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Assessment of hatchery management for the loggerhead turtle (*Caretta caretta*) nests on Göksu Delta, Turkey

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ABSTRACT

Sea turtles suffer from numerous threats such as predation, tidal inundation, and coastal building. We aimed to assess the effectiveness of hatchery technique on Göksu Delta beach, Turkey during the nesting season of 2010. For this purpose, eggs of loggerhead turtle (*Caretta caretta*) nests under the risk of tidal inundation were transferred into two protected hatchery sites that were constructed on Göksu Delta beach, in which there were no risk of predation and inundation, and the other nests were left to remain *in situ*. Hatching success of hatchery and natural nests were calculated. In addition, temperatures of both hatchery and natural nests (5 and 6 nests, respectively) were recorded, and sex ratios were determined using these nest temperatures and incubation periods. It was determined that hatching success increased with increasing distance from the sea (until 31 m) ($r^2 = 0.98$), increasing incubation period (up to 60 days) ($r^2 = 0.68$), and decreasing clutch size ($r^2 = 0.93$), implying that the production of male hatchling is high in a nest if hatching success of that nest is high (or *vice versa*). Mean hatching success, incubation period, and nest temperature for hatchery nests were found to be 72.8%, 51.1 days, and 30.2 °C, respectively, while the corresponding values for natural nests were found to be 40.5%, 49.9 days, and 31.1 °C, respectively. It was also detected that hatchery nests produced higher proportion of male hatchlings (25.2%) compared with natural nests (13.5%). Based on all these results, it can be concluded that hatchery management on this beach is not a completely effective conservation technique. Nest relocation and/or hatchery management enable the conservationists to increase hatching success rate, but they cause sex ratio alteration. In this respect, we can only partially support nest relocation and/or hatchery management. They should be considered as a last option due to sex ratio alteration.

1. Introduction

Sea turtles face numerous threats in each life stage (Lutcavage et al., 1997; Spotila et al., 2000), and these threats are caused by both natural and anthropogenic factors (i.e., Kaska et al., 2010). Some of the natural factors affecting sea turtles are predation, erosive waves, and flooding (Cornelius, 1986; Wetterer and Lombard, 2010). On the other hand, egg harvesting and turtle hunting (Kamezaki and Matsui, 1997; Lewison and Crowder, 2007), habitat degradation by coastal building development (Kamezaki et al., 2003; Kaska et al., 2010), and various types of pollution (Lewison and Crowder, 2007) are included to anthropogenic factors (Bugoni et al., 2001; Kaska et al., 2010; Lutcavage et al., 1997), which are believed to be more harmful on sea turtle populations compared with natural factors (Chan and Shepherd, 2002; Eguchi et al., 2010, 2012). Interactions of the continuous pressures by natural and anthropologic factors are causing a dramatic world-wide reduction of sea turtle populations (Scherer-Lorenzen, 2014; Wyneken et al., 1988).

Sea turtles are one group of oviparous animals. Females extend no maternal care to their hatchlings as they develop in the nest built in the sand during incubation. Incubation period depends on several nest environment factors, which also may affect embryological development (Foley et al., 2006; Özdemir et al., 2008). Hatching success of sea turtles is considered to be affected by a wide variety of biotic and abiotic factors such as predation, type of substrate, porosity, temperature, humidity, salinity, slope of the

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beach, nest elevation, rainfall, and tidal inundation (Ackerman, 1997; Bilinski et al., 2001; Donlan et al., 2004; Foley et al., 2006; Mortimer, 1990; Wood and Bjorndal, 2000). The hatching success of relocated nests depends on how soon and how carefully the nest is moved and to where the nest is relocated (Almeida and Mendes, 2007; Wyneken et al., 1988). All these parameters can markedly change the hatching success of sea turtle nests as well as hatchlings' survival (Başkale and Kaska, 2005; Dobbs et al., 2010).

The loggerhead sea turtle (*Caretta caretta*) has a circum-global distribution in temperate and subtropical regions including the whole of the Mediterranean (Bolten, 2003; Dodd, 1988), and is the most abundant sea turtle species in the Mediterranean Sea (Broderick et al., 2002; Margaritoulis et al., 2003). On the 2015 IUCN Red List, the loggerhead turtle is globally categorized as vulnerable (Casale and Tucker, 2015), while the loggerhead turtle in the Mediterranean is categorized as least concern (Casale, 2015). Based on nest numbers, Turkey holds the second most important loggerhead turtle stock in the Mediterranean (Margaritoulis et al., 2003), and this case demonstrates the importance and necessity of protecting sea turtles and their nests in the country. The Mediterranean coasts of Turkey are important nesting grounds for loggerheads. Göksu Delta beach on which green turtle (*Chelonia mydas*) nests as well (Piggelen and Strijbosch, 1993), with an annual mean nest number of 112, is one of the most important loggerhead turtle nesting beaches in the Mediterranean coastline of Turkey, and it marks the eastern edge of the nesting distribution in Turkey for loggerheads (Sarı and Kaska, 2015). Within the Mediterranean, this is one of the few sites, other than Cyprus, where both species nest (Glen et al., 1997), and the beach therefore is of great importance. However, there are some threats for sea turtles in Göksu Delta, and these threats include sand removal, beach inundation, high levels of nest predation by canids, pollution, and human use of habitat largely related to tourism (Glen et al., 1997). As a result of these threats, the more efforts for conservation of sea turtles on the beach are needed compared with some other beaches on which these kinds of problems do not exist. Nest protection through egg relocation from natural nests into protected hatcheries is a common practice used at rookeries around the world to increase hatchling recruitment into sea turtle populations (Başkale and Kaska, 2005; Boulon, 1999; Maulany et al., 2012a; Mortimer, 1999). It has been suggested that hatchery site or relocation should be taken into account for the nests under the risk of predation and inundation (Yalçın, 2003), and provides effective protection of sea turtle nests against predation and inundation (Başkale and Kaska, 2005). Nevertheless, it is very important that the conservation of the sea turtle nests in hatchery sites and/or relocation of them inland on the beach should result in similar hatching success and temperature to the natural ones in order not to influence the natural primary sex ratios on the beaches. Even though there are limited studies on mortality rates (Özdemir et al., 2008), nest temperatures (Candan, 2014), and nesting ecology (Durmuş et al., 2011), there is no detailed study on hatching success and temperature of both hatchery and natural nests and on effectiveness of hatchery management on Göksu Delta beach.

In this study, it was aimed (1) to evaluate the hatching success of the loggerhead nests, (2) to determine which parameters (distance from the sea, incubation period, and clutch size) influence the hatching success, (3) to compare the differences in incubation period, number of dead embryos, and hatching success between hatchery and natural nests, and (4) to test whether the relocation leads to changes in temperature and hence natural sex ratio on Göksu Delta beach. In light of the findings, it was also aimed to assess the effectiveness of hatchery practice on the beach to conserve sea turtles from natural and anthropogenic pressures.

2. Material and methods

2.1. Study site and species

Göksu Delta beach is situated in the Mediterranean Sea region of the south-eastern part of Turkey. The beach extends from Taşucu to Susanoğlu, and has a length of approximately 35 km (Fig. 1). This beach is also used by the green turtle and the soft-shelled Nile turtle (*Trionyx triunguis*) as a nesting ground, increasing the importance of the beach. The beach is a RAMSAR site and most of the area lies in Göksu Delta Specially Protected Area (Türkozan and Kaska, 2010).

2.2. Hatchery construction and nest relocation

This study was carried out from 28 May 2010 to 23 September 2010. Before 28 May, two hatchery sites with a distance of 15 m from the sea were constructed on the western part of the beach (Fig. 1) in order to protect the nests against predation by jackals (*Canis aureus*) and to relocate the nests which are likely to be inundated by high tides, and hence, to increase the hatching success of these nests as recommended by Başkale and Kaska (2005). We selected this part of the beach for hatcheries, since it was easy to arrive there from the camp site and to check the hatcheries and the nests in them. We constructed both hatchery sites with the size of approximately 10 × 15 m, which was sufficient to accommodate 100 nests and high enough not to be inundated by high tides. The distance between nests was set at 1 m in order to prevent any interaction and to allow hatchery personnel to walk stepping onto the nests.

The beach was patrolled at night from 21:00 to 02:00 and early in the morning from 06:00 to 11:00 to record any loggerhead turtle activity. The beach part from Kum District to old branch of Göksu River (approximately 26 km) was daily checked by two teams consisting of three people each, while the beach part between old branch of Göksu River and Susanoğlu was weekly checked by a team consisting of three people. All turtle nesting activities were observed between Kum District and old branch of Göksu River. All the activity from the previous night was recorded and evaluated as that day's activity. The nests under the risk of tidal inundation were transferred to the hatchery. The nests below the distance of 10 m from the sea on high-sloped parts of the beach or below the distance of 20 m on low-sloped parts of the beach were considered to be under the risk of inundation. For the transfer, we used a plastic bucket with 5 cm of sand from the inside of the original nest at the bottom in order to minimize the damage to the eggs and in order not to alter the environment around eggs. The eggs from each clutch were carefully transferred to separate nests in one of the hatcheries, constructed according to the original nest dimensions. The hatcheries were closely monitored daily for the threats of natural predators, especially ghost crabs and human disturbance. The nests that were not under the risk of inundation were left to remain *in situ* for their incubation, and some of them were screened with wire cages (1 × 1 m) with a mesh size of 9 cm against predation. The distances of both relocated and natural nests from the sea (distance to the high water mark in m) were measured with a 50-m measuring tape and recorded.

2.3. Temperature sampling

Temperatures in loggerhead turtle nests were measured by using electronic “tiny talk” temperature recorders [Orion Components (Chichester) Ltd., Chichester, UK]. The device fits into a 35-mm film case. The accuracy of the device was tested under laboratory conditions against a standard mercury thermometer and