The Herpetological Bulletin 151, 2020: 32-36
SHORT NOTE

https://doi.org/10.33256/hb151.32-36

Sea turtles in Lake Bardawil, Egypt - size distribution and population structure

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ABSTRACT - We investigated the size distribution, sex ratio, and proportion of sexually mature green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles in Lake Bardawil, a large coastal lagoon. During the study 30 green turtles (8 males, 4 females, and 18 juveniles / sub-adults) and 14 loggerheads (1 male, 8 females, and 5 sub-adults) were captured. Forty percent of the green and 64 % of loggerhead turtles were believed to be sexually mature. The green turtles had a mean curved carapace length of 65.23 cm (15 – 100 cm range) and the loggerhead turtles 68.79 cm but with a much narrow range (60 - 80 cm) reflecting the absence of juveniles. This study provides evidence that Lake Bardawil is an important feeding and development area for green turtles and feeding area for loggerhead turtles and expands our knowledge of such important sites in the Mediterranean basin.

INTRODUCTION

Lake Bardawil of North Sinai, Egypt has recently been recognised as being a major feeding ground for sea turtles in the Mediterranean Sea (Nada et al., 2013; Rabia & Attum, 2015; Bradshaw et al., 2017). It is known that the majority of post-nesting green turtles (*Chelonia mydas*) from Cyprus originate from the North Sinai feeding grounds and that these females have high fidelity to their feeding site (Bradshaw et al., 2017). Two man-made channels (Boghaz 1 and 2) in Lake Bardawil (Fig. 1) have lessened the Lake's environmental severity by reducing the salinity. This has probably increased the food supply and may have created a new foraging ground for green (Bradshaw et al., 2017) and, presumably also, loggerhead turtles (*Caretta caretta*). However, there is concern regarding the conservation of sea turtles in North Sinai, given the high rates of sea turtle mortality (Nada et al., 2013; Rabia & Attum, 2015, 2018).

Practically nothing is known regarding the population or size structure of sea turtles in the Lake Bardawil. The sand bar that separates it from the Mediterranean Sea is a nationally important nesting site for both green and loggerhead turtles (Rabia & Attum, 2015) and in the Lake itself, green and loggerhead turtles are the largest herbivore and consumer respectively. They may thus have an essential ecological and trophic role as do turtles in other coastal feeding grounds (Moran & Bjorndal, 2005, 2007). Knowledge of population structure is vital to determine the status of sea turtle populations (Heppell et al., 2003), hence the objective of this study was to determine the size distribution, sex ratio, and proportion of sexually mature green and loggerhead turtles in Lake Bardawil.

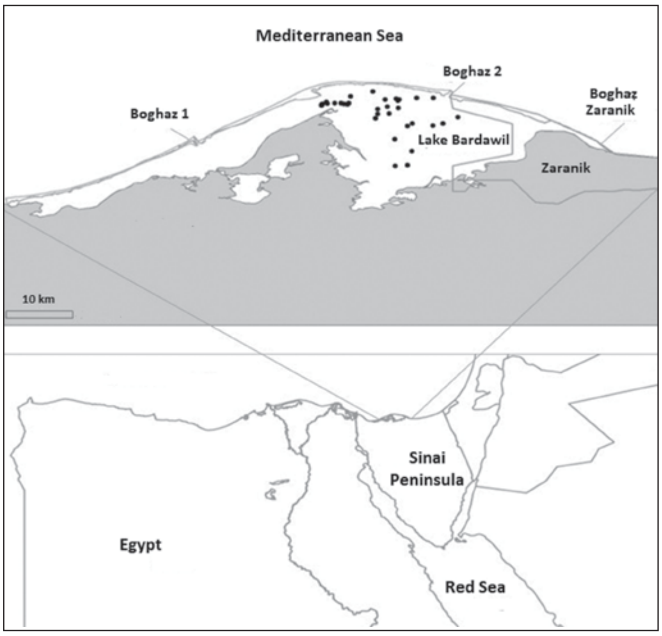

Figure 1. Map of Lake Bardawil, North Sinai, Egypt. The black circles represent locations of sea turtle capture. Boghaz 1 and 2 are man-made channels and Boghaz Zaranik is the natural seasonally open inlet.

METHODS

Study site

Lake Bardawil, a coastal lagoon, is located about 35 km to the west of El Arish city and covers an area of 600 km^2 (length 90 km, average width of 10 km, Anufriieva et al., 2018). There are extensive sea grass beds in the Lake that act as a nursery and spawning ground for several commercially important fish species (Mehanna & Hegazi, 2013). The Lake is substantially separated from the Mediterranean Sea by a long, narrow sand bar (300 m – 2000 m wide) but connects with it by a small, natural and seasonally open inlet (Boghaz Zaranik) and two man-made channels (Boghaz 1 and 2) that allow the exchange of water and organism (Fig. 1). The minimum widths of Boghaz Zaranik, Boghaz 1, and Boghaz 2 are roughly 80 m, 215 m, and 345 m respectively. The water in the Lake differs from the coastal Mediterranean Sea in being shallower (mean depth 1.2 m, maximum depth 6.5 m), warmer and with much higher salinity (Krumgalz et al., 1981; Khalil et al., 2013; 2016; Anufriieva et al., 2018). Vegetated coastal dunes and salt plains are the dominant mainland habitat surrounding the Lake and the eastern corner is within the Zaranik Protected Area (ZPA).

Survey method

In 2019, from 08.30h to 16.00h for 68 days (29th April to 23rd December), we surveyed for turtles in an area of the Lake where previously turtle observations had been most numerous (Rabia, unpublished data). We travelled by boat to our general study area and then moved in a 0.5 km radius around the different survey points. If a turtle was observed, it was encircled with small trammel nets and then placed in the boat for examination. We identified the species, noted its gender, measured the curved carapace length (CCL), and recorded water depth in 0.5 m increments (Bolten, 1999). The turtles were sexed by reference to the longer tails of males (Casale et al., 2018).

We also estimated whether individuals were sexually mature although the growth rate and age of sexual maturity of sea turtles is variable and thus there is some ambiguity. When a medium sized turtle is assessed it could be a large sub-adult or a small sexually mature adult (Casale et al., 2018). We used 78 cm CCL as the threshold for sexual maturity of green turtles (Broderick & Godley, 1996), and 65 cm for female loggerheads based on data from a previous study that reported the minimum size of nesting females (Broderick & Godley, 1996). We categorised the frequency of CCL length of each species in 10 cm increments to allow for comparison with other data sets.

Turtles were tagged on their left front flipper with uniquely coded metal tags (National Band and Tag Company, Newport, KY, USA). Tagging was undertaken as part of the routine work of the Protected Area, of which the first author is manager, and according to current best practice (Balazs, 1999).

RESULTS

Turtles were captured on 19 of the 68 surveys days and all were captured in depths ranging from 0.5 – 3 m. There were some days when turtles were almost captured but then escaped, especially at the beginning of the study, and we found it more difficult to detect turtles on cloudy days because of the lower contrast between the turtles and lake bottom. We captured 30 green turtles (8 adult males, 4 adult females, and 18 juveniles and sub-adults) giving an adult sex ratio of 2:1 M:F and 14 loggerhead turtles (1 adult male, 8 adult females, and 5 sub-adult turtles) giving an adult sex ratio of 1:8 M:F.

The distribution of curved carapace length (CCL) between the green and loggerhead turtles differed somewhat (Fig. 2). The mean (± SD) minimum length for all green turtles was 65.23 ± 22.85 cm with a range of 15 – 100 cm; for adult females 88.00 ± 9.09 cm, 80-100 cm; for adult males 84.38 ± 4.17 cm, 80 – 90 cm; and, for juveniles and sub-adults 51.67 ± 19.49 cm with a range of 15 – 77 cm. The mean minimum length for all loggerhead turtles was 68.79 ± 7.00 cm, 60-80 cm); for the for sub-adults 61.09 ± 2.24 cm, 60 – 65 cm; for adult females 72.88 ± 4.52 cm, 70 - 80 cm; and for the single male 75 cm.

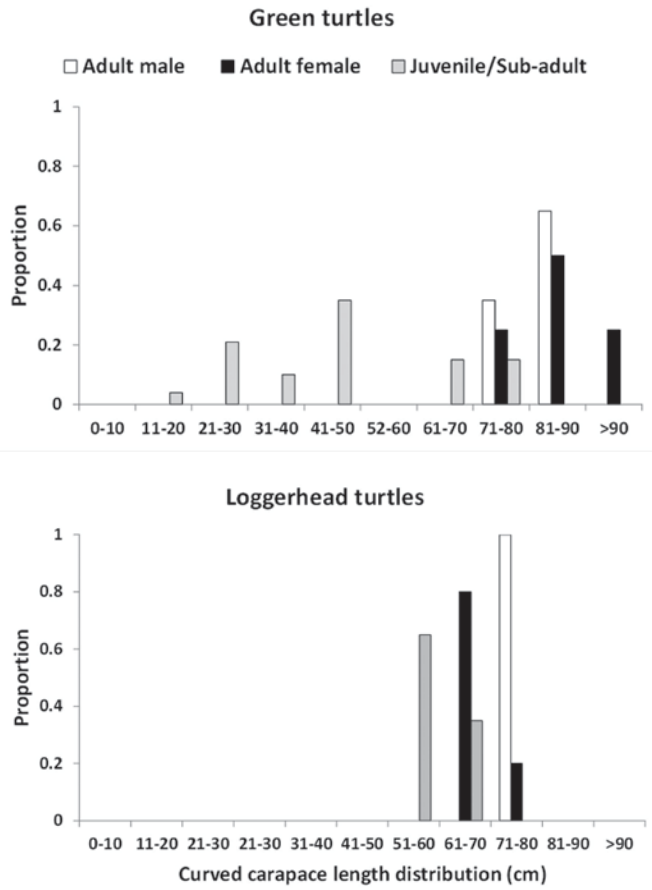

Figure 2. Curved carapace length distribution among adult male, adult female, and unsexed juvenile and sub-adult green and loggerhead turtles

We did not have any turtle recaptures during our study. We captured a female loggerhead turtle that had a flipper tag from Dalyan beach, Turkey and observed on 25 May, 10 June, and 26 June, 2018 at the same site (Yakup Kaska, pers. comm.). A fisherman also reported seeing a green turtle with a satellite transmitter on the carapace December 22, 2019. In addition, a pair of green turtles were observed mating in the Lake on April 30, 2019. We observed evidence of injury or predation, with one green turtle missing a front flipper, one green turtle had evidence of impact trauma to the carapace that had healed, one loggerhead turtle had a large semicircle part of its shell missing, comprising about 25 % of its body length that had healed and resembled an animal bite, and one loggerhead turtle was captured with blunt trauma on the top of the head that had healed as a notable depression. We also observed one fresh, dead adult male green turtle during the study. No obvious cause of death was discernable.

DISCUSSION

Our study is the first to describe the population structure of green and loggerhead turtles in Lake Bardawil. Despite our relatively small sample sizes, we believe we were still able to infer useful information regarding the populations of both species. Sex ratio can be useful to understanding the status of a population (Bender, 2006). Unequal sex ratio is typically interpreted to reflect sexual segregation in differential habitat use between males and females or different survival rates between the sexes, with usually lower survival among males (Bender, 2006). We believe the unequal sex ratios favoring female loggerhead and male green turtles in our study is not the result of sexual segregation in habitat use as this is apparently rare or not well documented in sea turtles (Hamman et al., 2006).

Sea turtles often have female biased sex ratios at birth (Heppell et al., 2003), which could be used as a baseline to compare adult sex ratio and any difference could be interpreted as different survival according to sex (Bender, 2006). The male biased sex ratio of green turtles could suggest that there is lower survival of females. Fresh water turtles often have lower female survival due to increased mortality from travelling to nesting sites or predation during nesting (Steen et al., 2006). However, increased mortality of female sea turtles as result of travelling to or nesting in Mediterranean is not documented.

Male loggerhead sea turtles could have lower survival than females as a result of males being smaller than females and more vulnerable to predation, males spending more energy and time travelling in search of females and competing with other males for access to females, higher vulnerability to predation because of lower male vigilance, and the increased search effort by males for females during the breeding season could make males more vulnerable to being captured in nets. However, a few studies from other populations have suggested that male and female green and loggerhead sea turtles have similar survival rates (Chaloupka & Limpus, 2002 & 2005). It is also difficult to interpret the unequal sex ratios as a result as different mortality rates of male and female sea turtles, because studies usually report survival of nesting females and combine the sexes together to estimate adult survival (Heppell et al., 2003; Campbell & Lagueux, 2005; Troeng & Chaloupka, 2007; Casale et al., 2018).

The size distribution and proportion or number of animals at sexually maturity can be used to infer size segregation of habitat use, potential reproductive growth, and viability of sea turtle populations (Heppell et al., 2003; Mazaris et al., 2005; Rees et al., 2013). There was a wide range in the distribution of size classes of green turtles, from 15 cm to 100 cm, suggesting that Lake Bardawil is a feeding ground for all size classes and both sexes, unlike other feeding grounds in which there is size segregation according to depth and habitat (Koch et al., 2007; Bresette et al., 2010). In addition, the size distribution of green turtles in our study was also wider than reported previously in Lake Bardawil and in other feeding sites in the Mediterranean (Nada et al., 2013, Casale et al., 2018). We were unable to determine if there was fine scale separation of depth utilised according to size class due to our small sample size and lack of more detailed sampling at depth. The inclusion of all size classes in a sea turtle population may indicate a healthy population (Bjorndal, 1985, Bjorndal et al., 1999). In contrast, the size distribution of loggerhead turtles consisted of mostly sexually mature and sub-adult turtles. This suggests that juvenile loggerhead turtles may use other areas to feed as size based segregation of sea turtles occurs according to ontogenetic shifts in food and/or habitat requirements and predation risk in feeding habitats (Limpus et al., 1994; Kock et al., 2007; Bresette et al., 2010; Rees et al., 2013).

The mean CCL of green turtles in our study was smaller than that of dead green turtles washed ashore while that of the loggerhead turtle CCL was similar to the dead loggerhead turtles but smaller than the stranded, dead green turtles along the Mediterranean coast of North Sinai and other sites of the Mediterranean basin (Rabia & Attum, 2015; Casale et al., 2018). We believe that our data may under represent sexually mature individuals and potential bias sex ratio as a result of capture bias as there were about 20 instances in which really large male and female green and loggerhead turtles were captured but escaped during the struggle of lifting the heavy individuals to the boat, especially at the beginning of the study when capture technique was still novel. We know that the largest individuals were not recaptured, but do not know if the other large individuals were recaptured later in the study once implementation of capture technique was more successful.

The high proportion of juvenile green turtles, the smallest recorded CCL being 15 cm, suggest that Lake Bardawil is a benthic feeding area for all size classes of green turtles, while the Mediterranean coast of North Sinai is used as a nesting site (Rabia & Attum, 2015, Bradshaw et al., 2017). The lack of small juvenile loggerhead turtles captured and the adult female captured from a nesting site in Turkey suggests that Lake Bardawil is used as a feeding site by sub-adult and adult loggerhead turtles from other parts of the Mediterranean basin but could also include females that nest along the Mediterranean coast of North Sinai (Rabia & Attum, 2015). Although small juvenile loggerhead turtles were not observed in Lake Bardawil, they have been observed in the Mediterranean coasts of North Sinai prior to this study (Rabia, unpublished data), suggesting that the Mediterranean coast of North Sinai could possibly be used as neritic foraging habitat for juvenile loggerhead turtles. The long-term population viability of sea turtles in part depends upon high survival of sub-adult and adult individuals (Heppell et al., 2003) and thus the protection of green and loggerhead sea turtles in Lake Bardawil is vital to the conservation of sea turtles in Egypt and the greater Mediterranean Sea. In conclusion, this study provides evidence supporting the classification of Lake Bardawil as an important feeding and development area for green turtles and feeding area for

Accepted: 4 October 2019

loggerhead turtles in Egypt and expands our knowledge of known sea turtle feeding and development sites in the Mediterranean basin.

ACKNOWLEDGEMENTS

We would like to thank Wessam Hassan for his committed assistance in the field. We would also like to thank the Egyptian Environmental Agencies and Indiana University Southeast for their continued support.

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Accepted: 26 February 2020