other Mediterranean countries (Godley et al., 2001; Mrosovsky et al., 2002; Rees and Margaritoulis 2004; Zbinden

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et al., 2007). However, recent studies have shown a balanced adult sex ratio from different foraging grounds in the Mediterranean (Rees et al., 2013; Casale et al., 2014). However, the operational sex ratio (OSR), which refers to the ready to mate male to female ratio in a breeding area, is considered as a key determinant of population viability (Berglund, 1994) and the use of OSR is a more reliable criterion than the use of the hatchling sex ratio for population assessments (Hays et al., 2010). Casale et al. (2014) suggested that the juvenile sex ratio and adult sex ratio at foraging grounds, and OSR should be investigated as separate entities.

Our knowledge of male and juvenile loggerhead turtle distribution and possible foraging areas in Turkey are mainly limited to stranding data (Kaska et al., 2004; Türkozan et al., 2013; Tonay and Oruç, 2016; Başkale et al., 2018a; Sönmez, 2018; Türkozan et al., 2018). In addition to previous stranding reports, loggerhead turtle tracking studies using satellite telemetry suggests that the Aegean and southwest coast of Turkey are used by loggerhead turtles as foraging areas (Schofield et al., 2009; Patel et al., 2015; Rees et al., 2017). Moreover, the biochemical blood parameters of loggerhead turtles captured from the Köyceğiz-Dalyan SPA, were reported that there is a foraging area, although the sample size was limited (Sözbilen and Kaska, 2018).

In the present study we report the results of the first capture-mark-recapture (CMR) study of the loggerhead turtle in-water population from Turkey. The aim of our study is (i) to determine the in-water loggerhead turtle population structure and estimate the population size before the beginning of breeding season, and (ii) the importance of the study area for loggerhead turtles as a foraging and overwintering area. We also provide information about the ecologic characteristics such as food availability, salinity, and the water temperature of the Delta, and anthropogenic threats to the population.

2. Materials and methods

2.1. Study area

The Köyceğiz-Dalyan SPA is located on the southwest of the Turkish Mediterranean coast (36°4`N,28°37`E). Dalyan Beach, which is an important loggerhead turtle nesting beach in the Mediterranean, is located within the border of this SPA. A lagoon and a large delta have formed behind the beach. The delta contains reedbeds, two lakes and a connected channel system, which forms the Dalyan River and extends to the freshwater Köyceğiz Lake (Figure 1). The area provides shallow water habitats (depth range 2–4 m). The salinity of the water in the Delta varies seasonally, however, a strong stratification and opposite currents exist in the channel system; the bottom of the water column has high salinity (from 20 ppt to 34 ppt) and the current is upstreaming to the Köyceğiz Lake, while the top of the water column has lower

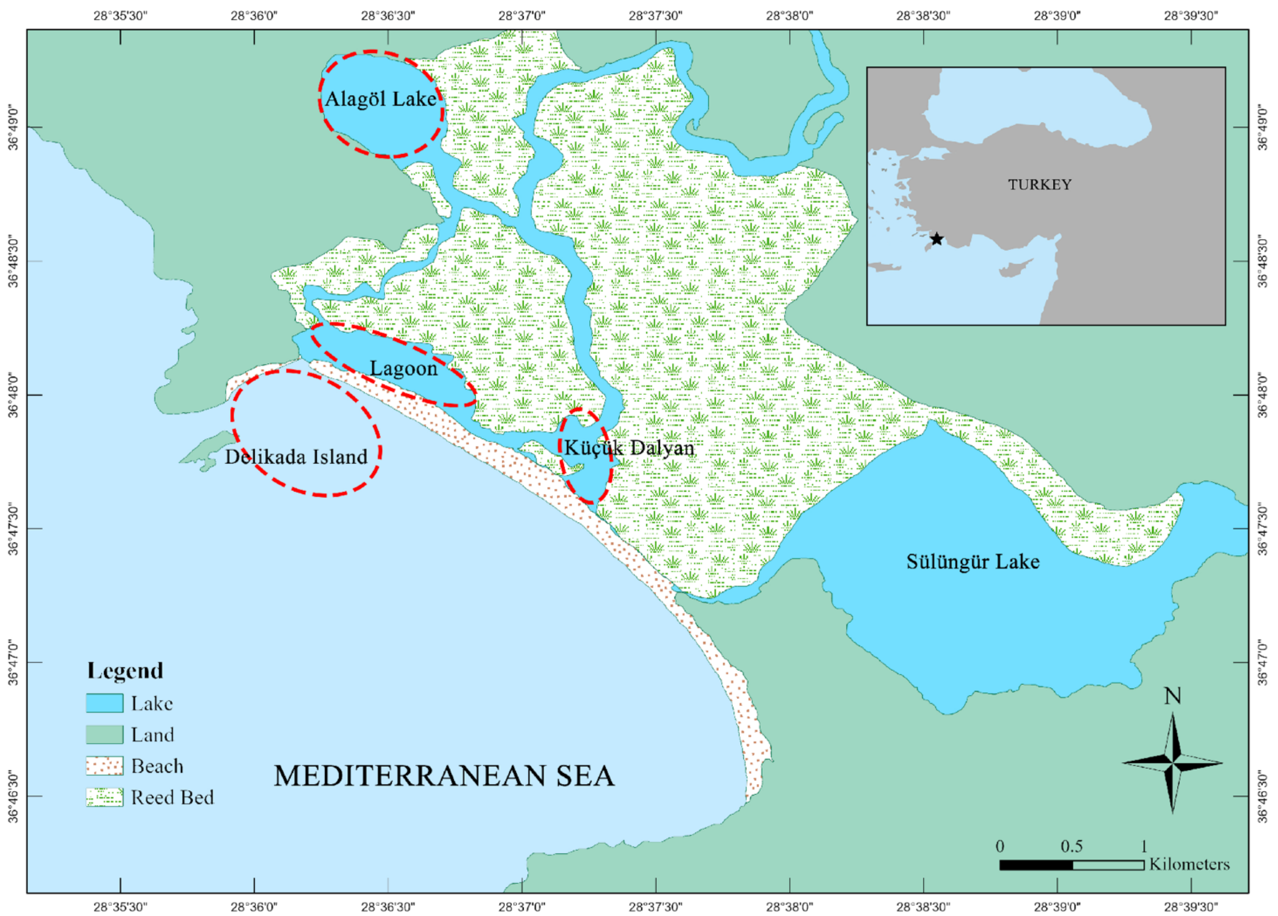

Figure 1. Map of study area (dashed circles indicates sampling locations).

salinity (from 0 ppt to 10 ppt) and the current is downstreaming to the sea (Ertürk, 2002). In addition, there are several subaqueous hot springs in the delta (Avşar et al., 2017). The Atlantic blue crab (*Callinectes sapidus*), which is a natural prey for the loggerhead turtle is also abundant within the Köyceğiz-Dalyan SPA.

Our initial visual observations showed that loggerhead turtles aggregated in the delta, and within the sea (up to 1 km offshore). To calculate the available area for the loggerhead turtles in the region, the polygons of Alagöl Lake, Küçük Dalyan, Lagoon and the channel system of Dalyan River, and marine area were created in Google Earth and these polygons were later transferred to ArcGIS 10.4 to create the map of the area (Figure 1). Available areas for turtles were obtained by calculating the areas of the polygons with ArcGis 10.4.

2.2. Loggerhead turtle capture

We determined the sampling sites according to a previous study in the region (Sözbilen and Kaska, 2018), and unpublished stranding records of the Sea Turtle Research, Rescue and Rehabilitation Center (DEKAMER). The four sites for sampling areas are; the Alagöl Lake, Lagoon, Küçük Dalyan, and the Delikada Island, which is at the seaside of the opening of the lagoon (Figure 1).

The loggerhead turtles were captured during February and March of 2016 and 2017. This time of year was chosen because in Turkey, nesting starts in May (Türkozan and Kaska, 2010), and in the Mediterranean breeding aggregation usually start to occur during April (Hays et al., 2010). Our aim was to estimate the foraging/overwintered loggerhead turtle population size; hence, we avoided capturing turtles later in the season, as turtles captured after April are more likely to represent the breeding population. Sampling surveys started in February for both study seasons with an interval of a week between each sampling event. During the study, a total of 11 sampling events were held: six in 2016 and five in 2017.

We used an entanglement net to capture the turtles (600 m wide × 8 m depth, mesh size = 15 cm) because the water visibility in the delta was less than 2 m and capturing turtles by other techniques would not be suitable. The entanglement net was set during the day and monitored continuously, and the netting time was 3 h on each occasion. The turtles were captured immediately after becoming caught in the net and transferred to the boat. All the captured individuals were kept on board until the net had been collected from the water. The catch per effort unit (CPEU) was also calculated and one-unit effort was accepted as 3 h set for a 600 m net.

All procedures performed in this study involving animals were permitted under the standards of Pamukkale University Animal Experimentation Ethics Committee (60758568-020/2541).

2.3. Morphometric measurements

The morphometric measurements of straight carapace length (SCL) and straight carapace width (SCW) were measured by a 1.5-m long wooden callipers, and curved carapace length (CCL) and curved carapace width (CCW) were measured by a measure tape according to the technique specified by Bolten (1999). We did not include the measurements of recaptures to the statistical analyses in the same season. The turtles were also weighted by using an electronic balance (ACS, model OCS 300) in kg. A body condition index (BCI= Weight/SCL^3 × 10,000) was calculated as Fulton's K index according to Ricker (1975). All individuals were tagged with metal tags (National Band and Tag Co, Style 681) on both front flippers.

The sex of the captured individuals was determined through visual examination of the tail length, concave softened plastron. The tail length is a secondary sex characteristic in marine turtles, with adult males having a large and muscular prehensile tail which extends well beyond the carapace, and the tail of female marine turtles is short and is just visible slightly beyond the edge of the supracaudal scutes (Wibbels, 1999). Previous studies showed that tail elongation starts around 65 cm of CCL for the Mediterranean loggerhead turtle population (Casale et al., 2005; Rees et al., 2013). Therefore, we accepted an elongated and muscular prehensile tail as a male character for the individuals over 65 cm CCL, but we did not measure the tail length. In the Mediterranean, the average size at maturation for females starts at 66.5 cm CCL and males appear to reach maturity at a similar size (Casale et al., 2018); however, the size of loggerhead turtles is smaller in the eastern Mediterranean (Margaritoulis et al., 2003) and on Dalyan Beach a considerable number of loggerhead turtles are nesting between 65 and 70 cm CCL (Kaska et al., 2016). Therefore, individuals smaller than 65 cm CCL were accepted as subadult.

2.4. Observations on anthropogenic effects

We visually observed and recorded past and present injuries and any anthropogenic effects on the captured turtles. Injuries were determined as follows: (i) fractures and propeller marks on the shell defined as marine vehicle collision, and (ii) entanglement of fishing line, fishing hook, ingestion of fishing gear, and fishing line entanglement marks of soft tissues (e.g., around the flipper) were defined as fisheries related injuries. We classified the injuries into two categories: (i) Primary injuries, which are the only visible injury, or the most recent injury if more than one injury occurred, and (ii) secondary injuries, which occurred before the primary injury and are likely to have less effect on the turtle than the primary injury. The wounds were accepted as healed in natural conditions if: (i) synostosis occurred in the fractured shell parts, (ii) keratin tissue developed on the wound, and (iii) no open wounds but fishing gear entanglement marks on the soft tissue. If turtles assessed as healthy (e.g., healed shell fractures, or removal of fishing gear is available on the boat), they were released after measurements and tagging. The turtles with fresh injuries, or fishing gear ingestion were transferred to DEKAMER for treatment.

2.5. Statistical analyses and populations size estimates

All morphometric measurement data showed normal distribution (Kolmogorov-Simirnov test $p > 0.05$) except for the calculated BCI values ($p < 0.05$). We used a Kruskal-Wallis test to compare the BCI of male, female, and subadult individuals. If statistically significant differences were found, Mann-Whitney U test were used. Student's t-test is used to compare SCL, CCL, and weight of male and female individuals. We used Minitab v. 16.2 for statistical analyses. The linear and nonlinear regression models were tested to explain the relationship between weight and SCL. We tested the weight and SCL relationship for three groups: (i) females and males, (ii) adults and subadults, (iii) all individuals are included, then the best fitted model was selected.

We assumed that the study area was a foraging area and the loggerhead turtles overwintered in the study area. In addition, we accepted that the migratory individuals had not entered the study area for breeding. Nevertheless, a breeding season had occurred between the two study years and it was likely that the area had some new recruits, while other individuals had left the area. Even so, loggerhead turtles show a high degree of fidelity to specific neritic areas (Broderick et al., 2007; Rees et al., 2013; Schofield et al., 2010). We therefore accepted that the loggerhead turtle population was a closed population for each of the sampling sessions but open year to year in the study area. We also assumed that there was no tag loss during our study period, and the catchability of each individual in each sampling sessions were equal. We selected the model Pollock's robust design full likelihood under the Program MARK v. 6.2 (White and Burnham, 1999) to estimate the population size, annual survival (S), capture probability (p) and recapture probability (c), for each sampling session.

3. Results

3.1. Loggerhead turtle population in the study area

A total of 113 capture events of 88 loggerhead turtles during 33 h of netting time during 11 sampling events. We captured a total of 57 individuals in Alagöl Lake, 25 individuals in Küçük Dalyan, 22 individuals in the lagoon, and nine individuals at Delikada Island. A total of 55 captures of 47 turtles occurred during 2016 on 6 occasions, and 58 captures of 41 turtles occurred during 2017 on 5 occasions. A total of 8 turtles recaptured on the first six occasions during 2016, and 13 turtles from 2016 and 4 turtles from 2017 were recaptured on five occasions during 2017 (Table 1). A total of eight males, four females, and one subadult turtle were captured in both sampling years.

The vast majority of captured individuals were adult (88.6%) and highly male biased for two successive years (70.5%). In 2016, 64.3% of adult individuals were male, and 35.7% were female. In 2017, 77.8% of adult individuals were male, and 22.2% were female (Table 1). Six of 23 female turtles were observed nesting on the Dalyan Beach during the nesting seasons before or after the sampling period. One female (T21; Table 2) which was known to nest on Dalyan Beach in 2012 captured in both sampling years and nested in 2017; one turtle captured in 2017 nested in the same year, and one turtle captured in 2017 nested in 2018. Three females captured in the first sampling year were also known to nest on Dalyan Beach in 2013–2015, but they were not observed on the beach during the following nesting seasons. In addition, four male turtles that were tagged during CMR study were observed in the lagoon area during summer in 2017, but these individuals were not included into population estimates because these turtles were not observed with standard CMR methodology during the winter period.

Although the study period for both study years were the same, the CPUE showed variations during each occasion. The highest CPUE was yielded in Alagöl Lake with 14.5 (one turtle per 0.2 h), and the lowest was yielded in Delikada Island with 1.0 (one turtle per 3.0 h). The estimated mean number of loggerhead turtles was 78 (95% CI: 53.7– 191.6; SE: 28.7) with the mean capture probability (p) of 0.14 and recapture probability (c) of 0.06 for 2016, and 96 (95% CI: 63 – 246; SE: 38.2) with the mean capture probability (p) of 0.15 and recapture probability (c) of 0.03 for 2017. The survival probability (S) among two study years was calculated as 0.66.

3.2. Habitat use and population density

The available area for turtles was calculated as 1.52 km^2 in the Delta, and 4.50 km^2 in the sea. The use of marine habitats during winter was limited, and overwintering loggerhead turtles were frequented in the Delta. Only nine individuals were captured in the sea, which was between the opening of the lagoon and Delikada Island. However, loggerhead turtles used both delta and marine areas during the nesting period.

During our CMR study, 89.7% of all captures occurred in the delta. The same individuals captured in the sea were also captured in the delta during later sampling events. Therefore, we accepted that all loggerhead turtles were using the delta for overwintering. We calculated that there were 51.3 individuals per km^2 for the mean number of 78 loggerhead turtles in 2016, and 63.2 individuals per km^2 for the mean number of 96 loggerhead turtles in 2017.

3.3. Turtle morphometrics and BCI

We captured female, male and subadult loggerhead turtles in the study area. The size, weight and the BCI showed variations between both sexes. The size of the turtles ranged from 47.8 cm CCL to 94.0 cm CCL, and from 45.3 cm SCL to 90.6 cm SCL. The SCL (Student's t-test, $t = 3.06$; $df = 44$; $p < 0.01$) and the CCL (Student's t-test, $t = 2.90$; $df = 44$; $p < 0.01$) were significantly different between males and females. The weight of the turtles ranged from 12.8 kg to 90.2 kg (Table 3). The mean weight of the males (50.5 kg) was higher than the females (45.6 kg), but there were no significant differences between sexes (Student's t-test, $t = 1.19$; $df = 35$; $p > 0.05$). The weight and SCL showed a significant relationship in each

Table 1. The number of captures during the study

Years	Adults		Subadults	Total captures	1st recapture	2nd recapture
	Male	Female				
2016	27	15	5	55	5	3
2017	28	8	5	58	17	0
Total	55	23	10	113	22	3

Table 2. Description of past and recent injuries of the loggerhead turtles captured in the study area.

Turtle	Cause of primary injury	Cause of secondary injury	Description of injuries
T1	Marine vehicle		Fracture on the 5th neural scute and 15 cm long transverse propeller cut
T2	Marine vehicle		A fracture from the 5th neural scute to left supracaudal scute and an older fracture on the 5th supracaudal scute
T3	Marine vehicle		Fractures on 2nd and 3rd neural scutes and fractures on both supracaudal scutes
T4	Fisheries related	Marine vehicle	Ingestion of fishing line with hooks. Fishing line was partly defecated. Fracture on 2nd coastal scute
T5	Marine vehicle		Propeller cut on 7th and 8th marginal scutes on the right side
T6	Fisheries related	Marine vehicle	Fishing line entanglement on the left front flipper. Distal end of the left front flipper was severed via unidentified reason. Old propeller cuts on the left 8th marginal scute and on the left supracaudal scute
T7	Marine vehicle		Propeller cut on both supracaudal scutes and a fracture on the 3rd left costal scute
T8	Marine vehicle		A straight and deep cut from the left marginal scutes to 3rd inframarginal scute of the plastron
T9	Marine vehicle		Propeller cuts on the 1st, 2nd, 3rd, and 4th costal scutes on the left side
T10	Marine vehicle		Propeller cuts on the left 9th and 10th marginal scutes
T11	Marine vehicle		Fractures on the left 5th costal scute and on the 5th neural scute
T12	Marine vehicle		A fracture on the 3rd neural scute
T13	Marine vehicle		Propeller cut on supracaudal scutes
T14	Marine vehicle		Fractures on the 1st costal and 1st marginal scutes, 3rd and 4th neural scutes, and supracaudal scutes on the right side
T15	Fisheries related		Two fishing lines in the mouth
T16	Marine vehicle		Fractures on the right 3rd and 4th costal scutes, and on the 3rd neural scutes
T17	Marine vehicle	Fisheries related	Fractures on the 3rd and 4th neural scutes, and a fishing hook in the mouth
T18	Marine vehicle		Propeller cut on the supracaudal scutes
T19	Marine vehicle		Fractures on the right 10th and 11th marginal scutes, and a fracture on the left 11th marginal scute
T20	Marine vehicle		A fracture on the 2nd left costal scute
T21	Fisheries related	Marine vehicle	Fishing line entanglement and fractures on the 10th and 11th left marginal scutes. This turtle was also found stranded with a head injury in Rhodes Island in 2013 and released in 2014 after successful rehabilitation.
T22	Marine vehicle		Large and deep fractures on the 2nd and 3rd left costal scutes and on the 2nd and 3rd neural scutes
T23	Marine vehicle		Propeller cut on the 2nd neural scute
T24	Marine vehicle		Propeller cuts on the 1st and 5th right costal scutes and a fracture on the 5th neural scutes
T25	Marine vehicle		Propeller cuts on the 3rd and 9th left marginal scutes
T26	Marine vehicle	Fisheries related	Propeller cut on the supracaudal scutes, and healed fishing line entanglement marks on the front right flipper
T27	Marine vehicle		Fractures on the nuchal scute, the 3rd right costal scute, and the 8th right marginal scute
T28	Marine vehicle		Propeller cuts on the 3rd, 4th, 5th right scutes, the 1st, 2nd, 3rd, and the 4th neural scutes, the 6th, 7th, 9th and the 10th right marginal scutes. Fractures on the 10th and 11th left marginal scutes
T29	Fisheries related	Marine vehicle	Fishing line entanglement on the left front flipper. Propeller cut on the 3rd and 4th right costal scutes
T30	Fisheries related	Marine vehicle	Amputated front left flipper and healed fishing line marks on the neck. Older propeller cuts on the 7th, 10th, and 11th marginal scutes

Table 2. (continued)

Turtle	Cause of primary injury	Cause of secondary injury	Description of injuries
T31	Fisheries related	Marine vehicle	Entangled fishing hook on the front right flipper. Fractures on the supracaudal scutes
T32	Marine vehicle		Fractures on the 10th and 11th left marginal scutes and a propeller cut on the right supracaudal scute
T33	Marine vehicle		Fracture on the 2nd left costal scute
T34	Marine vehicle		Fractures on the 10th, 11th, and 12th left marginal scutes
T35	Marine vehicle		Propeller cuts on the 3rd and 4th left costal scutes
T36	Marine vehicle		Propeller cuts on the 1st neural scute, 1st, 2nd, and 3rd right scutes, and 10th and 12th left marginal scutes. Front left flipper was also amputated via unidentified reason
T37	Fisheries related		Fishing line cut on the front left flipper
T38	Marine vehicle		Propeller cuts on the 5th neural and on both supracaudal scutes
T39	Marine vehicle		Fractures on the 2nd and 3rd right costal scutes and a deep propeller cut on the supracudal scutes
T40	Fisheries related		Fishing line entanglement on the neck. A hole on the right supracaudal scute via unidentified reason
T41	Marine vehicle		Propeller cut on the 3rd right costal scute and the 3rd neural scute
T42	Marine vehicle		Propeller cut on the 3rd right costal scute
T43	Marine vehicle		Fractures on the 2nd and 3rd right costal scutes
T44	Marine vehicle		Propeller cuts on the 2nd and 4th costal scutes, and a fracture on the 2nd neural scute
T45	Marine vehicle		Propeller cuts on the 6th, and 11th right marginal scutes
T46	Marine vehicle		Fractures on the 3rd neural scute and the 3rd and 4th left costal scutes
T47	Marine vehicle		Fractures on the 1st and 2nd left costal scutes
T48	Fisheries related		A fishing hook in the mouth

Table 3. Descriptive statistics of SCL, SCW, CCL, CCW, weight and BCI of captured individuals (F: Female loggerhead turtle; M: Male loggerhead turtle; SA: Subadult loggerhead turtle)

Variable	Group	N	Mean	Std Dev	Min	Max
SCL (cm)	F	23	68.3	5.55	60.0	78.5
	M	55	73.1	6.25	62.7	90.6
	SA	10	56.5	4.85	45.3	61.0
SCW (cm)	F	23	52.4	3.23	48.5	59.0
	M	55	54.9	3.89	48.0	64.7
	SA	10	44.8	4.00	35.2	48.5
CCL (cm)	F	23	71.0	5.26	65.0	81.0
	M	55	75.3	6.12	66.5	94.0
	SA	10	58.6	4.76	47.8	62.5
CCW (cm)	F	23	65.0	4.17	58.0	73.7
	M	55	68.4	4.52	60.0	83.0
	SA	10	55.4	5.09	42.5	59.0
Weight (kg)	F	21	45.6	13.19	29.7	74.6
	M	44	50.5	12.83	32.0	90.2
	SA	9	23.7	5.68	12.8	31.6
BCI	F	20	1.39	0.126	1.19	1.60
	M	44	1.26	0.100	1.10	1.55
	SA	9	1.29	0.138	1.13	1.54

tested group. The first group ($F_{2,64} = 286.54$, $R^2 = 89.9\%$), and the second group ($F_{2,73} = 326.82$, $R^2 = 89.9\%$) showed a linear regression, but the best fitted model estimating the weight was a nonlinear model for the third group including all individuals:

Weight (kg) $= 39.4 - 2.206\text{SCL} + 0.04115\text{SCL}^2 - 0.000121\text{SCL}^3$ ($F_{3,70} = 253.09$, $R^2 = 91.6\%$) (Figure 2).

BCI was calculated separately for females, males and subadults. Although the males had larger SCL and CCL than the females (Figure 3), and the males were heavier than the females (Figure 4), BCI was highest for the females and lowest for the males (Figure 5). The differences between the males and females were statistically significant ($H_2 = 16.19$, $p < 0.001$) but BCI of the subadults did not show differences from males ($W = 1215.00$, $p > 0.05$), but showed differences from females ($W = 370.00$, $p < 0.05$).

3.4. Anthropogenic effects

We recorded primary injuries in 48 turtles (54.5%). Of these, eight turtles (9%) had secondary injuries (Table 2). Of these primary injuries, 38 of them were carapace injuries caused by marine vehicle collision, and 10 of them were fisheries related injuries caused by fishing line entanglement or ingestion, and fishing hook entanglement. We also recorded six secondary injuries resulting from marine vehicle collision and two secondary injuries that were fisheries related. In addition, three turtles found with fresh injuries and transferred to DEKAMER for treatment. A male turtle (T4) was also

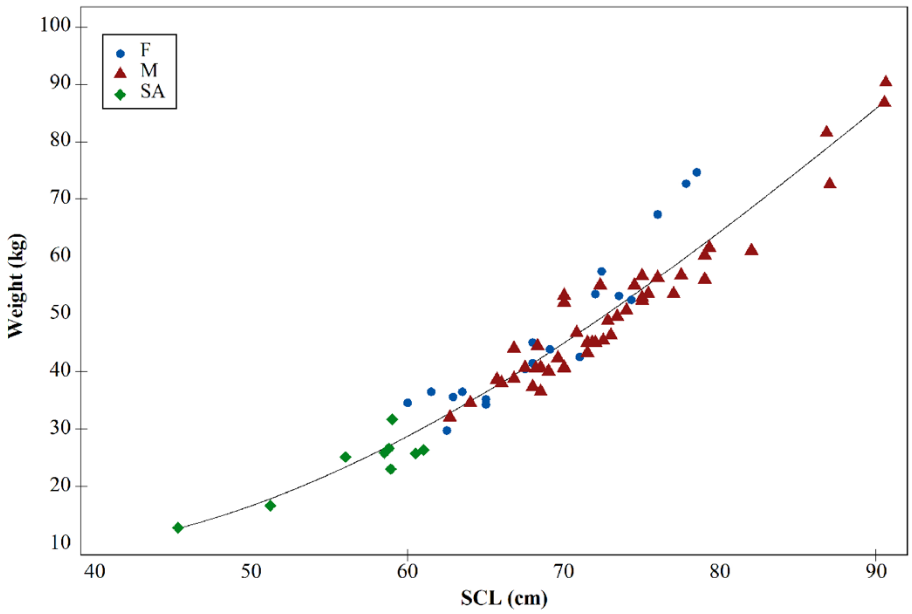

Figure 2. Relationship between weight and SCL.

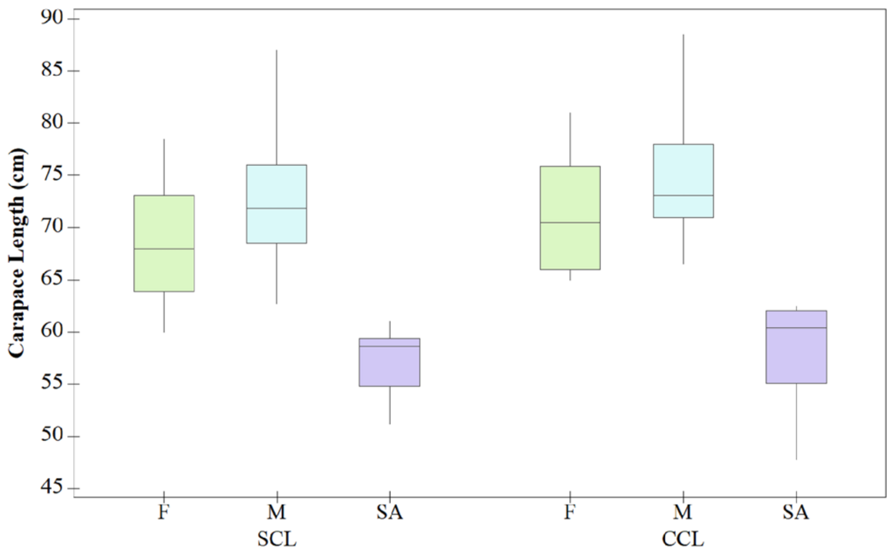

Figure 3. Comparison of SCL and CCL between female, male and subadult individuals (The line in the boxes represents the median value, the boxes represent interquartile range between first and third quartiles).

ingested a fishing line with hooks. Another male turtle (T17) which was initially captured in 2016 in healthy condition was recaptured in 2017 with a fresh shell fracture and a fishing hook in the mouth. The third male turtle (T22) was also found with fractures on the shell.

4. Discussion

4.1. Loggerhead turtle population in the study area

We found that Köyceğiz-Dalyan SPA is an important loggerhead turtle foraging and overwintering area with a male biased population. Previous studies have shown that male and female loggerhead turtles from western Greece are using Aegean coasts of Turkey as overwintering and foraging areas (Schofield et al., 2010; Patel et al., 2015; Rees et al., 2017). Additionally, stranding data (Türkozan et al., 2013; Başkale et al., 2018a; Türkozan et al., 2018) suggested that Turkey may have important foraging areas for loggerhead turtles. Our results confirmed previous studies suggestions that Turkey has important foraging areas and Köyceğiz-Dalyan SPA is an important area for Mediterranean loggerhead turtles. Loggerhead turtles show high fidelity to foraging areas, they can visit several foraging areas during their migration, especially when they move along coastal shelves, and in this context, assessing the localization of the specific foraging areas is a suggested research priority (Luschi and Casale, 2014). In our study, we identified a local area, with the majority of all captures occurring in the delta, rather than at sea. This was interesting finding because during the winter, the delta in Köyceğiz-Dalyan SPA is subject to heavy rainfall and major streams bring cold freshwater into the delta system

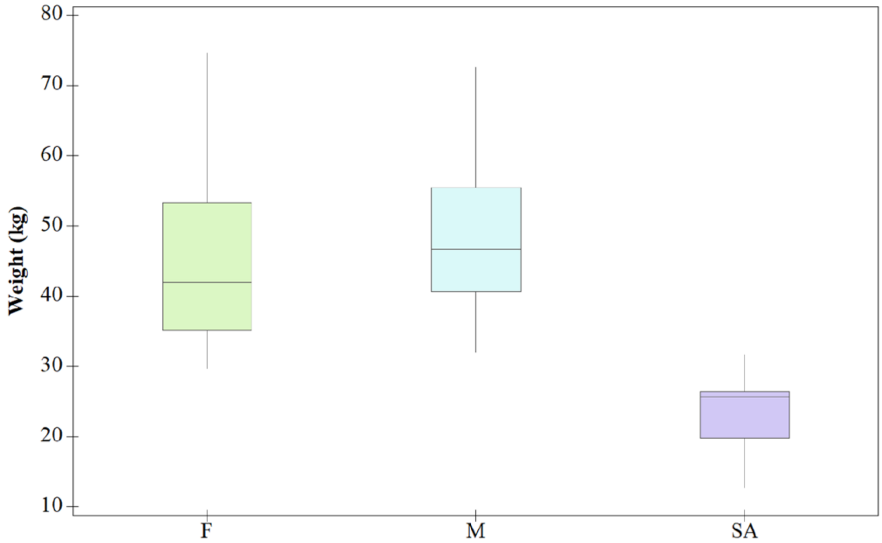

Figure 4. Comparison of body mass between female, male and subadult individuals (The line in the boxes represents the median value, the boxes represent interquartile range between first and third quartiles).

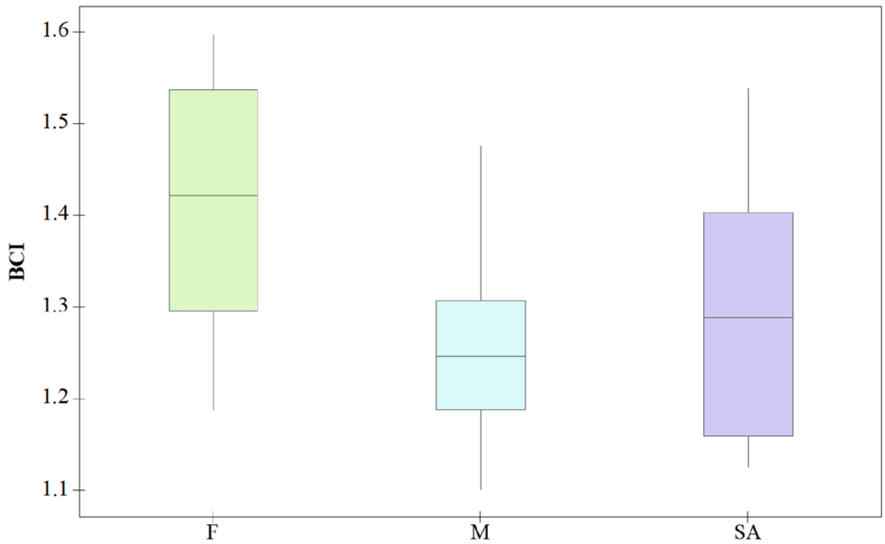

Figure 5. Comparison of BCI between female, male, and subadult individuals (The line in the boxes represents the median value, the boxes represent interquartile range between first and third quartiles).

with the mean surface temperature dropping to 9.5 °C in December (Ertürk, 2002). Previous studies have shown that temperatures below 15 °C may result in the hypothermic stunning of marine turtles (Gerle et al., 2000; Bentivegna et al., 2002; Lamont et al., 2018). On the other hand, the environmental conditions and hydrology of the area are apparently suitable for loggerhead turtles. Despite the very low salinity (e.g., 4.98 ppt at 0.5 m depth) and relatively colder waters at the surface of the water column, there is a strong stratification within the water column (e.g., vertical salinity gradient was 7.6 ppt/m in Alagöl) (Ertürk, 2002), and higher ambient temperatures can be found at the bottom of the water column due to the presence of subaqueous hot springs (Avşar et al., 2017), providing elevated levels of temperature (27–28 °C discharge temperatures in Dalyan channel) and salinity. In addition to these conditions Atlantic blue crab, one of the main food sources of loggerhead turtles (Seney and Musick, 2007), is abundant in the area (Genç and Yılmaz, 2017). These environmental conditions may help turtles actively forage in the region even during cold periods and may explain why the turtles are more frequently observed in the inner part of Köyceğiz-Dalyan SPA rather than in the sea and the lagoon.

Total population abundance in the Mediterranean has an important knowledge gap due to lack of information on demographic parameters and adult sex ratios, and that population estimates are mainly derived from female nest counts (Casale et al., 2018). Casale et al. (2018) also stated that the results derived from these nest counts should be regarded with caution and that standardized monitoring at sea through direct sampling is required for such population estimates. However, adult sex ratios vary throughout the year in foraging areas and ultimately different sampling periods represent different population information from which different sex ratio estimates can be obtained (Casale et al., 2014). We conducted a standard direct sampling methodology in two successive years at the same sampling period and therefore, our results will contribute to population estimates of the Mediterranean loggerhead turtle population.

Previous studies have showed that females and males move to their natal beaches for breeding, and those males return to their foraging areas following mating with females remaining in the nesting area until they deposit their final clutch (Schroeder et al., 2003; Bowen et al., 2004; Bowen and Karl, 2007). On the other hand, Mediterranean loggerhead turtles breeding in Greece show different breeding periodicity with male turtles moving to breeding areas a few months earlier than the females with females arriving at the breeding beaches a few weeks prior to their first nesting (Hays et al., 2010; Schofield et al., 2010). Such information is not available for loggerhead turtles from Turkey but considering the sampling period in our CMR study, we can assume that all captured individuals overwintered in the area.

Our preliminary observations suggested that some turtles could be resident all year round. Although we could only obtain data about male and subadult turtles from the CMR studies, we were able to obtain data from females during nesting seasons. Six female turtles observed at Dalyan Beach while nesting before or after this study. One of the female turtles (T21) initially tagged at Dalyan Beach after nesting there in 2012, was subsequently found stranded in October 2013 on Rhodes Island, which is located 50 km southwest of Dalyan Beach. She was released in 2014 after a successful rehabilitation process (Corsini-Foka et al., 2016). Therefore, we can assume that the turtle was foraging in an area between Köyceğiz-Dalyan SPA and Rhodes Island. Apparently, the turtle has remained in the area and has not migrated anywhere, at least since 2012. The other five female turtles also remained in the area during winter and observed during nesting periods. We also found that male turtles are resident and remain in the Köyceğiz-Dalyan SPA. Recaptured females and tagged males may suggest that an important proportion of the population from both sexes are residential in the region. This is important because being residential in the area will reduce the energetic cost of migration between foraging and nesting sites, which might affect remigration interval of an individual (Hatase and Tsukamoto, 2008, and references therein). Remigration interval is defined as the number of years between two breeding seasons and is largely used to estimate female abundance (Casale and Ceriani, 2020, and references therein). Remigration intervals can be affected by environmental conditions, foraging area, and food availability (Hays, 2000). The estimated remigration interval is reported as two years (Broderick et al., 2003), and three years (Omeyer et al., 2019) for loggerhead turtles in the Mediterranean. If a proportion of the overwintered population is not migrating from the study area and contributing to the nesting population more frequently than the estimated remigration interval for Mediterranean loggerhead turtles, this may lead to an overestimation of female abundance based on nest counts from annual monitoring studies. Casale and Ceriani (2020) highlighted the possible overestimation of sea turtle populations from remigration intervals and suggested caution when using these estimates to derive the conservation status of populations. The number of loggerhead turtle nests have dramatically increased at Dalyan Beach during the last decade (Kaska et al., 2020) and this can be considered as a sign that the situation of the general population is improving. However, in parallel with the increase in the number of nests, the loggerhead turtle females nesting every year on Dalyan Beach have been observed in the last 10 years (Kaska unpublished results). Therefore, before reaching a conclusion on an improved population, it would be appropriate to make evaluations considering the remigration interval of the population.

Our results suggest that if the environmental conditions are suitable and there are enough food sources in the area, the loggerhead turtles as ectoderms may prefer to stay in the nesting area or in close proximity to their nesting sites for overwintering rather than migrating to remote foraging grounds. Köyceğiz-Dalyan SPA is a relatively limited area for a large population. This is important, as aggregating in a constricted area will increase the packing density, which is related to the rate of multiple paternity (Lee et al., 2017). The population was male biased in our study. If the male turtles remain in the area during the breeding season, we can expect high multiple paternity in the loggerhead turtle nests on Dalyan Beach. Sari et al. (2017) reported that the multiple paternity rates at Dalyan Beach are 70%. This result may support our assumption that the overwintered males contribute to the breeding population in the area later in the season. Additionally, the contribution of the males to other close breeding areas could be open to question. If the males are making short-ranged migrations to other close breeding areas, such as those in Ekincik, Dalaman, and Fethiye, which are within a 40–50 km range which is one or two days travelling for a loggerhead turtle for mating during April and May, these males may be important for several populations, providing gene flow among different breeding populations. Nevertheless, as stated above, these assumptions should be validated with genetic, stable isotope, and satellite tracking studies.

4.2. Anthropogenic impacts in the study area

Human impacts such as boat strikes, fishing-related impacts are one of the major factors causing death and injury to marine turtles, and intervention strategies have been and continue to be developed to reduce the anthropogenic impacts on marine turtles (Flint et al., 2013). The designation of protection areas is one of the main strategies to reduce the impact on a species or a habitat. Köyceğiz-Dalyan SPA has been under such protection over the last three decades. Commercial fishing activities with fishing gears (e.g., gillnets, longlines) are not allowed and use of speed boats is restricted. Human activities are extremely limited from October to May, and only increase during the high tourism season which is between July to September. Despite the well-designed conservation measures, our results showed that an important proportion of the population is under heavy anthropogenic threats. Even though the use of speedboats is restricted, and commercial fishing is prohibited in the region, a limited number of speedboats are operating, and recreational fishing activities continue throughout the year. The effects of recreational fishing are generally overlooked, and most conservation measures are targeted at addressing the commercial fishing fleets. Wildermann et al. (2020) underlined the effects of local recreational fishing activities on marine turtle behaviour and ecology while assessing a marine turtle population in a coastal area, even though the fishing activities in use do not pose an imminent risk to the species. Considering that the vast majority of the population in the study area consists of adults, existing conservation measures in the region should be reviewed for the survival of marine turtles. Our findings suggest that the specific measures such as regulation of recreational fishing should be considered in the important areas where marine turtles are aggregated.

5. Conclusion

Although the current state of marine turtle populations is far from the true natural baseline levels, accurate and complete information on population demographics is essential for robust population estimates and demographic models, which have strong conservation implications (Casale et al., 2018). In addition, as an ectotherm species with TSD, marine turtles are expected to be affected by climate change in the future. Their range distribution is defined by temperature (Hawkes et al., 2007) and food availability (Witt et al., 2007). Clusa et al. (2013) have shown prehistoric colonisation, extinction, and recolonisation of the loggerhead turtle during the Pleistocene era in the Mediterranean, and the colonisation processes were largely affected by environmental changes during glacial periods. Witt et al. (2010) predicted potential effects of climate change on loggerhead turtles and suggested that an increase in available habitats through time. We do not have comparable past information, but the results of this study suggest that there is an important loggerhead turtle population in Köyceğiz-Dalyan SPA. In addition, eight of the ten warmest years between 1880 and 2018 have been recorded in this period (NOAA, 2019). This might be indicating a change in range distribution of loggerhead turtles in the Mediterranean, and the northern Aegean Sea may gain a greater importance as warmer refugia in the future. Recent studies support this assumption, with both sporadic nesting records on the Aegean coast (Başkale et al., 2018b; Özdilek et al., 2020) and stranding records in the northern Aegean (Tonay and Oruç, 2006; Özdilek et al., 2018). This highlights the importance of in-water studies to reveal the current status of the loggerhead turtle populations in coastal neritic areas and thus to monitor possible future changes.

Different male vs. female breeding periodicity have previously been reported, and it has been suggested that different periodicity between the sexes may help reduce the acute risk of female biased hatchling production caused by climate change (Wright et al., 2012; Hays et al., 2014). Therefore, the importance of the current male-biased population at foraging or breeding areas is vital for the future of Mediterranean loggerhead turtles. Threats to marine turtles in marine habitats that result in death may alter adult sex ratios in the future, and this alteration may have an irreversible impact on the population. Our results show that a significant proportion of the population is under heavy anthropogenic threats. Although turtles may survive these threats, most of the recorded past injuries could equally result in their death.

Therefore, we recommend that the conservation and environmental mitigation of marine turtle aggregation areas, including breeding and foraging areas, should be revised and implemented. In addition, we can expect behavioural, demographic, and adult sex ratio variations between the different foraging and breeding populations. As a result, the important marine turtle areas should be determined, and mitigation should be revised accordingly, especially in Turkey and in the Eastern Mediterranean, where there is a lack of information on loggerhead turtle populations in marine habitats.

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