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Impacts of Human Activities and Predators on the Nest Success of the Hawksbill Turtle, *Eretmochelys imbricata*, in the Arabian Gulf

GENTILE FRANCESCO FICETOLA[1,2]

[1]*Department of Biology, Università degli Studi di Milano, Via Celoria 26, Milano 20133 Italy;*
[2]*Present Address: Department of Environmental Sciences, University of Milano-Bicocca, Piazza della Scienza 1, 20126 Milano Italy [francesco.ficetola@unimi.it]*

ABSTRACT. – I investigated the effect of predators on hawksbill reproduction and evaluated the effectiveness of protecting nests using plastic net at a beach in Qatar along the Arabian Gulf. Predators such as feral cats and the fox, *Vulpes rueppelli*, were present at very high densities. Nests not protected by plastic net were 100% depredated to some extent; > 80% were completely destroyed.

The hawksbill turtle, *Eretmochelys imbricata*, is critically endangered at a global scale because of a dramatic decline during the last century (Meylan and Donnelly 1999; but see also Mrosovsky 2003; Richardson et al. 2006). The most commonly cited causes of hawksbill decline are direct exploitation and the alteration or destruction of habitats. Human alterations of beaches where *E. imbricata* nests can have profound consequences on the demography of populations. In some cases, human activities destroy beaches, and this will obviously cause dramatic effects on populations. However, human alteration can also have indirect effects. For example, the alteration of natural vegetation along the coastline can increase the temperature of nests and thus bias the sex ratio of hatchlings (Kamel and Mrosovsky 2006). It is therefore extremely important to evaluate whether human activities indirectly cause alterations that affect turtle reproduction.

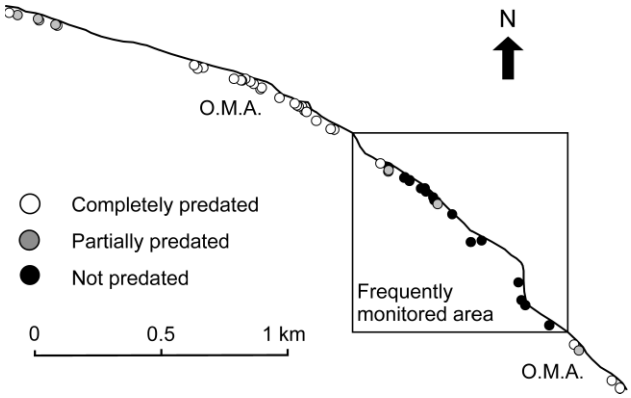

Figure 1. Study area and distribution of nests of *Eretmochelys imbricata*. The inset shows the frequently monitored area, where nests were protected by predation; points outside the inset are in the occasionally monitored area. Some points are superimposed.

The increased frequency of synanthropic (i.e., ecologically associated with humans) and exotic species are common consequences of human utilization of land (e.g., McKinney 2002; Ficetola et al. 2007). These species are able to exploit the resources available from human activities to reach unnaturally high densities, and therefore have the potential to threaten the native fauna (McKinney 2002). Here I studied reproductive success in a rookery located close to an industrial area in the Arabian Gulf. The Gulf hosts important populations of *E. imbricata* but is poorly studied and is undergoing a fast development that might threaten turtle populations. This study shows that the increased abundance of synanthropic predators can be so strong as to cause an almost complete reproductive failure in a population of *E. imbricata*.

Methods. — The study area was a beach located in Rass Laffan, an industrial city in northeastern Qatar, in the Arabian Gulf (lat 25°56′, long 51°31′). The climate is extremely arid, and the vegetation on the dunes is limited to few xerophilic grasses and bushes. The area of Rass Laffan includes 14 km of coastline composed of a mix of rocky and sandy areas. Submerged rocks, coral patches, and seagrass beds are present offshore. In this area, a program of nest monitoring and protection has been running since 2001 and has identified about 300 turtle nests per year. Although adults of the green turtle *Chelonia mydas* are often spotted offshore, only one turtle species, the hawksbill turtle, has been observed nesting in this area. Further details on the study area are reported elsewhere (Tayab and Quiton 2003; Ficetola 2007). Terrestrial mammals are almost absent because of the desert environment. However, feral cats and Ruppell's foxes (*Vulpes rueppelli*) are present at high densities close to the industrial settlements where they scavenge (see also Cuzin and Lenain 2004).

I monitored 3.1 km of coastline from late April to September 2005, to detect the presence of hawksbill nests (Fig.1). A subset of this area (1.4 km; hereafter, the "frequently monitored area"; Fig. 1) was monitored daily, 5 times per day (immediately before sunset, 3 times per

night, and immediately after dawn). This area was the focus of a detailed study on the nesting habitat of *E. imbricata* (Ficetola 2007). The remaining 1.7 km of coastline (hereafter, "occasionally monitored area") were monitored immediately after dawn every 7–10 days. Local regulations precluded a more frequent monitoring of this second area. For each nest, I also recorded the geographic coordinates using a global positioning system (Garmin Extrex, accuracy = ± 5 m). Moreover, because nest location can influence nest success (Caut et al. 2006), I also measured the distance from the low tide.

The emergence of hatchlings occurred during July and August. Nests were opened if signs of hatchling emergence or predation were found; I recorded if the nest was excavated by predators (fox or cats), if predated eggs were present within or close to the nest, and if hatched eggs were present. On the basis of these findings, nest success was classified in 3 categories: 0) failure: the whole nest destroyed by predators, i.e., no eggs successfully hatched; 1) partially successful: signs of predation but at least 1 egg successfully hatched; 2) successful: emergence of hatchlings and no sign of nest excavation and predation.

I used Moran's I to evaluate the spatial autocorrelation of nest success. Significance of Moran's I was calculated using 10,000 permutations. Spatial autocorrelation was calculated first for the whole study area, and then only for the occasionally monitored area, to evaluate if there was heterogeneity among the different sections of beach. Analyses were performed using SPDEP 0.3 under the R 2.2 environment (Bivand 2005).

Results and Discussion. — Fifty-one nests were detected within the study area, 20 within the frequently monitored area and 31 within the occasionally monitored area (Fig. 1). The average distance of nests from the low tide was 19 m (range: 10–35 m).

Between 2 July and 5 July, 1 nest was completely predated and 3 partially predated within the frequently monitored area. After these predation events, all nests within the frequently monitored area were protected using plastic net (Yerli et al. 1997; Irwin et al. 2004). All nests protected were successful.

None of the nests within the occasionally monitored area was protected, and none of them was successful. Out of the 31 nests observed in this area, 19.4% were partially predated, and 80.6% were completely destroyed by predators (Fig. 1). Nest success was not related to distance from the low tide (ANOVA: $F_{1,29} = 0.169$, $p = 0.66$).

The predation of nests across the whole monitored area was spatially autocorrelated, if the protected nests were included in the dataset (Moran's $I = 0.22$, permutation $p = 0.01$). This pattern arose because all the protected nests were clustered in the same area (Fig. 1). However, spatial autocorrelation disappeared if the analysis was repeated removing the nests protected after 5 July ($I = 0.056$, $p = 0.18$) or removing the whole frequently monitored area ($I = 0.0047$, $p = 0.33$). This indicates that, if nests were not protected, there was no spatial pattern for nest predation in the study area. In other words, it is unlikely that the striking predation rate is a peculiarity of a subset of the investigated area, and these results probably apply also to the other areas near the settlements and the industrial facilities.

This study shows a dramatic reproductive failure of *E. imbricata* in an area where the presence of human activities favor the abundance of predators. All the nests that were not protected were at least partially predated; more than 80% of predated nests were completely destroyed. Predators naturally destroy a significant proportion of nests of marine turtles. Nevertheless, in natural situations the predation rate rarely attains these levels, and usually ranges between 5% and 60% (Hitchins et al. 2004; Antworth et al. 2006; Caut et al. 2006; Xavier et al. 2006). However, a striking increase in predation rate of turtle nests has been recorded several times in areas recently colonized by synanthropic and exotic predators, with levels similar to those observed in this study (Feinberg and Burke 2003; Spencer and Thompson 2005).

In most of cases, I did not directly observe the predators destroying the nests; therefore, it was not possible to attribute each nest destruction to a given predator. Only 2 species of carnivores are present in the area: feral cats and Ruppell's foxes. Unfortunately, the area is very windy, and tracks quickly become unidentifiable, so it was impossible to determine the predator for many nests. Nevertheless, Ruppell's foxes were the predators most frequently observed approaching and excavating the nests, and thus may be responsible for most nest destructions. Foxes and other canids are opportunistic predators that are well known to depredate turtle nests (Brown and Macdonald 1995; Spencer and Thompson 2005) and can reach high densities in suburban areas. Their increasing abundance is also becoming a conservation concern in other areas of the Middle East where economic development is fast (Dolev et al. 2006). To my knowledge, this is the first time the Ruppell's fox has been observed performing systematic predation over nests of marine turtles (see Cuzin and Lenain 2004).

The physical alteration of coastlines can make them unsuitable for turtle nesting. A large conservation effort is therefore devoted to the preservation of nesting beaches from the direct effects of human activities (Ficetola 2007). However, human activities have indirect effects that are more difficult to detect than physical alteration, and these indirect effects can cause dramatic consequences that are comparable to beach destruction. Lighting (Longcore and Rich 2004) and the alteration of biotic communities are examples of these indirect effects. For example, the modification of coastline vegetation can increase nest temperature and cause the feminization of 100% of embryos in *E. imbricata* (Kamel and Mrosovsky 2006). In this study, I showed that the high densities of synanthropic predators near human industrial centers can cause an almost complete reproductive failure. Nest protection can be an effective measure to prevent predation, but it is not feasible over entire coastlines and is strongly

dependent on the availability of funding and workforce. The control of synanthropic predators through, for example, waste disposal and better regulation of domestic/feral animals may be the most effective strategy. These measures can also benefit other animals within the targeted ecosystem, such as lizards, small mammals, and birds.

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Dispersal of *Phrynops geoffroanus* (Chelidae) in an Urban River in Central Brazil

FRANCO LEANDRO SOUZA[1], JOSUÉ RAIZER[2], HIGOR THIAGO MOREIRA DA COSTA[3], AND FERNANDO IBANEZ MARTINS[2]

[1]*Universidade Federal de Mato Grosso do Sul, Centro de Ciências Biológicas e da Saúde, Departamento de Biologia, 79070-900, Campo Grande, Mato Grosso do Sul, Brazil [flsouza@nin.ufms.br];*
[2]*Programa de Pós-Graduação em Ecologia e Conservação, Universidade Federal de Mato Grosso do Sul, Centro de Ciências Biológicas e da Saúde, 79070-900, Campo Grande, Mato Grosso do Sul, Brazil [jraizer@nin.ufms.br; fimquelonio@hotmail.com];*
[3]*Programa Institucional de Bolsas de Iniciação Científica/Conselho Nacional de Desenvolvimento Científico e Tecnológico (PIBIC/CNPq), Universidade Federal de Mato Grosso do Sul, Centro de Ciências Biológicas e da Saúde, Departamento de Biologia, 79070-900, Campo Grande, Mato Grosso do Sul, Brazil [htmcosta@hotmail.com]*