EDITORIAL

WHERE TO NOW? BIASES AND KNOWLEDGE GAPS IN SEA TURTLE SATELLITE TELEMETRY STUDIES CONDUCTED THROUGHOUT THE INDIAN OCEAN AND SOUTH EAST ASIA

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To complement papers in Issue 28, which summarised satellite telemetry studies from the South West Indian Ocean north to the Red Sea, Arabian/Persian Gulf, and Arabian Seas, the current issue of IOTN includes reports from countries in South Asia, South East Asia, and the South East Indian Ocean. The combined contributed papers by Antonopoulou & Pilcher (2018), Hays *et al*. (2018), Mancini *et al*. (2018), Phillott & Jalihal (2019), Pilcher *et al*. (2019), Rees *et al*. (2018a,b) Richardson (2019), Robinson *et al*. (2018), Swaminathan *et al*. (2019), Tiwari *et al*. (2018) and Waayers *et al*. (2019) to the Indian Ocean Turtle Newsletter special issues (#28 and 29) summarise the contribution of satellite telemetry studies towards improving our understanding about sea turtle biology and conservation needs in the Indian Ocean and South East Asia.

As expected, most studies focus on the most prevalent species' in each sub-region (for example, leatherback turtles in the South West Indian Ocean and flatback turtles in the South East Indian Ocean; see Phillott & Jalihal, 2019). There is an additional study bias towards post-nesting, migrating females on the return to their foraging grounds- again, understandable as this is the most accessible life-stage in the sea turtle life cycle and can be most easily tracked.

Post-hatchlings, juveniles, sub-adults, adult males, and non-breeding adult females have been largely overlooked in tracking studies in the region. Although a similar gap also occurs in other regions worldwide, continuing to focus on nesting females will not help answer the important questions raised by Hamann *et al*. (2010), Rees *et al*. (2016), Hays & Hawkes (2018) and Wildermann *et al*. (2018).

Post-hatchling sea turtles

Post-hatchlings may be tracked if facilities are available in which turtles can be reared to an appropriate size, and suitably sized and powered tags are available. Tracking turtles in this age class can provide information on dispersal paths, rates and behaviour of small turtles from the nesting beach, information about developmental habitats, identify potential threats, and help determine the boundaries for Protected Areas (see Mansfield *et al*., 2012).

Immature turtles

Wildermann *et al*. (2018) recently consulted international sea turtle experts to identify priority areas for study on immature (including juvenile and sub-adult) turtles. The Indian Ocean was identified as the region with the greatest need for research on this cohort and their developmental habitats. Satellite telemetry studies on these life-stages will be most relevant if addressing any of the four priority areas identified by experts contributing to the study by Wildermann *et al*. (2018): population ecology, habitat use and behaviour, threat identification, and management of threats.

The rodeo style of capturing turtles (first described by Limpus & Reed (1985) and used in the region by Pilcher *et al*. (2015)) may be possible for researchers with access to a vessel. Challenges in encountering and capturing immature turtles may be overcome by working with small-scale and commercial fisheries vessels, ecotourism operators, offshore oil and gas platforms etc (see Wildermann *et al*., 2018).

Adult male turtles

In a similar manner to immature turtles, adult male turtles can be captured in neritic foraging grounds using the rodeo technique or through cooperation with local fishers in the areas that turtles frequent. Additionally, adult male green turtles occasionally come close to shore at their breeding areas for mating, where they may be opportunistically captured for tracking and other studies (e.g. Wright *et al*., 2012). Given that satellite tags often transmit for longer than 12 months, tagging adult males will allow researchers to test the hypothesis that male sea turtles maintain an annual breeding cycle, due to the smaller amount of resources a male is required to expend during a breeding season when compared to an adult female (e.g. Hays *et al*., 2010).

Non-breeding, adult female turtles

Capturing and tracking non-breeding adult females at their foraging and overwintering areas provides information on residency patterns and home ranges but lacks the important linkages to their breeding sites and nesting remigration interval, as the breeding remigration interval of adult female turtles in the region is often 2 years or more (e.g Bourjea *et al*., 2007; Ekanayake *et al*., 2010; Nishizawa *et al*., 2018) and, therefore, generally longer than the life of a satellite tag. It is possible to identify adult females captured in foraging grounds that are likely to undertake reproductive migrations in the near future using ultrasonography, or the more invasive laparoscopy, to identify the presence of mature ovarian follicles that indicate the turtle is in breeding condition (see Hamann *et al*., 2003). These turtles can then be the focus of satellite telemetry studies to determine the timing and pathways for breeding migrations.

How many satellite tracks are enough?

There is no simple answer to questions about the ideal sample size in satellite telemetry studies. Hays & Hawkes (2018) suggest that the number of required tags will depend on the location, species, population, focus of the research, and the variability in turtle behaviour. It is challenging (and expensive) for one individual person or group to accumulate enough data, and some studies only opportunistically apply satellite tags and delay publishing their results until a large number of tracks have been accumulated. However, Godley et al. (2008), Jeffers & Godley (2017) and Hays & Hawkes (2018) all emphasise that the greatest benefit of satellite tracking studies will be realised when data are widely shared (preferably through peer-reviewed publication) and data sets are combined in collaborative studies. We strongly encourage researchers to publish their small data sets or collaborate with other researchers in the region (or internationally) to ensure their efforts and the funding invested in the tracking work make the greatest contribution possible to improving our understanding of sea turtle biology and conservation needs.

Combining satellite tags with other research tools

The use of stable isotope analysis (SIA) to upscale findings from satellite tracking studies is becoming more widespread and can be used to varying degrees on different turtle species. The procedure is to identify stable isotope signatures for certain geographic locations from a number of tracked individuals and then the foraging area of a larger number of non-tracked individuals can be determined from their SIA signature (see Seminoff *et al*. (2013) for a topic overview). This combination of research tools can lead to population-level characterisation of foraging habitats and identify differing trajectories in turtle numbers contributing to a breeding population from widely separated source foraging sites, as eloquently described for green turtles in the Mediterranean in Bradshaw *et al*. (2017).

Flipper tagging

The value of traditional flipper tagging should not be forgotten. While satellite tags may provide more accurate data when answering some questions (e.g. the number of clutches laid by an individual per season; Tucker *et al*., 2018), well-applied flipper tags made of an appropriate material can allow individual turtles to be followed over decades (e.g. flatback turtle X23103 has been followed at Mon Repos, Australia, since first tagged in 1974; DES, 2016).

Far cheaper than satellite tags - hence larger sample sizes possible, more likely to receive permit approval, with a longer tag life, and accessible to anyone who is close enough to read the tag, flipper tagging has already proven its value in studies conducted throughout the region. A nesting olive ridley turtle tagged at Hawkesbay Beach, Pakistan, was captured 223 days later by a fisher off Bhaidar Island in the Gulf of Kachchh, India (Firdous, 1991), indicating potential foraging grounds and the need for international conservation efforts. Similarly, recoveries of metal flipper tags applied to olive ridley turtles at mass-nesting beaches in Odisha, India, indicated long-distance migrations to foraging grounds in the Gulf of Mannar and Sri Lanka. Some of the tag recoveries occurred at these distant locations during the known arribada period in the following year, suggesting females may utilise nesting beaches other than those in Odisha where they were tagged or not nest every year (Shanker & Pandav, 2001 in Pandav & Choudhury, 2006). Intra- and inter-seasonal shifts in nesting beaches were also directly observed via tag recoveries (Pandav, 2001 in Pandav & Choudhury, 2006). Because of their longevity flipper tags should also be used in conjunction with satellite tags. The flipper tag will often remain in place after a satellite tag has been shed from the turtle's carapace, so the identity and origin of the study animal is maintained for extended periods. Increasing the important individual-based dataset contributes greatly to our understanding of sea turtle life-history traits in different study locations.

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CALL FOR SUBMISSIONS

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