ARTICLES

TIPS AND TRICKS FOR SEA TURTLE SATELLITE TELEMETRY

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DESCRIBE YOUR EXPERIENCE WITH TRACKING IN THE INDIAN OCEAN AND SOUTH-EAST ASIA REGION

Adhith Swaminathan: In 2010 I had the opportunity to work on leatherback sea turtles in the Andaman and Nicobar Islands, India. Little did I know that a year into the project, we would be attaching satellite transmitters on nesting leatherbacks for the first time in India. Between 2011-2014, Dakshin Foundation in collaboration with the Centre for Ecological Sciences, Indian Institute of Science, Bangalore and the Andaman Nicobar Environment Team deployed 10 transmitters in the West Bay of Little Andaman Island to study migratory routes and identify foraging sites. We used Platform Terminal Transmitters manufactured by Sirtrack (which was officially renamed Lotek NZ Ltd after the acquisition) model Kiwisat 202 that were specifically designed for leatherbacks to be surgically attached using the direct attachment method. Two transmitters deployed in 2014, gave us 266 and 395 days of data and these individuals even returned to nest after several years with no evidence of a transmitter attachment. More recently in 2023, I also assisted in the deployment of two transmitters (SPOT-317C) by Wildlife Computers on leatherbacks nesting in Sumatra, Indonesia.

ALan Rees: I have been involved in tracking sea turtles, with Argos satellite tags in the Indian Ocean since 2006, having tracked over 30 turtles from Oman, Kenya, Kuwait and Saudi Arabia. These tags were deployed on loggerhead, green, olive ridley and hawksbill turtles. Most tags were deployed on nesting turtles, but several were deployed on rehabilitated juvenile and subadult green turtles in Kuwait. I have also led projects tracking over 50 loggerhead turtles in the Mediterranean, since 2002, which have involved tracking adult male and female turtles as well as juveniles and subadults.

Nick Pilcher: I have had the great pleasure of being involved in numerous projects across the IO and SEA, and this has given me the opportunity to deploy transmitters on sea turtles in some interesting locations. I tracked seven post-nesting green turtles from Con Dao, in Viet Nam in partnership with WWF-Vietnam. I then tracked five juvenile green turtles from Mantanani island in Malaysia, hoping to see where their secondary foraging grounds were – but none went anywhere! I also tracked 25 post-nesting green turtles from the Turtle Islands Park in Sabah, Malaysia, and watched them move throughout the Sulu Sea and beyond into the Sulawesi Sea and the South China Sea. Between 2010 and 2014 in partnership with Emirates Wildlife and numerous national partners we deployed a total of 102 transmitters on post-nesting hawksbill turtles from multiple locations in Iran, Oman, Qatar and the United Arab Emirates and found that there was little movement in and out of the Straits of Hormuz. Gulf hawksbills mostly stayed inside the Gulf. Alongside Emirates Nature and partners in the United Arab Emirates in 2016-2019, we then deployed 75 transmitters on foraging green turtles at Ras Al Khaimah and out on Bu Tinah Island, some 80km off the coast of the UAE.

This last one was a fun project because we had to reverse engineer our plans to track reproductive turtles. From a nesting beach it is a relatively straightforward process to select a turtle and deploy a transmitter. But at these foraging grounds things were far more complicated. We needed to catch and tag turtles in breeding condition, so that they could be tracked when they migrated to nest. And this required being able to identify which turtles were adults and, among these, which were reproductively active. As you know, sea turtles do not breed every year, nor do they do so year-round. But the satellite transmitters used on this project were programmed to last between nine and 12 months. If our team caught a turtle at random and put a transmitter on it, there would be no guarantee that it would be an adult, or more precisely, that it would migrate to nest that year, and therefore the project might not get any

migration data or be able to link feeding and nesting sites. To solve this, I used a small surgical procedure called laparoscopy. This allowed me to determine the sex and the age class of the turtles, and importantly if they were in breeding condition. Laparoscopy is a delicate procedure that involves making a small incision close to the rear flippers and inserting a scope with a fibre optic light supply to look at the reproductive organs. Once the sex and reproductive condition were determined, and the turtles selected for tracking, the incision was sewn up with two stitches and the turtles were ready for the attachment of satellite transmitters.

Paul Whittock: I have attached tracking units to 40 flatback turtles and four green turtles in Western Australia, as well as five olive ridley turtles in the Philippines. All units were placed on adult female turtles during their nesting activities on the beach. For flatbacks, we use a harness approach for attaching the units due to the poor adherence of epoxy to their carapace. The purpose of these attachments was to provide a better understanding of their movements and behaviour around client infrastructure and offshore activities during their inter-nesting phase. They also provided valuable insights into their post-nesting migration and foraging phases.

TIPS AND TRICKS FOR SATELLITE TELEMETRY

Choosing a satellite tag to meet your research objectives

Adhith Swaminathan: Argos-only tags are cheaper and the batteries also tend to last longer in comparison to FastGPS tags. These tags are great for tracking migratory routes and identifying foraging sites. FastGPS tags are more expensive but provide better spatial resolution, which might be crucial to study inter-nesting movements and foraging behaviour. Both tags have an option of adding dive sensors to collect dive data, which increases the cost and affects the battery life of the tags.

ALan Rees: Choice of tag involves a trade-off between two competing components that are driven by the normal limitation of constrained funding. These are sample size (the number of tags you can deploy) and data requirements (the need for accurate location data or other data such as dive behaviour). In general, if the research question only requires broad-strokes location data – typical for determining post-nesting migration routes and overwintering grounds – then the cheaper Argos location only tags are sufficient. However, if the objective is to study fine-scale movement in a foraging or internesting area then more expensive tags with accurate GPS derived locations (which may cost approximately double the Argos location only tags) are required. Similarly, if understanding use of the water column is required then more expensive tags with pressure sensors are what you need. It should be noted that projects can use more than one style of tag to generate location or other data, for example most tags in a study can be simple Argos location only tags, but a subset have pressure or GPS sensors to enhance the overall results. Where more than one style of tag is used it is important to ensure they are all programmed in such a way as to generate comparable datasets. Ensuring data compatibility is most important for pressure sensing tags where, for example, time and depth thresholds can be set by the user to qualify the onset and end of dives or separate depth bins.

Nick Pilcher: Choosing the right model is all about knowing what the research question is to start with. Transmitters are just the tools with which we acquire information. They are not the information themselves. So, prior to choosing a transmitter the real question is 'What do I want to know?" Once you clearly articulate the objective of the study, choosing the right transmitter is likely to be the easy part. Transmitters that rely on Argos services provide location data that are typically far coarser than those that rely on Fastloc GPS data, but while 'Argos' data is often perceived as being of lower quality than Fastloc GPS data, a lot depends on what the researcher is after. The degree of precision between the two data services, in some cases, can be quite comparable, it just depends on what the question is, and the precision required. A rule of thumb I use is as follows: If you want to get a large-scale idea of where turtles travel after nesting, with a goal of identifying the general areas where they feed, then Argos data is probably more than sufficient for your needs. If knowing which headland they round on the way to a feeding area, you probably need something with greater spatial resolution. One last thing about these transmitters is that they are not the only choices out there. There are Iridium tags that transmit data through the Iridium satellite communications constellation, and there are GSM tags that rely on the signal being picked up by a phone communications tower. While these are not located all over the oceans, the system would work if you wanted to track internesting movements of sea turtles when they are close to shore. Another thing is that they can store the location data and upload it all when they are next in contact with a receiving station. For me another important consideration is also the design. I find that the transmitters with 'rhino' horns at the front end provide better protection for the antenna – and trust me, turtles go to no small measures to knock the units off! And then there is cost: Fastloc transmitters are double or more than the price of Argos location transmitters, so this is likely another key consideration in your selection process.

Paul Whittock: The weight of the tag, as a proportion of the animal's weight, should be a primary consideration. If the tag is too heavy or too large, it may affect the animal's movement and behaviour, potentially biasing your research findings.

Consider the spatial scale and location accuracy necessary to meet your research objectives. This will help determine whether cheaper tags that generate low accuracy Argos locations are sufficient or if more expensive highly accurate Fastloc GPS tags are required. For example, if you aim to understand movement across an ocean, high accuracy may not be essential, whereas tracking movement around infrastructure or within a small harbour may require high accuracy.

Transmitter programming

Adhith Swaminathan: Transmitters can also be programmed to collect data at different intervals depending on the objectives. This can significantly reduce or increase the battery life of the transmitter. Since our project objectives were to identify the migratory routes and their foraging sites, we programmed the transmitters to transmit data continuously for the first 3 months and every alternate day after that as we prioritized longer battery life through low usage. The transmitters were also fitted with a salt-water switch that automatically turned on the transmitter to send the data when the turtle surfaced to breath.

ALan Rees: Sat tags have two kinds of transmission scheduling. The first is repetition rate which is how frequently the tag sends transmissions when at the ocean surface. This is programmed at the time of manufacture. The interval between transmissions used to be around 40 seconds but more recently 15 second intervals are more common. Given the accuracy of an Argos location depends in part on the number of transmissions received by the passing satellites, the reduced interval has led to an increase in the number of higher quality Argos locations generated per tag per day. The second scheduling is called duty cycling and is a user defined schedule on when the tag sends transmissions and when it is dormant. My advice is to not schedule dormant periods to save battery as battery running out is rarely the cause for the tags to stop working and hence you lose data that could be acquired during the dormant periods. However, there are certain 'dead times' in different parts of the globe where there can be reliably predicted to have little to no satellite coverage per day, and scheduling your tags to be quiet during those periods can extend battery life with no detriment to data collection. Note though that CLS will have a new fleet of satellites coming online in the not-too-distant future and these will hopefully dramatically reduce the coverage 'dead times.' Check with your tag manufacturer about appropriate duty cycling for your tags at your deployment location.

The other programming your tags may require varies according to your need for additional data (e.g. GPS derived locations and depth utilisation). Again, talk with your tag's manufacturer to discuss their tags capabilities and optimum settings.

Nick Pilcher: One thing I have repeatedly heard is about how researchers want to get the longest tracking plots they can, and sometimes they programme their tags to be off for a certain number of hours or even days to extend battery life. But turtle biology is rather predictable, and in my opinion, it is best to keep the transmitters sending signals frequently. This is because today's units (certainly those typically used to track post-nesting female or larger male turtles) have battery systems that can last for a good 9 to 12 months. This means that if a nesting season lasts two to three months, and a migration lasts another month or two, the battery would have sufficient power in most cases to track the turtle to its feeding area. And once there, how much data is needed to identify it as a feeding area? A month or two? If the turtle stayed six months, would it be any different of a feeding area? If the question (as noted above, it is always about the question) is about identifying where the feeding areas are, how long is 'long enough' to identify these clearly? In my opinion a month or two of data is more than sufficient. If the question is about extent of feeding areas and feeding area use, there may be reasons to programme a tag differently, but in my opinion the more data we get during internesting and migrations and arrival at the feeding areas, the better we expand our knowledge of sea turtle biology.

Paul Whittock: Discuss your research objectives and data collection priorities with the tag manufacturer. They have the expertise to program the tag to ensure your needs are met. They generally have the best understanding of how the tag may perform in your case. For instance, if you are particularly interested in capturing data during a specific period, such as inter-nesting, the tag can be programmed to maximise location and dive data collection during that time.

For peace of mind, verify that the option for the tag to turn on automatically when the turtle dives below a particular depth is turned on. This way, if you forget to turn the tag on, it will turn on (and stay on) once the turtle returns to the ocean.

Transmitter attachment

Adhith Swaminathan: I have only used transmitters with the direct attachment method. This requires additional equipment and materials that do not come with the transmitter. I would advise procuring all these before heading to the field site as some of these materials (like Equinox 40 (slow-set silicone putty that is placed between the tag and the leatherback's dorsal ridge to ensure a conformed fit), battery-operated drill, orthopaedic drill bit) might not be readily available. During the deployment in Indonesia, we had to use dental putty as we could not source Equinox 40. Though the Dental putty works great as a substitute, it has very little curing time, so we had to ensure that the tag was snug and secured in place within two minutes.

ALan Rees: I have used several methods of attaching tags to turtles such as seating the tags on silicone elastomer before covering them in fibreglass and polyester resin or encasing the tags in viscous marine two-part epoxy. For the last six years I have been using the method recommended by Wildlife Computers, generally using the kits that they supply to go with their tags. This involves sticking a base plate of fibreglass on the turtle's carapace with epoxy, attaching the tag to the baseplate using 'putty epoxy' with a final wrapping of the tag using strips of epoxy-soaked fibreglass. It is possible to make equivalent kits purchasing the components separately, though take care to purchase the correct epoxies otherwise you may find yourself waiting for several hours with your turtle while the epoxy cures instead of a matter of minutes (learned from bitter experience!).

However, before you get to the attachment stage you need to prepare the carapace. This involves removing all epibionts and sanding away flaking parts of scutes. I choose the second vertebral scute to position the tag. When doing this on the beach at night, do not be afraid to use white light to inspect the carapace. It is not possible to correctly identify that all epibionts (algae etc) have been removed under red light, so white light is imperative. If you leave any live stuff under the tag, it can only cause problems for tag retention. Do not sand through the dead keratin scute towards the live tissue below. Live tissues ooze and this ooze, like algae, will only cause problems for tag retention. As a last stage before attaching the transmitter, give the sanded area of carapace a good rub over with a clean rag soaked with acetone. This will clear away any powder from the sanding process and remove grease, which will improve tag adhesion. Do not touch the cleaned surface. Always clear an area larger than the zone that will be covered by your tag and epoxy to give yourself and the tag a buffer from epibiont growth. You can use a marker pen to outline the area covered by the fibreglass baseplate to ensure you have cleared enough area of the carapace and to guide you when you place the first layer of epoxy. To ensure repeatability in your attachment process – if following the Wildlife Computers method – count the number squeezes on the epoxy 'gun' that you use per stage. For example, I find five squeezes extrudes sufficient epoxy for attaching the baseplate fibreglass layer. Talking about fibreglass, precut the fibreglass to required sized pieces prior to going into the field and minimise the number of fraying threads on the pieces as they are a pain to deal with while spreading epoxy. I found that placing the cut fibreglass pieces between folded sheets of ~A4 sized paper keeps them in pristine condition ready for the attachment process.

Nick Pilcher: In Malaysia I have had a hard time sourcing the right Sika epoxies and have had to import them sometimes from Australia. But I find that the fiberglass and resin method is extremely reliable, and pretty much anywhere that manufactures anything in fiberglass will have the materials (resin, catalyst and mat) available. It takes longer and can be a bit messier, but I personally feel it holds better, and the fact that the materials can be readily found pretty much anywhere means it is an attachment protocol of choice for me.

Another thing I like to use, particularly with hawksbill and juvenile turtles whose carapace is not gently rounded but rather 'peaks' in middle, is Elastomer. This is a two-part silicone product that can be moulded to form a baseplate so that the transmitter sits flat on the turtle when the dorsal ridge is prominent. The product I use is called Sammons Preston Rolyan® 50/50 Mix™ Elastomer Putty.

Paul Whittock: Many of the epoxy/resin glues, epoxy putties, cleaning fluids, and anti-foul paints used in the attachment process are hazardous and must be handled according to the manufacturer's Material Safety Data Sheet (MSDS). Make sure that people using these chemicals wear the specific personal protective equipment, including gloves, safety glasses, and full-length clothing. Also, due to their hazardous nature, many of these chemicals are also prohibited from air travel. Therefore, you should either source them locally or allow plenty of time to transport them using a dangerous goods freight forwarder.

Ensuring animal welfare is the top priority when attaching tags. Securing the animal in a pen to prevent movement minimises both disturbance and improves the attachment process. Additionally, placing a cloth over its eyes, while keeping the nostrils uncovered, further

reduces disturbance to the animal.

"Fail to plan, plan to fail!" Make sure all equipment needed for the attachment process is available and stored in a designated location. Using labelled containers within a waterproof duffel bag for transport can greatly improve organisation when on the move.

If applying an extra coat of anti-foul after attachment, ensure there is sufficient time for it to dry before releasing the animal. Biofouling is a major cause of tag failure, so taking the time to apply it correctly could significantly improve the longevity of your transmission time.

Data analysis

Adhith Swaminathan: I found STAT (Satellite Tracking and Analysis Tool) on seaturtle.org very easy to use, especially to produce basic maps with some environmental layers. It's best to seek help from friends and colleagues to analyse the data, especially if you do not possess the knowledge and skills.

ALan Rees: You should have already thought about what data analyses you want to carry out before you selected your tag type, and had it programmed so the data you collect will be sufficient for your needs, which all ties in with the research question you are asking. If you do not have the technical skills yourself or within your group to complete the analysis, then it is worth reaching out to colleagues who can do so. Again, it is probably a good idea to make such arrangements prior to purchasing and programming your tags to ensure maximum utility of the data they generate.

Nick Pilcher: There are some powerful modelling tools available if you have access and the right skills, but for me the simplest way to interpret the data is visually. We know that sea turtles deposit multiple clutches of eggs in a season, and so we can account for movements in an internesting area between these events. We also know that turtles migrate back to home feeding areas after nesting is concluded, and that they reside in these areas for substantial periods before nesting again. Multiple tracking records across the planet tell us that the migrations are usually direct, and do not involve stopping to feed or other detours. Armed with this information, we can then infer what turtles might be doing from the data derived from satellite transmitters. I normally import the location points into a GIS package like QGIS, and manually edit the data set, deleting all erroneous points. I then look at the data and classify all points that are received after tag deployment and before a purposeful departure point from the nesting site as internesting (the period when turtles may be laying additional clutches of eggs). Within these data sets, subsequent nesting events could be presumed based on known internesting interval for sea turtles at that site. Next, location fixes after the purposeful departure can be categorised as migration fixes (direct purposeful travel from the nesting site with minimal deviation from a straight path). Finally, foraging activity at the home feeding areas can be inferred by a reduction in travel rates and a shift from purposeful migration direction and unidirectional orientation to short distance movements with random heading changes. Of course, Fastloc data allow even greater interpretation, as the data points might tell you exactly what beach they emerged on to lay eggs, and have far less ambiguity and variation than Argos data.

Another thing about data analysis relates to sample size and what we infer from the data set(s). One track from A to B does not tell us much about a population. It tells us a lot about that turtle, but it is not until we have a robust sample size that we can start to make inferences on where a population of turtles goes after laying eggs, or where they come from. Another thing to consider is what a turtle might have been doing when the signals ended. If a track was headed in a certain direction and then simply ended, would it be reasonable to assume the turtle had reached its home feeding areas? Or could the signals have ended in the middle of a migration? If we knew the turtle had reached an area where she subsequently spent several months moving around in short random movements she likely reached home. But an abrupt end to a track is likely not as informative.

Paul Whittock: Recording a large number of locations in a particular area does not necessarily indicate more time or usage by a turtle compared to another area with fewer locations. The turtle may have spent more time in the area with fewer locations, but data transmission issues could have occurred. Data analysis must therefore account for this imperfect dataset by temporally separating the dataset. This can involve selecting one location within a particular timeframe or using more complex state-space models to standardise the dataset across the time period.

Received location data should be filtered to remove biologically implausible locations based on inferred swim speeds between locations and excessive turning angles. This can be done through simple filtering in a spreadsheet or automatically using specialised R packages.

Track reporting

Adhith Swaminathan: Sharing the tracks with the local

communities and administration has always been a rewarding experience for us during our sensitisation or capacity-building workshops. Having the tracks accessible through platforms like STAT will be very valuable as people can track these animals in real-time.

ALan Rees: When presenting your tracking data, always indicate the species, life stage and – if possible – sex of the turtle(s) you are tracking. The start and end dates also should be reported. It used to be commonplace to report on the number of locations of different accuracy that were obtained from the tag over its lifespan, but with vastly improved capabilities of tags in recent years this type of information is now rarely required or useful. Try to publish your tracking studies as soon as possible after data acquisition is completed. Tracking turtles takes a lot of effort and relatively large sums of money so the results of your study should be shared with the community to increase the value of your work. Also consider sharing your tracking data with other researchers so that they may be used in meta-analyses thus adding further value to the work you have carried out.

Nick Pilcher: This is the hardest part of tracking for many people, but I actually find that once I have done all the graphics and made sure I have tidied up the tracks, it is actually not that hard to describe the movement pattern for turtles. I find that sometimes it is useful to put the movement patterns into 'bins'. For instance, several turtles went off in this direction, and a number of others followed the coast and went off in a different direction. That way you can simplify the graphics and guide the reader through what you found. The recent project tracking foraging animals was fun because we tracked them to their nesting beach, waited while they deposited all their clutches of eggs, and then watched them come back to their original feeding areas. That was an amazing tracking feat!

But I think it is super important to get the data published in one form or another, and also added to large global data sets like SWOT, OBIS Seamap or the like, so that it can be of use long after you get what you need and help inform on larger ocean migration patterns.

Paul Whittock: Data from satellite-tracked turtles is incredibly engaging and provides a unique opportunity to showcase their vast ocean-wide migrations, impressive diving ability, and the threats they face during their journey. Many tag manufacturers offer tools to share live data through maps that can be easily embedded on a website or shared on social media. If sharing data this way, be prepared to explain the turtle's fate if the tag stops transmitting, which is more likely due to tag failure rather than an issue with the turtle itself.

"Publish or be damned" was the motto I repeatedly heard with regards to reporting tracking data collected with expensive satellite tags. While track data can be presented in grey literature, client reports, or at conferences, it is best shared in the public domain through a peer-reviewed publication. This not only adds credibility to the recommendations made but also fosters collaboration and leads to better conservation outcomes.

Editor's note: Fastloc and FastGPS are trademarked methods for acquiring GPS locations with only small snapshots of GPS data.