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Biometric relationships, size class structures, and growth rates of foraging Hawksbill (*Eretmochelys imbricata*) and Green (*Chelonia mydas*) Sea Turtles in Anguilla, with observations on occurrence and prevalence of fibropapilloma.

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ABSTRACT

Three species of sea turtles are regular visitors to the waters surrounding Anguilla: *Chelonia mydas*; *Eretmochelys imbricata*; and *Dermochelys coriacea*. A small number of reports have also been made regarding *Caretta caretta* sightings, but none of these were confirmed with direct evidence. Biometric measurements of turtles sampled in Anguilla began in September 2002, with efforts increasing over subsequent years initially driven by a regional project funded across the UK overseas territories by the UK Foreign and Commonwealth Office and the UK Department for Environment Food and Rural Affairs. After the completion of this project, work continued under the leadership of the Department of Fisheries and Marine Resources (DFMR), Government of Anguilla. Today, the work load is shared with the Anguilla National Trust who lead land based turtle nesting beach surveys with the in-water work remaining under the lead of DFMR. A small number of reports have been produced over the years based on this work, but to date none of the biometric data has been analyzed. This report presents this data, combined with other previously unpublished information. Analysis found clear linear relationships between all biometric measurements taken, except turtle head width, possibly due to growth rate acceleration with age varying between sexes. This suggests that when measuring turtles during sampling, one single measurement may be made from which all other measurements (except head width) can be inferred. This may be beneficial when sampling nesting females susceptible to disturbance. The measurement suggested to be taken in these circumstances for later extrapolation is curved carapace length (CCL) due to simple equipment needs and ease of measure. Growth rates were obtained via recapture measurements from seven individuals (four *C. Mydas* and three *E. imbricata*) which gave growth rates for *C. Mydas* of approximately 6 cm/yr-1 CCL with E. imbricata more variable at between 2-6 cm/yr-1 CCL. Fibropapilloma was first recorded on a *C. mydas* individual in June 2010, with no occurrences yet reported for E. imbricata. In 2014 and 2015, 31% and 17% *of C. mydas* individuals captured in Island Harbour showed signs of the virus respectively, with most cases exhibiting well-formed tumors. It is hoped that funding can be secured to expand the current turtle program allowing more frequent sampling, increased numbers of sampling sites, and initiation of GPS tracking studies. With the current moratorium on harvesting sea turtles due to end in 2020 it is essential that as much information is collected as possible on these species, thus allowing properly informed management decisions to be made.

Introduction

Sea turtles around the world are threatened across their range (Eckert *et al*., 1999). Of the seven recognized species, six have been recorded in the Caribbean (Plotkin, 1995), although only four are considered regular visitors to the region: Green (*Chelonia mydas*); Hawksbill (*Eretmochelys imbricata*); Loggerhead (*Caretta caretta*); and Leatherback (*Dermochelys coriacea*). Of these, three have been well-documented in Anguillian waters (*C. mydas, E. imbricata, D. coriacea*), but only anecdotal or unconfirmed sightings of *C. caretta* have been recorded (Wynne, 2009). Under the IUCN Red List of Threatened Species categorization is: *E. imbricata* – critically endangered; *C. mydas* – endangered; *D. coriacea* - vulnerable. In the coastal waters of Anguilla, two species are known to maintain foraging populations *C. mydas* and to a lesser extent *E. imbricata*. *D. coriacea* has an entirely pelagic life history aside from when it comes ashore to nest. All three species are known to nest on mainland Anguilla, although interestingly the most common to do so is the critically endangered *E. imbricata*, followed by *C. mydas* and lastly *D. coriacea*.

In Anguilla sea turtles have been the subject of scientific research since September 2002, an effort initially driven by a regional UK Overseas Territories project funded by the UK Foreign and Commonwealth Office and the UK Department for Environment Food and Rural Affairs (Godley *et al*., 2004). Beyond 2004 work was carried on by the Department of Fisheries and Marine Resources (DFMR), Government of Anguilla, and has continued ever since. Aside from having an academic interest in these species, one of the main factors behind this work was the 1995 five year moratorium on turtle harvesting, later extended and brought into force under the Fisheries Protection Act of 2000, which was again extended in 2005 for a following fifteen years. With this moratorium due to end on the 15th December 2020, DFMR is charged with providing detailed information and suggested future management to those decision makers who will either extend the moratorium or end it.

Initially the survey work carried out by DFMR included nesting beach surveys as well as in-water work. However, recognizing the Anguilla National Trust's (ANT) existing volunteer network, DFMR trained ANT staff and volunteers and transferred responsibility for surveying nesting beaches to the organization in 2009. Since then DFMR and the ANT have worked together closely to ensure their respective aspects of this important work have continued unhindered into the future, despite limited financial and logistical resources.

The work aspects undertaken by DFMR since the end of the UKOT project in 2004 have been the subject of two past reports describing the progress of this work (Wynne, 2009) and the concluded status of populations based on surveys completed at the time (Wynne, 2010). Since then no further reports have been produced, and at no time since 2005 have biometric data collected been analyzed or presented. With the end of the moratorium rapidly approaching this current report aims to begin filling this gap by presenting biometric data collected up until the end of 2015 for foraging *C. mydas* and foraging *E. imbricata*. It is hoped that this report will form the basis of an increased survey effort for both DFMR and the ANT that is being planned on into 2016, should sufficient funding be found by both agencies.

Methodology

C. mydas are primarily captured during netting exercises at Island Harbour and in a coastal lagoon on Scrub Island. Full capture methodology can be found Wynne (2010). Plans for 2016 are to expand capture locations to Road Bay and Forest Bay also. *E. imbricata* are primarily captured by hand while snorkeling along northern coastal regions.

Survey location details and full capture methodology can be found in Wynne (2010). Once captured biometric and other data are collected:

- Straight Carapace Length (SCL) and Width (SCW) – Measured by calipers
- Curved Carapace Length (CCL) and Width (CCW) – Measured by tape measure
- Plastron Length (PL) – Measured by calipers
- Whether previously tagged – Checked for both flipper and PIT tags
- Occurrence of fibropapilloma
- Water depth and habitat where captured (etc)

Note: Measurements are taken to the nearest mm but recorded in cm. SCL and SCW was not recorded until mid-2008 when large calipers were purchased by DFMR for taking these measurements.

Results

In total 308 individual foraging turtles where measured during the study period (first time captures), 197 *C. mydas* and 111 *E. imbricata*. Further to this, 67 recapture events took place, of which 2 individuals were recaptured on three occasions, and 9 on two occasions. The remaining 43 events were of individuals only recaptured on a single occasion.

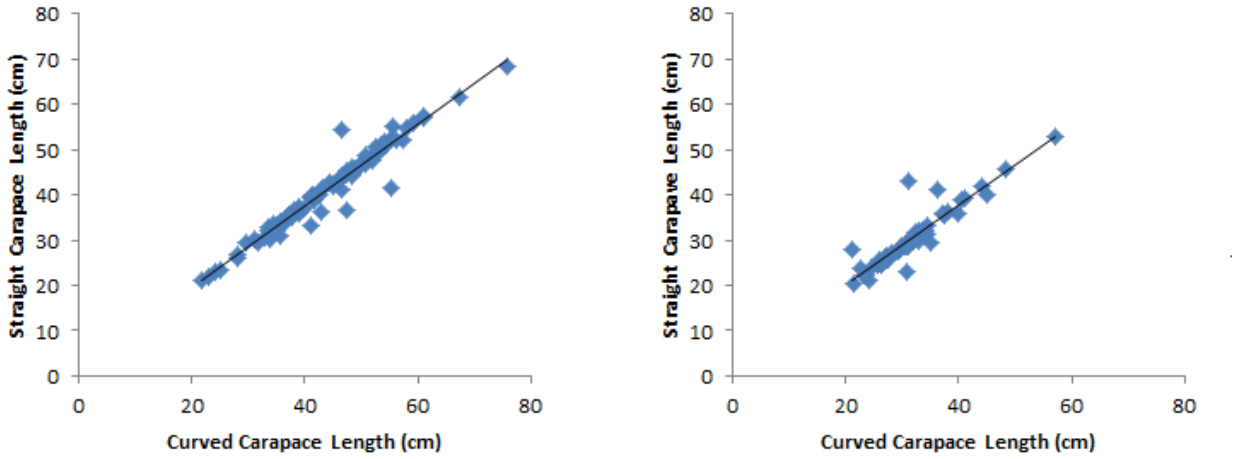

Figure 1: Relationship between curved and straight carapace measurements of first time captured foraging C. mydas where y = 0.9026x + 1.4705, R^2 = 0.9494, n = 89 (left); and E. imbricata where y = 0.8796x + 2.5609, R^2 = 0.8435, n = 53 (right). Calipers used to measure straight length were not acquired until 2008.

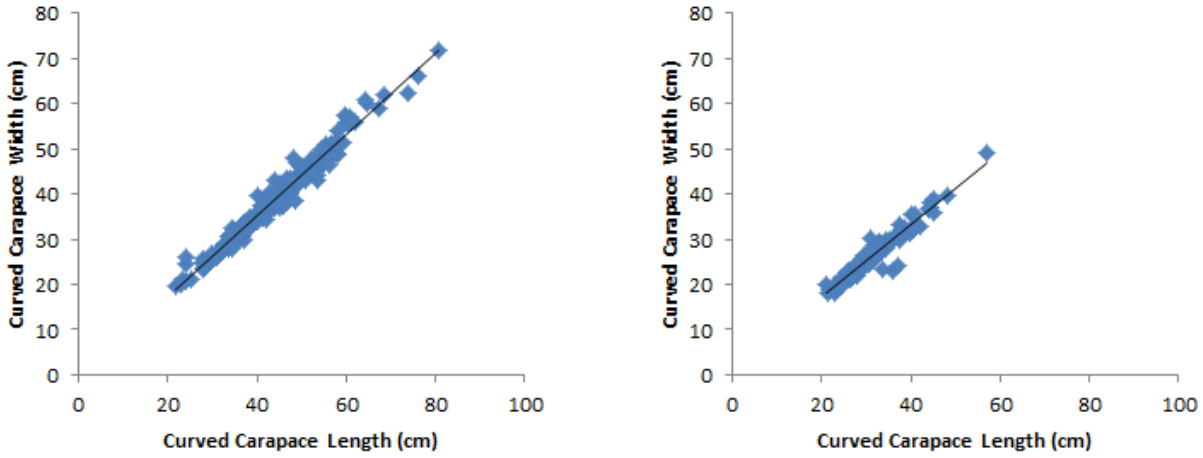

Figure 2: Relationship between straight carapace length and width measurements of first time captured foraging C. mydas where y = 0.9008x – 0.8792, R^2 = 0.9721, n = 197 (left); and E. imbricata where y = 0.8066x + 1.0154, R^2 = 0.9264, n = 111 (right).

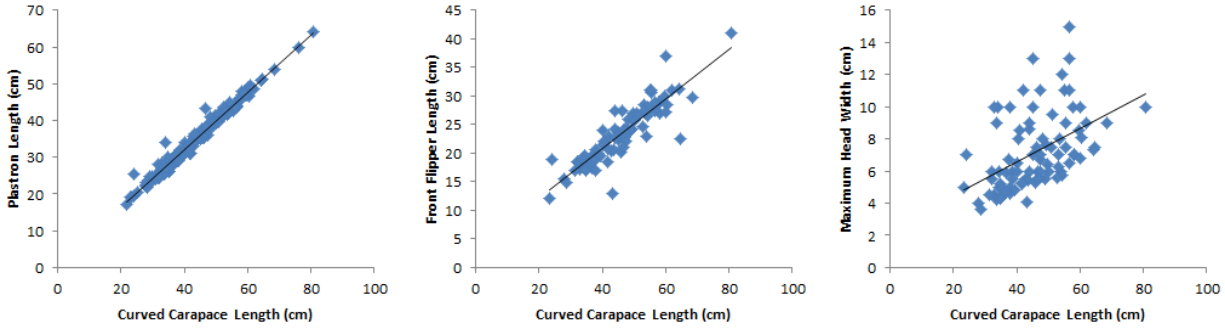

Figure 3: Further biometric relationships of first time captured foraging C. mydas between straight carapace length and plastron length where y = 0.7801x + 0.8577, R^2 = 0.9786, n = 191 (left); front flipper length where y = 0.4342x + 3.3819, R^2 = 0.794, n = 86 (middle); and head width where y = 0.1036x + 2.4199, R^2 = 0.2241, n = 86 (right). Flipper and head widths were only measured until 2005. Relationships of these measures for E. imbricata are not illustrated but followed similar patterns.

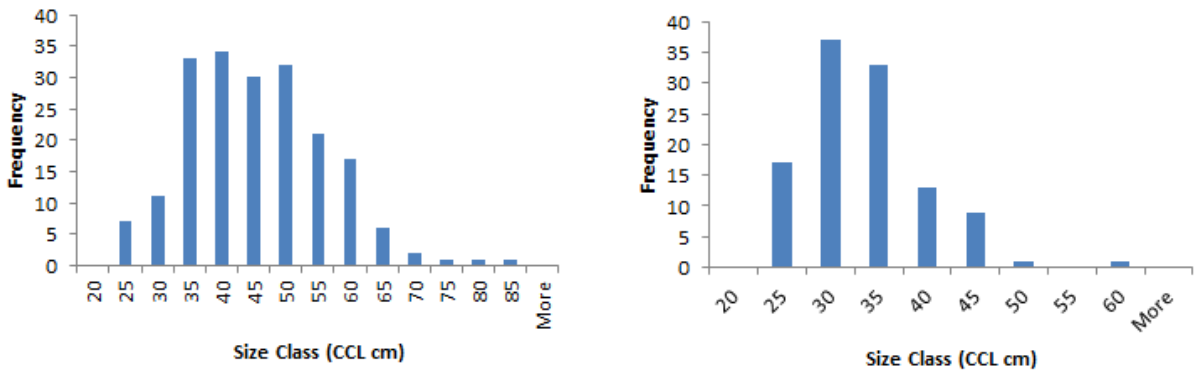

Figure 4: Size class structure (CCL) of first time captured foraging C. mydas (left) and E. imbricata (right). n = 308.

In terms of SCL, the largest foraging *E. imbricata* recorded was 53 cm, followed by 49.0, 45.6, and 43.0 (including recaptures), with a mean size of 30.3 cm (first time captures only). The largest foraging *C. mydas* recorded was 74.5 cm SCL, followed by 70.8, 68.5 and 66.7 (including recaptures), with a mean size of 41.7 cm (first time captures only).

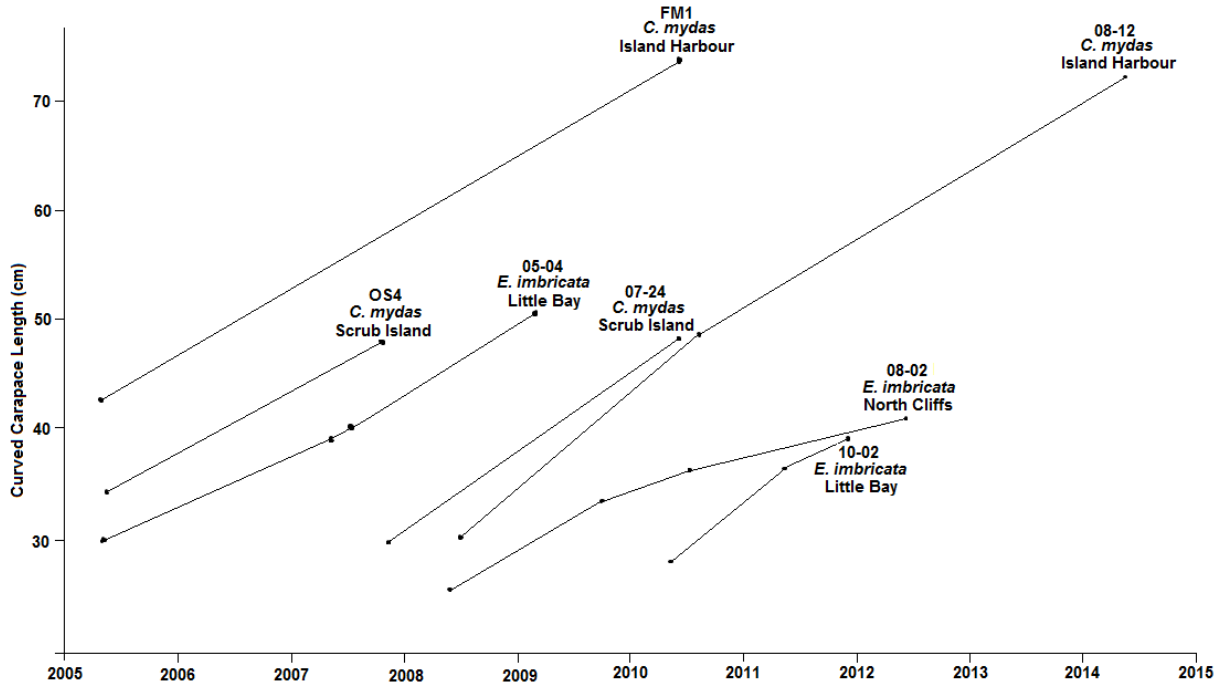

Figure 5: Growth rates based on the seven individuals with highest recapture rates across greatest temporal span. Species and locations, along with unique ID for each turtle are detailed in the figure. A standardized unique ID was introduced in 2005, which was fully adopted in 2007.

Disease Observations: Fibropapilloma was first recorded on a *C. mydas* individual in June 2010 as a raised warty lump on its right rear flipper. This was the only occurrence is 2010 despite four extensive netting surveys conducted. No occurrences were reported 2011-2013, although during this period only *E. imbricata* survey work was undertaken (to date no cases have been recorded in *E. imbricata*). When *C. mydas* survey work resumed, 31% and 17% of individuals captured in Island Harbour showed signs of the virus in 2014 and 2015 respectively, with most cases exhibiting well-formed tumors, often around the eyes. No cases of fibropapilloma have been recorded in foraging *C. mydas* populations at Scrub Island[1].

Discussion

In terms of biometric relationships, figures 1 through 3 illustrate, with only one exception, reliable linear correlations between measurements and thus how a single measurement could in fact be used to infer all others. The exception is head width, and the lack of a relationship possibly due to differences between male and female *C. mydas* head growth rates. Although it is not necessarily recommended to reduce the number of measurements currently taken while conducting surveys, it does mean that if measurements are unable to be taken (plastron of nesting adult for example), or mistakenly forgotten while in the field, gaps can be filled if needed during later analysis. Furthermore, if wishing to minimize disturbance while sampling, for example, a nesting female, curved carapace length could be measured only and all other biometrics (aside from head width) inferred. Curved carapace length is suggested as the biometric of choice as it needs only a simple tape measure, rather than the sometimes cumbersome calipers needed to measure straight carapace length. It is also interesting to note in figure 1 that despite *E. imbricata* appearing to have a markedly more domed carapace than *C. mydas* very little difference can be observed overall between graphs.

Figure 4 also presents some interesting similarities between the two species, with the first individuals arriving into a foraging population at c. 21 cm CCL. However, across larger size classes *E. imbricata* peaks much earlier than *C. mydas*, and by the 40 cm CCL size class individuals become less common (it is unknown if this is through predator interaction, harvesting or migration), and by 50 cm CCL they are extremely rare. *C. mydas* on the other hand peaks more gradually, and are still common up to the 50 cm CCL size class. From here, size class abundances begin to drop (again, it is unknown if this is through predator interaction, harvesting or migration) and by 65 cm CCL most individuals appear to be absent from the foraging population: on rare occasions size classes greater than 70 cm CCL have been recorded. On the whole, although reasons for early size class declines are unclear and may be due to a gradual increase in migration behavior as discussed in following paragraphs, generally speaking *E. imbricata* appear to depart from the foraging coastal populations before reaching 50 cm CCL and *C. mydas* before 70 cm CCL.

Growth rates (figure 5) for all *C. mydas* plotted were relatively constant at approximately 6 cm per year in CCL, irrespective of whether they were foraging at Scrub Island or Island Harbour. Growth rates of *E. imbricata* were more variable ranging from a similar value for that observed in *C. mydas* to a value as low as 2 cm per year on one occasion. Reasons for these differences remain unclear but may be a natural decrease with age and/or related to environmental factors such as water chemistry or habitat quality (Diez & Dam, 2002).

Although this report is merely a presentation of collected biometric data for circulation around government agencies and/or other interested parties, it does allow some limited conclusions to be drawn in terms of challenges to

[1] This is still the case, although later work in 2016 confirmed fibropapilloma in the foraging *C. mydas* population at Road Bay.

management beyond that provided by previously published provisional population estimates. More work is needed to delve into the intricacies of this, but initial results highlight why foraging turtle populations are so easily threatened by human harvesting, and thus how this contributes to the status of regional populations.

What has become clear through capture-tag-release exercises over the last decade in Anguilla, is that foraging *E. imbricata* have an extremely high fidelity to small geographical locations, with no cases yet recorded of a tagged turtle being recaptured in another study area. Even areas in close proximity to one another, for example Little Bay and Katouche Bay (North Cliffs), where numerous individuals have been tagged over the years, show no signs of a foraging population cross over. Bearing in mind actual numbers in these areas may only be in the low teens, it is easy to see how, if the moratorium were lifted, that these individuals could easily be targeted via speargun: *E. imbricata* often relies on camouflage rather than flight, hence why it can be captured relatively easily by hand during DFRM survey work. *E.imbricata* have been documented to spend at least four years in their foraging sites (figure 5), thus even if only one turtle were harvested every three months, after four years their population would likely be decimated.

A differing situation, albeit with identical consequences, is observed with *C. mydas*. As sampling has at this time only been limited to two very different geographical locations (Island Harbour seagrass area and a salt water lagoon on Scrub Island known as Fish-Hole Pond), conclusions relating to dispersal of foraging populations cannot yet be drawn. However, a high site fidelity can be concluded at least in terms of a protected area to spend the night: sampling occurs during the early hours of the morning, and numerous recaptures have been made of those tagged in the same location during previous surveys. As with *E. imbrictta*, *C. mydas* have been documented to spend extended periods (at least up to six years) using the same area as part of their life history. Thus, even though *C. mydas* rely on flight rather than camouflage, because they overnight in the same shallow seagrass/sandy areas night after night, they can be easily targeted using a net. Populations could be decimated even if only one day per year were opened up to harvesting (as has been suggested by some stakeholders) due to the effectiveness of this method.

What is clear is that more work is needed to assess exactly how much of a threat is posed by this site fidelity. For example, in other parts of the Caribbean foraging *C. mydas* have been documented to move out of their protective bay areas during the day into more open waters. If they do this in Anguilla, it will be crucial to know how far they travel and how often. Do those seen in Island Harbour first thing in the morning move out to forage along the coast of Little Bay, or even as far as Road Bay, Sandy Island and beyond? If so, anecdotal turtle numbers are likely being greatly overestimated, as fishers (for example) may simply be observing the same turtle in a completely different location. An example of this extensive movement can be found on www.seaturtle.org where tracking data are presented for a foraging *C. mydas* based in St Martin that is documented to visit Anguillian waters. This particular turtle is a large foraging individual (>70cm CCL), and so may be becoming more migratory as maturity is reached. It is suspected that this ‘adventurous with age’ behavior is also taking place in Anguilla and explains the reducing size classes towards maturity (a tendency to begin leaving protected areas and not necessary returning on a daily basis). It might also explain the lack of larger individuals recorded at Scrub Island: Fish-Hole Pond is hard to locate and access by sea, and so juveniles may enter by chance and remain there until they begin to instinctively start to roam towards the mid-50 cm CCL size classes. Once they leave, it is possible they do not return. Again, such potential increases in activity with age will be crucial to understand if correct management recommendations are to be made.

The importance of protecting foraging individuals was often overlooked in decades past, probably due to a lack of scientific research and the need for technological development. A past report advocating the extension of the

original 1995 moratorium (Hodge, 2000) stated: "All the advice received to date indicates that in the absence of a moratorium on harvesting, emphasis should be placed on the effective monitoring and strict protection of adult nesting turtles and their nests". While the protection of adult nesting turtles and their nests should be a very high priority, the current data now also suggests that foraging populations should also receive the highest level of protection due to their vulnerability from harvesting caused by the longevity of site fidelity. Much more work is needed however, as there are still many unanswered questions before informed management recommendations can be made.

Future Work Recommendations

Since the reports detailing the first preliminary foraging population estimates that were produced in 2009 and 2010, no updated estimates have been made. It is a goal on into 2016 for DFMR to increase its turtle monitoring work in light of the current moratorium coming to an end in a few years' time and provide these new estimates. During conversations with the ANT, who also aired their concern and a willingness to increase their nesting beach survey work, it was decided to submit a project proposal to an external funding agency to allow this to happen[2]. This proposal also aims to fill all the remaining knowledge gaps as they relate to turtles in Anguilla, while building on the past research that has been conducted. Funding will allow nesting beach surveys to be expanded over the unpopulated offshore cays, and increase the frequency of in-water work conducted by DFMR. Another key aspect of the project is to attach satellite based data loggers onto both nesting and foraging turtles (of all species present) to fully assess their movements. Cheaper GPS loggers will also be tested to assess their viability as a research tool.

One of the key pieces of information relating to the foraging populations discussed within this report is the openness of populations. For example, do the foraging *C. mydas* at Fish-Hole Pond leave the lagoon during the day? How often do new individuals join the population there and how long do they remain? How far do *C. mydas* travel from Island Harbour and do they return every day or move from place to place around Anguilla, returning sporadically? What is the population status of *C. mydas* in other seagrass areas around Anguilla, such as Road Bay or Forest Bay? How far do *E. imbricata* travel, and do they ever venture away from the coastal regions? Do size specific daily/weekly migration patterns exist?

With this information the Government of Anguilla will be better able to make decisions on the moratorium renewal in 2020. For example, if after 25 years turtle populations have still yet to show signs of significantly increasing, maybe it is time to consider having turtle protection a permanent feature of the Fisheries Protection Act. It is very clear from the work conducted to date that all aspects of their life history make turtles extremely vulnerable, and it is highly unlikely that any managerially controlled harvesting could be effectively enforced for the benefit of sustainability. It would be far better for the island of Anguilla to be seen as taking a forward thinking conservation stance on turtles, reaping the economic benefits they bring via tourism and research, rather than the limited short term benefit they bring when consumed.

[2] Following the production of this report DFMR, in partnership with the ANT and the University of Roehampton, were successful in gaining funding from the IUCN Best 2.0 initiative to conduct their proposed project entitled 'Saving the sea turtles of Anguilla: combining community action with scientific evidence to drive legislative change' due to run from 1st April 2016 until 31st March 2019.

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