Unraveling Behavioral Patterns of Foraging Hawksbill and Green Turtles Using Photo-Identification

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For centuries, marine turtles have been intensely exploited for their eggs, scutes and meat, resulting in a dramatic decline of populations all over the world (Malakoff 1997), including the Indian Ocean (Frazier 1980). Consequently, conservation and monitoring programs are now employed to study population trends and behaviors. Recently, research emphases have focused on foraging ecology and at-sea behavior (Proietti *et al.* 2012; Schofield *et al.* 2010). One monitoring program conducted by Kelonia, the marine turtle observatory, over the last ten years in Reunion Island (21° 06 S, 55° 36 E), which is a French territory located in the southern Indian Ocean 700 km east of Madagascar, revealed that foraging turtle populations have increased (4.9 turtles sighted per ultralight aircraft survey in 1998 and 27 in 2008) (Jean *et al.* 2010a).

Two species of marine turtle may be found year-round along the coastline of Reunion Island: the hawksbill turtle (*Eretmochelys imbricata*) and the green turtle (*Chelonia mydas*). They are listed as Critically Endangered and Endangered, respectively, on the IUCN Red List of Threatened Species 2011. Understanding their habitat use and feeding ecology is essential for their conservation (Arthur *et al.* 2009). However, until now research on feeding ecology in Reunion Island has been scarce. In the South Indian Ocean, only a few studies are currently published and have focused on green turtle foraging behavior, specifically in Mayotte Island, North of the Mozambique Channel (Ballorain *et al.* 2010; Taquet *et al.* 2006). These two studies used expensive bio-logging technologies (acoustic telemetry and data logger) to provide important results on fine scale behavior of adults on the foraging grounds; however, the time and spatial scales of the studies unfortunately failed to provide any significant results about movement over time between foraging grounds.

The identification of individuals within a population is a key issue for conservation metrics (e.g., distribution, habitat use, movement, population size) (Jean *et al.* 2010b; Reisser *et al.* 2008; Schofield *et al.* 2008). Most identification methods rely on the capture of marine turtles in order to tag them, which is costly and often traumatic for the turtle (Reisser *et al.* 2008; Schofield *et al.* 2008). Alternatively, photo-identification (photo-ID) relies on the natural marks of the turtle's body that may be photographically captured to identify and re-sight individuals (Jean *et al.* 2010b; Reisser *et al.* 2008; Schofield *et al.* 2008). The natural marks on the animal must be stable over time and independent of sex or age (Reisser *et al.* 2008; Schofield *et al.* 2008). For marine turtles, photo-ID is based on the scutes on either side of the head (Jean *et al.* 2010b).

Photo-ID methods have successfully been applied to a wide range of animals from tigers (stripe patterns) (Karanth *et al.* 2006) to whale sharks (stellar patterns) (Meekan *et al.* 2006). This is a useful method to monitor long-lived species such as turtles throughout their lifetime (Reisser *et al.* 2008) and in most habitats (e.g., development habitats, foraging grounds, and nesting sites).

This paper focuses on the foraging behavior of marine turtles in Reunion Island using photo-ID data collection and analysis. This monitoring program of marine turtles in Reunion Island was initiated in 2005 and is based on a computer-aided process using the coding of the facial profiles according to the position and the shape of the scutes. Data collected for this study were used to define spatial distribution and study movements among foraging areas of both foraging hawksbill and green turtles.

Data collection. Data were collected from 2003 to 2012 in the coastal waters of Reunion Island. Photographs of marine turtles were captured by volunteer scuba divers and free divers at frequented diving spots. Whenever possible, photographs were taken of both sides of the head and the entire body. A total of 98 divers took part in this program at 33 different diving spots. Each spot is identified by fixed buoys, which are mostly located on the western coast of the island. For each turtle sighting, the date, dive location, estimated carapace length and behavior (swimming, feeding, cleaning or resting) were recorded. Sampling effort was constrained by diving club presence. Thus, surveys were limited along the eastern coast because of both difficult weather conditions and lack of diving clubs in comparison to the western coast.

A new system of photo-ID implemented by Kelonia and based on a computer-assisted process using the TORSOOI database (TORtues marines du Sud-Ouest de l'Océan Indien – Marine Turtles of the South West Indian Ocean: www.torsooi.org) was used for the study. The TORSOOI database, an online MySQL database managing

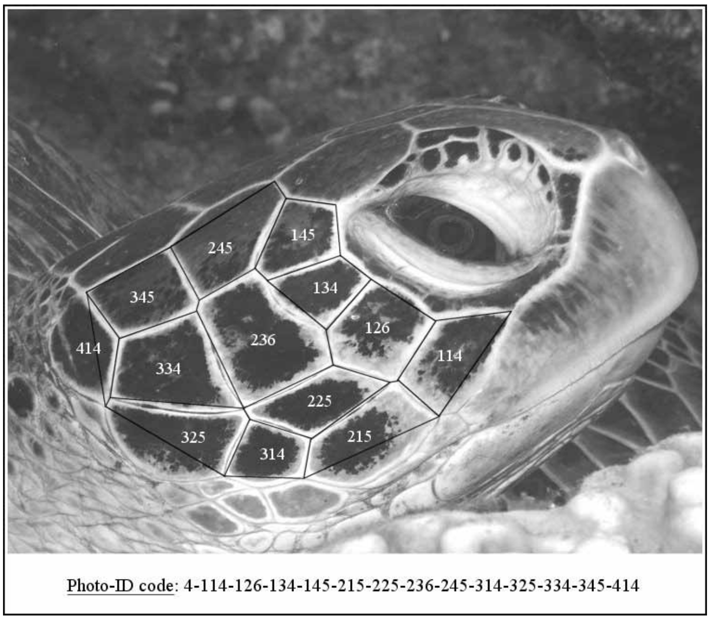

Figure 1. Coding process for a green turtle's right profile based on the position and the shape of the scutes.

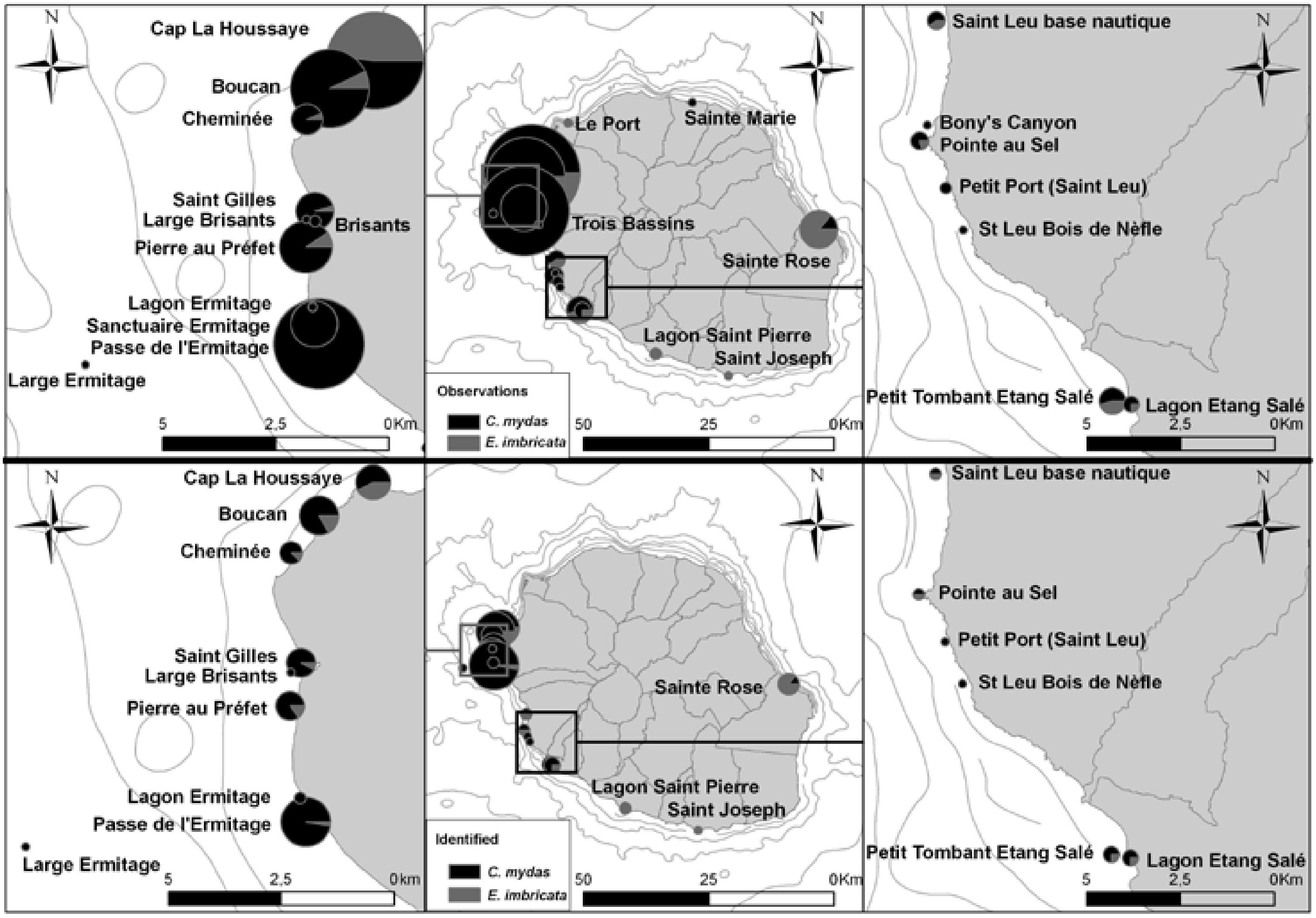

Figure 2. Distribution and abundance of hawksbill and green turtles in Reunion Island based on photo-ID.

photographs and sighting reports, includes 852 images (423 right profiles and 429 left profiles) that were used in this study.

Data processing. The photo-ID method allows the identification of individuals with specific physical characteristics: the spatial position and structure of the scutes from both facial profiles located posterior to the eye toward the neck and from the line of the upper jaw to the top of the turtle's head (Fig. 1) (Jean *et al.* 2010b). Photographs were received by email, selected, cropped and named. Then they were analyzed using TORSOOI photo-ID software for recognition. The photographer's name and email address, latitude and longitude of the dive spot, observation date, species and sex were also included with each photograph. The protocol for matching photos used for the study is presented in Jean *et al.* (2010b).

Years	Divers	Hawksbills sighted	Greens sighted
2003	2	0	2
2004	3	0	7
2005	5	1	11
2006	3	5	4
2007	12	25	35
2008	20	16	48
2009	27	14	68
2010	46	27	93
2011	37	24	108
2012	30	7	55
TOTAL		119	431

Table 1. Diver participation and marine turtles sighted between 2003 and 2012 (2012 from January through May only) in Reunion Island.

The TORSOOI database contains two categories of data: individuals with right and left associated profiles labeled here as "identified individuals" and single profiles. Initially, the sample was composed of 107 identified green turtles, 25 identified hawksbill turtles, 56 single profiles of green turtles and 11 single profiles of hawksbill turtles. Juveniles accounted for 75% of green turtles (n = 163) and 78% of hawksbill turtles (n = 36).

In order to study spatial movements, data were limited to turtles that changed their feeding sites at least once; this resulted in a sample size of 23 green turtles and 5 hawksbills.

Turtles previously have been observed foraging at each spot. Thus, for statistical analyses we considered each diving spot that was separated by more than 500 meters as a discrete feeding site and diving spots located less than 500 meters and displaying similar habitats (e.g., fringing reef, external slope, isolated reef) were grouped as a single spot. This grouping resulted in 24 distinct feeding sites.

Statistical analysis (Student's T-Test) was implemented using R (R Development Core Team 2011). Maps were created with ArcGIS 9.2 (®ESRI). To create movement maps, the distance between any two sites was measured along 20-m isobaths, which is the average depth where turtles are found in Reunion Island (between 5 to 35 meters). Indeed, according to Jean *et al.* (2010a), marine turtles were recorded on the outer reef slopes (40 meters) but most frequently in coral reef zones (fringing, platform and bank reefs, 5-8 meters).

It is important to note that all information concerning dive frequency per site was not available and the divers' participation effort could not be measured. The only element related to the sampling effort available was the number of sightings and the number of participants per site along with total sightings. Thus, we assumed sampling effort did not change the order of importance of the feeding sites.

Distribution of individuals. The distribution of both species was based on two parameters: the number of turtles identified and the number of sightings. Participation effort increased from 2003 to 2012, beginning with 2 divers in 2003 to 46 divers in 2010 (Table 1). The spatial distribution of effort also increased with time: sightings occurred on the western part of the island every year since 2003, whereas on the eastern part of the island sightings were recorded for the first time in 2006.

The number of marine turtles sighted increased each year, reaching a maximum of 27 hawksbills sighted in 2010 and 108 green turtles sighted in 2011. More photo-ID data were collected between 2007 and 2011 as a result of increased sampling effort (communication campaigns) and the number of turtle sightings.

Green turtles were mostly observed along the west coast (Fig. 2), specifically in northwest areas called Passe de l'Ermitage (127 sightings, 37 identified turtles) and Boucan (90 sightings, 20 identified turtles). Hawksbill turtles were more scattered and sighted less than green turtles. For this species, the two most important feeding sites were Cap La Houssaye (71 sightings, 9 identified turtles) and Sainte Rose (19 sightings, 6 identified turtles). Distribution of the turtles seemed to vary according to species. At Sainte Marie, Large Brisants, Digue Brisants Saint Gilles, Lagon Ermitage, Large Ermitage, Trois Bassins, Bony's Canyon, Petit Port Saint Leu and Saint Leu Bois de Nèfle, only green turtles were observed and hawksbill turtles were dominant on other feeding sites such as Sainte Rose (19 sighted hawksbill turtles, 3 sighted green turtles, 6 identified hawksbills and 1 identified green turtle).

Turtles, mostly juveniles (75% for green turtles and 78% for hawksbill turtles), were frequently sighted along the west coast particularly between Cap La Houssaye and Trois Bassins (94% of sighted green turtles and 73% of sighted hawksbill turtles). This may be a result of the high concentration of dive shops on the west coast particularly between Cap La Houssaye and Saint Gilles (Vivier 2002). Thus, the number of participants was higher in Saint Gilles area, which may explain the differences observed between this area and the rest of the island. However, ultralight aircraft surveys were conducted on the western coast and also revealed that marine turtles frequented areas between Cap La Houssaye and Trois Bassins with higher numbers at Boucan and Ermitage (Jean *et al.* 2010a). This is consistent with the results obtained with the photo-ID method.

The increase in marine turtle numbers was also inferred with ultralight aircraft surveys (Jean *et al.* 2010a) and is consistent with the increase in sightings from 2007 to 2010 (Table 1). Therefore, the increase may also be a consequence of the creation of the Marine Protected Area from Cap La Houssaye to Etang-Salé in 2007, which limited the number of human interactions with turtles (e.g., bycatch, boat strikes).

Movements. Of 56 green turtles, 41% changed their feeding sites at least once, and 33% of hawksbill turtles (n = 15) moved from one feeding site to another. Most movements were observed between Cap La Houssaye and Ermitage, where the number of diving participants was greatest. Eight green turtles and 1 hawksbill returned to their first feeding site after moving to another one (Fig. 3). The mean distance covered by hawksbill turtles was 6.4 km (SD = 7.2) and 4.6 km (SD = 3.6) by green turtles, with no significant difference between species (Student's T-Test, p = 0.60). Distances between sightings of individuals ranged from 1.1 to 15.5 km for hawksbill turtles and from 1.1 to 5.8 km for green turtles.

A total of 22 turtles, all juveniles, moved from one feeding site to another, but their individual behavior varied. Among these turtles, 9 individuals returned to their original feeding sites after being observed at another one. Thirteen individual turtles moved to a new feeding site and remained there.

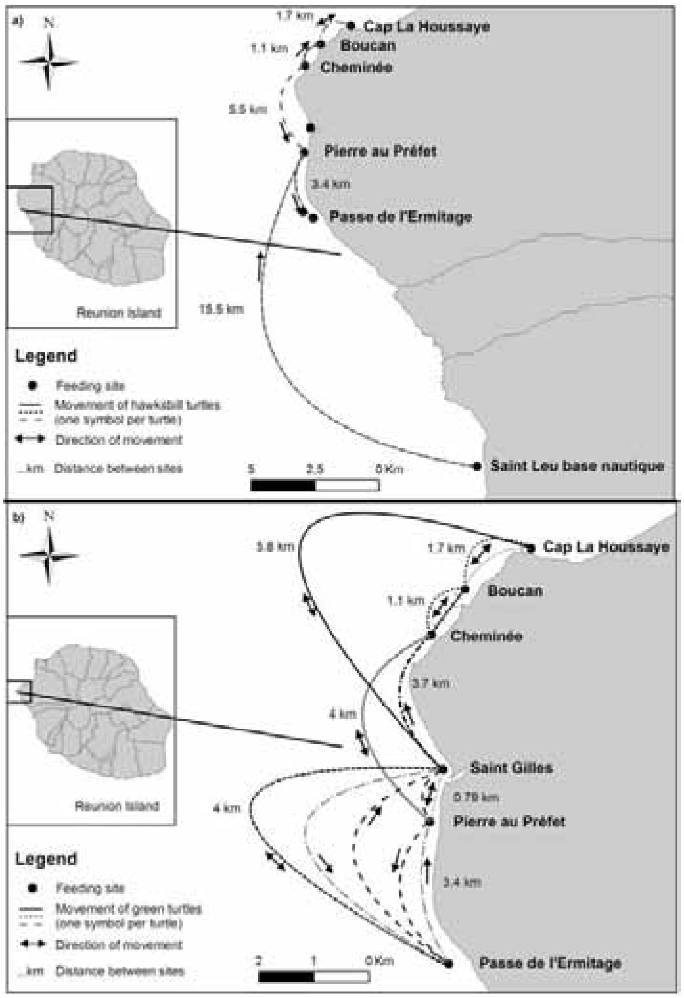

Figure 3. Movements of 5 *Eretmochelys imbricata* (a) and 16 *Chelonia mydas* (b) between feeding sites monitored by photo-ID from 2003 to 2012. Distances between sites were measured along 20-m isobaths. The representation of the movements between two sites does not match to the real trajectories of turtles.

Among the 31 adults sighted using photo-ID at Reunion Island, no movements between feeding sites were observed. This result may be due to the sampling method. The method used in this study did not allow for monitoring of all the turtles very regularly as it was a volunteer-based monitoring program that was dependent on the weather and tourism activity. Adult turtle monitoring is more difficult because they are generally seen off the coast in deeper water where there is less diving activity. Reunion Island is also a mating and nesting site for marine turtles (Ciccione & Bourjea 2006; Ciccione *et al.* 2008). Therefore, adults may visit the island for short periods thus increasing the difficulty of monitoring. For example, one male green turtle was sighted twice in 2007, and then twice again in 2011 with no observation during the intervening three years. Thus it might have visited the island twice for reproduction.

Some turtles were not re-sighted for several months or even several years after their initial sighting. Without a second observation, we cannot be certain if turtles moved from one feeding site to another or not. Movements of green and hawksbill turtles during foraging seem to be rare, which is consistent with Balazs (1979). According to some previous studies, these turtles generally tend to display fidelity to one foraging site (Blumenthal *et al.* 2009; Senko *et al.* 2010; Taquet *et al.* 2006). However, marine turtles do on occasion change their residency sites for different reasons: a decrease in the quantity and quality of food (Congdon *et al.* 1992; Dunbar *et al.* 2008), the presence of predators or other turtles (Heithaus *et al.* 2007), or the error of two sites being actually one single large and continuous foraging area (Ballorain *et al.* 2010; Taquet *et al.* 2006). A more regular sampling may help to confirm the rarity of transient behavior to generalize the phenomenon to the entire population.

Long-term and regular photo-ID monitoring is needed to validate these results. Additional surveys have the potential to reveal what degree of fidelity these turtles have to their foraging areas. A combination of photo-ID methods with satellite tracking using Argos and the Fastloc GPS system would allow better definition of core foraging areas and spatial movements.

The use of this photo-ID method increases the understanding of habitat use and foraging behavior of the resident turtle populations of Reunion. This island seems to be a stable developmental habitat for juvenile green and hawksbill turtles and a foraging ground for a few adults of both species.

The increase in the number of turtle sightings since 2003 may be due to awareness campaigns initiated by Kelonia, and it may also be the result of the measures to protect marine ecosystems due to the creation of the marine reserve. Marine turtles in Reunion Island seemed to be spatially attached to specific sites, but some individuals did move from one foraging site to another. Increasing the sampling effort could help discover the reasons for movement and determine whether we can generalize this phenomenon to the entire population.

At the present time, the photo-ID program is ongoing, and Kelonia will initiate new awareness campaigns, which could provide more reliable and conclusive results over time. To this end, a website dedicated to divers was developed so that participants could look online for the turtles they had photographed. This study demonstrates that participation of the general public is essential for marine turtle preservation and that it is a powerful awareness tool.

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Sea Turtles in the Waters of Almofala, Ceará, in Northeastern Brazil, 2001–2010

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Projeto Tamar-ICMBio (TAMAR), the Brazilian sea turtle conservation program (Marcovaldi and Marcovaldi 1999), established a conservation and research station at Almofala Beach, northeastern Brazil in 1992 (Marcovaldi 1993). Almofala is a foraging area for sea turtles: green (*Chelonia mydas*), loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*) and olive ridley (*Lepidochelys olivacea*), the same five species that occur in other places in Brazil (Marcovaldi & Marcovaldi 1999). About 85% of the sea turtles recorded at Almofala are green turtles, and both juvenile and adult-sized green turtles regularly occur there, which distinguishes Almofala from green turtle foraging areas in southern Brazil, where individuals of that species are generally juveniles (e.g. Gallo *et al*. 2006). The central objective of TAMAR's conservation actions at Almofala is to deal with the incidental capture of sea turtles by artisanal fisheries; this is carried out through monitoring, research, educational activities with local communities and the development of economic alternatives for them (Lima 2001).

Here we present an integrated summary of sea turtle data gathered by the Almofala station, focusing on the carapace size distribution of each species and connections between Almofala and other known nesting or foraging locations in the Atlantic Ocean.

Study area and period. Almofala Beach (2°56'17"S, 39°48'51"W; Fig. 1) is situated in the municipality of Itarema, in western Ceará, northeastern Brazil. The coastline monitored by the Almofala station is about 40 km long. For operational reasons, the fieldwork coverage has varied over the years. Here we present data gathered between 2001 and 2010. Starting in 2001, a noticeable increase in fieldwork occurred as more trained people started working for TAMAR at Almofala, facilitating increased effort in monitoring for both incidental captures of sea turtles in fishing gear and turtle strandings.

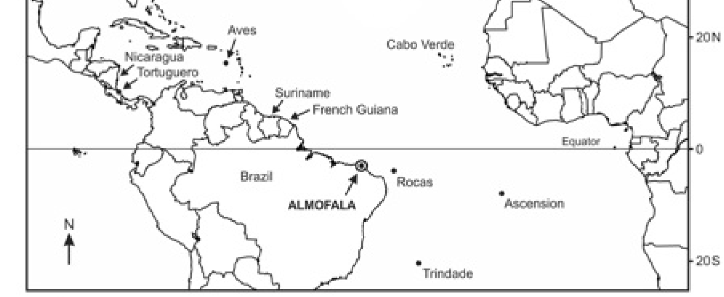

Figure 1. Map of the central part of the Atlantic Ocean, showing the location of Almofala in Brazil and the locations of some other sites mentioned in the text.