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CAMERA TRAPS IN SEA TURTLE RESEARCH AND CONSERVATION

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INTRODUCTION

Initially developed as an instrument for wildlife photography, camera traps were subsequently used in hunting and have now transformed into a conservation tool (Kucera & Barrett, 2010). Camera traps allow us to observe activities taking place in the wild with minimal intrusion and have many current and potential applications in sea turtle research and conservation.

Any camera that is not triggered by a human (instantly or at a pre-set time) is a camera trap, although some studies that use the term include pre-programmed cameras. In the past, camera trap studies have primarily focused on terrestrial mammals, exploring behavioural patterns as well as their presence in certain habitats. Such methods allowed researchers to collect relatively unbiased data for long periods of time. With technological advances, increased availability, and reduced prices, the popularity of camera traps as a research tool grew and they were adopted to study a variety of species.

For camera trap studies to be viable, it is necessary for researchers to know the exact area in which the target animal is expected, to ensure that it will trigger the camera trap. As terrestrial phases of the sea turtle life cycle are confined to predictable regions of nesting beaches and areas immediately adjacent to known nest locations, camera trapping is a viable method to study turtle biology and threats during nesting, egg incubation and hatchling emergence; camera traps could also be used during in-water observational and monitoring projects. This paper demonstrates the current and potential application of camera traps in sea turtle research and conservation using examples from studies of freshwater and marine species of turtles, then reviews the technical aspects of deploying camera traps in terrestrial and marine environments.

APPLICATIONS OF CAMERA TRAPS ON NESTING BEACHES

Monitoring nesting sea turtles

There are no reports of triggered camera traps being deployed to monitor nesting beaches at this time. However, time-lapse beach photography projects using pre-programmed cameras with trap capabilities have been employed using two approaches. One is to position cameras at sites where much or all of the beach is visible, for example on a headland or sand cliff overlooking a cove, and to program the camera to take photos every morning and record fresh new tracks made by nesting turtles (S. Whiting, pers.comm). Another approach is to use the camera to take pictures at intervals to record how many days turtle tracks remain visible on the beach. When used for such a purpose, however, care is needed to ensure that representative beach microhabitats are monitored to account for the impact of different environmental conditions on track longevity. At select beaches at Diego Garcia and Nelson Islands in the British Indian Ocean Territory, time lapse photography is being used to inform beach monitoring frequency and improve estimates of nesting activities in the study locations (Esteban & Mortimer, 2018; Wood *et al*., 2019). Similar approaches could be used at other sites, depending on physical characteristics of the nesting beach and surrounds.

Identifying predators of nesting sea turtles, eggs and hatchlings

Camera traps can be used to complement findings from other methods of identifying predators, such as trackboards (Buzuleciu *et al*., 2016), scat analysis (Dawson *et al*., 2016) and physical observation (Doody *et al*., 2009; Erb & Wyneken, 2019; Unger & Santana, 2019). However, the potential for cameras to introduce bias and affect rates of predation by attracting or deterring some predator species from their normal behaviour (e.g., Richardson *et al*., 2009) should also be taken into consideration.

Animal predation on nesting turtles is rare, and throughout countries in the Indian Ocean and Southeast Asia it may be limited to isolated incidents involving saltwater crocodiles (Whiting & Whiting, 2011) and hyenas (Olendo *et al*., 2016). In the event that predation on nesting sea turtles by these or other species does increase, camera traps could give insight into predator behaviour. For example, Guilder *et al*. (2015) and Escobar-Lasso *et al*. (2016) determined the importance of sea turtles as a dietary item to jaguars (*Panthera onca*) in Costa Rica, as well as jaguar feeding and scavenging behaviour, using camera traps.

While predation on nesting sea turtles might be rare, depredation of nests is an ongoing concern in the same region (Ekanayake *et al*., 2002, 2010; Islam *et al*., 2002a,b; Shanker & Choudhury, 2006; Ficetola, 2008; Tripathy & Raiasekhar, 2009; Thi *et al*., 2011; Whiting & Whiting, 2011; Salleh *et al*., 2012; Ellepola *et al*., 2014; Mancini *et al*., 2015; Nasher & Al Jumaily, 2015; Olendo *et al*., 2016; Phillott *et al*., 2018a; Williams *et al*., 2019). To mitigate this threat, eggs are often relocated to a fenced area commonly known as a hatchery (Salleh *et al*., 2012; Abd. Mutalib & Fadzly, 2015; Phillott, 2018; Phillott & Kale, 2018, Phillott *et al*., 2018a,b; Howard *et al*., 2019). However, best practices in the collection, transport and incubation of eggs and handling of hatchlings have to be followed to reduce risks to embryo survival and hatchling fitness (reviewed by Phillott & Shanker, 2018), and require economic and human resources that might not be available to local conservationists. An alternative to reducing predation of eggs and hatchlings by relocating them to a hatchery is protecting nests *in situ*.

As the appropriate method for protecting sea turtle eggs in their original location on the nesting beach can depend on the species of predator (reviewed by Phillott (2020) in this issue of IOTN), tools to identify animals depredating nests are also required. Predators can potentially be identified from their tracks and patterns of digging into a nest (e.g., Gandu *et al*., 2013; Korein *et al*., 2019) but these signs might actually be created by scavenging behaviour or secondary predation after earlier predators have opened the nest (e.g., Barton & Roth, 2008).

Camera traps have proved effective in helping researchers identify species that pose a threat to sea turtle eggs. The use of camera traps to monitor artificial nests was first popular amongst ornithological studies and has been adopted to understand sea turtle predators. Maier *et al*. (2002) studied the depredation of artificial freshwater turtle nests using subterranean triggers to activate the shutter of a 35mm film camera. The triggers were installed within the nest chamber, connected by a trigger wire to a camera facing the entrance to the nest. It effectively captured images of predators such as racoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), gray foxes (*Urocyon cinereoargenteus*), and fishers (*Martes pennanti*). Motion-triggered camera traps have also been used in such studies; for example, artificial nests of alligator snapping (*Macrochelys temminckii*) turtles near the primary nesting area were monitored to identify and quantify the relative contribution to nest depredation by raccoons (*Procyon lotor*), armadillos (*Dasypus novemcinctus*), opossums (*Didelphis virginiana*), bobcats (*Lynx rufus*) and otters (*Lontra canadensis*) (Holcomb & Carr, 2013).

Camera traps have also been used to identify predators of hatchlings. Erb & Wyneken (2019) investigated the nest-to-surf mortality of loggerhead (*Caretta caretta*) sea turtle hatchlings by combining techniques of camera trapping, direct observation and hatchling track maps. The camera traps were placed behind nests and programmed to take an image every 5 to 10 seconds using the time lapse mode, recording predation events by ghost crabs (*Ocypode quadrata*), night herons (*Nyctanassa violacea*) and gray foxes. Bieber-Ham (2010) used camera traps to identify raccoons and opossums as predators and monitor their feeding on painted, plaster-cast turtles (*Chrysemys picta*) hatchling replicas. Giuliano *et al*. (2014) used camera traps to film and photograph nocturnal depredation on flatback (*Natator depressus*) sea turtle hatchlings by nankeen night herons (*Nycticorax caledonicus*) and black-necked storks (*Ephippiorhynchus asiaticus*), the first steps in assessing the impact of avifauna predation on turtle population dynamics.

Determining the behavioural patterns of predators

The behavioural patterns of predators, including foraging times and cues used to find nests, can also be studied using camera traps. Anyone planning this type of study might find the review of camera trapping for conservation behaviour research by Caravaggi *et al*. (2017) helpful to read.

The characteristics of loggerhead sea turtle nest visitations by lace monitors (*Varanus varius*) and yellow-spotted monitors (*V. panoptes*) were studied using camera traps (Lei & Booth, 2017a,b; Madden Hof *et al*., 2020). By capturing motion-triggered still images and metadata (time and date), the number and frequency of visits in different time frames within a day (Lei & Booth, 2017a) and temperature at with depredation occurred by each species were recorded (Madden Hof *et al*., 2020). Images also revealed that nest predation significantly increased after hatchlings emerged from the nest, suggesting visual and olfactory cues guided goannas to the nests (Lei & Booth, 2017b). Similarly, Buzuleciu *et al*. (2016) found that skunks and raccoons may rely on olfactory cues to locate diamondback terrapin eggs soon after oviposition then visual and/or tactile cues once the scent of freshly excavated soil had dissipated. Understanding when eggs are most vulnerable to predation and by which species can guide management decisions, such as the timing of nest protection strategies.

As flag markers may be used to indicate the position of sea turtle nests on the nesting beach, Tuberville & Burke (1994) investigated the potential attractive or repulsive effect of flags on predators of freshwater turtle eggs. A combination of camera traps, track boards and baited stations, to reduce the probability of bias, found that flagging neither attracts or repels nest predators, confirming that it can safely be used as a method of marking and identifying individual nests.

Assessing nest protection strategies

Methods of protecting nests from predators can be assessed using camera traps. Geller (2012) created fenced and unfenced areas at Ouachita map turtle (*Graptemys ouachitensis*) nesting sites which were baited and monitored using camera traps. The study found a lower predation rate of fenced nests in comparison to unfenced nests, and the camera traps revealed predator behaviour. The fencing comprised one strand of electrified wire and two strands of unelectrified wire, and racoons were observed testing the fences deliberately before receiving shocks. This indicates the potential for conditioning raccoons to avoid the nesting areas.

Eskew (2012) employed camera traps to test the efficiency of coyote (*Canis latrans*) trapping efforts in decreasing predation of loggerhead sea turtle eggs. Traps were deployed to monitor nests before and after rounds of coyote trapping and found a reduction in coyote depredation of nests. The researchers chose to use camera traps over physical observations of nests in order to avoid the potential disturbance caused by a human presence; the use of a camera trap also allows uninterrupted data collection while being less labour intensive.

Camera traps were also used to test the efficacy of different raccoon excluder devices on simulated diamondback terrapin nests (Buzuleciu *et al*., 2015), allowing researchers to understand why some cage features were more successful than others without the potential interference that may be associated with direct observations.

Surveillance for illegal take of eggs

Recently, camera traps have also emerged as a covert and relatively inexpensive surveillance tool, monitoring remote regions to detect the illegal take of sea turtle eggs without the need for regular patrols by rangers (Wearn & Glover-Kapfer, 2017). Camera traps on nesting beaches can identify those involved in the illegal take of eggs and collect evidence against them. The use of networked camera traps would also allow preventive measures to be taken when illegal take is detected. As camera traps used for this purpose are at a high risk of theft, equipment must be as covert as possible as well as located at a height that captures identifiable features of responsible persons (Wearn & Glover-Kapfer, 2017).

In-water studies of sea turtles

Due to the failure of sensors underwater, remote exploration of the aquatic realm using camera traps has been limited (Wearn & Glover-Kapfer, 2017). Instead, studies have used submerged underwater cameras to record continuous videos and hence gain an insight into the activities of marine organisms. The use of Baited Remote Underwater Video (BRUV) systems has allowed researchers to study marine species diversity (Osgood *et al.*, 2019) and behaviour (Bond *et al.*, 2012) by recording the organisms which were attracted to the bait. Favaro *et al.* (2012) developed a modified version of this, known as the TrapCam, which was also effective in obtaining *in situ* observations of marine animals at depths up to 100m and could be modified to understand sea turtle interactions with deep-water fishing gear.

Recent innovations in camera trap systems have, however, proved promising in capturing remotely triggered images of underwater phenomena. An underwater stereo camera such as the TrigCam can be programmed with an algorithm to record images whenever a predefined change in pixels is detected. The technology allows researchers to tailor their study to target wildlife of a specific size (Williams *et al.*, 2014), and may be useful in studies of the in-water behaviour of animals such as sea turtles.

TECHNICAL ASPECTS OF CAMERA TRAPS

Camera and trigger features

When choosing a camera trap, care must be taken to ensure the features of the trap model are compatible with the specific nature of the study. Newey *et al.* (2015) provides a user's perspective on the deployment, operation and data management when using more affordable 'recreational' models in comparison to expensive 'professional' models which could help novices in camera trap usage in their decision about which model to purchase. Features of the camera and trap trigger as described below should also be considered.

As the quality of data captured is dependent on the effectiveness of the trigger system, the trade-off between availability, affordability, and suitability of camera traps with desired features must be considered. The target animal for the study will also help determine whether a camera trap should employ an indirect or a direct trigger system.

An indirect trigger system- which senses the presence of the animal in the vicinity of the camera trap via movement or heat signatures- is ideal when the target animal is large and endothermic, like feral pigs or dogs. Of these, a passive infrared (PIR) trigger is the most suitable considering the large body mass and heat signal of many predators, and most commercially available camera traps have PIR triggers as the market is driven primarily by its demand for deer scouting and hunting. These trigger systems are also more concealable and less startling (Wearn & Glover-Kapfer, 2017). An emerging technology for underwater camera traps also employs an indirect trigger system. It employs a software algorithm to trigger recording when an animal appears by detecting a change in pixels. The algorithm may be tailored to capture animals of a particular size and, hence, reduce the possibility of unwanted shots (Williams *et al.*, 2014).

Smaller mammals and reptiles may not have a heat signal strong enough to trigger a PIR (Eskew 2012; Hobbs & Brehme, 2017) and might require the use of direct triggers. These include mechanical triggers which can be installed within the nest chamber such that the camera trap is triggered only when directly pushed or pulled by the animal during depredation or when the nest is otherwise disturbed. Options include tilt switches (as in Maier *et al.*, 2002), trip wires, pull wires, pressure plates, and active IR (AIR) triggers (Tuberville & Burke, 1994). The most modern direct trigger, AIR sensors require the animal to move through a predictable path such that it disturbs an IR beam between a transmitter and receiver. However, in addition to being less commercially available, these are also more visible and intrusive and many studies have found PIR camera traps to be effective, even in the cases of reptiles like monitor lizards (Beukeboom, 2015; Lei & Booth, 2017a,b; Madden Hof *et al.*, 2020) and small mammals like rats (Gronwald *et al.*, 2019). Many camera traps have the option of increasing PIR sensitivity, which would increase the likelihood of capturing ectotherms (Wearn & Glover-Kapfer, 2017).

In addition to motion-triggered image capture, the time lapse feature of camera traps can also be used to record potential predators in the nest environment at regular intervals (Geller, 2012; Beukeboom, 2015; Erb & Wyneken, 2019). This setting would ensure that images will be taken even if the trigger does not detect the presence of a predator; however, it produces a huge volume of images for analysis.

It is also important to consider the detection zone and field of view of the camera. These are integral to the study as the detection zone is the range within which movement must occur to trigger the camera and the field of view of the camera is the area that will fall within the frame of the image. If the study is investigating nest predation, a detection zone that is narrower than the field of view would be appropriate as it would prevent accidental triggers and empty shots, ensuring all the shots taken include the target i.e. the predator at the nest (Trolliet *et al.*, 2014). However, if the study intends to include nesting behaviour or hatchling predation, a wide detection zone would be important as the target activity may occur beyond the immediate nest. The trigger speed of the camera and the relay time (delay between each shot) should also be factored in when choosing a camera trap. A fast trigger speed can compensate for a narrow detection zone (Rovero *et al.*, 2013).

The camera must also have a battery capacity sufficient for it to be deployed for potentially extended periods of time. This is dependent on the number and type of batteries used as well as the energy efficiency of the camera. Based on the battery life as well as the capacity of the memory card, the camera trap may have to be regularly visited and items replaced. In cases of remote camera trapping locations, networked camera traps may be deployed which can send almost real-time data to the researcher. Though these are expensive, they also allow the data to be regularly backed up such that in case of any damage or theft, the data is not lost (Wearn & Glover-Kapfer, 2017).

Cameras deployed at night on nesting beaches should have the feature of IR flash. While white flashes can produce coloured images as opposed to the monochrome images from IR flashes, the former may deter predators and introduce bias while IR flashes are invisible to most animals. A visible white flash could also attract human attention to the camera trap and increase the risk of theft (Wearn & Glover-Kapfer, 2017), or temporarily misorient hatchlings. In specific cases where the red glow of IR frightens predators, such as coyotes (Eskew, 2012), no-glow (black) IR cameras can be deployed which emit a wavelength that is almost undetectable (Wearn & Glover-Kapfer, 2017).

If images are only to be used for detection and identification of predators, lower quality images would suffice but if the collected images may be used for campaigns or conservation awareness programs then higher resolution images will be required. In cases where individual predators need to be identified, a higher resolution may be necessary to discern unique features. Additionally, if the study requires insights into behavioral aspects, the video feature available in many camera traps would be helpful (Giuliano *et al.*, 2014; Gronwald *et al.*, 2019).

Camera mount and position

Camera traps in a beach environment may be mounted on a tripod, wooden stakes, metal t-posts (Urbanek & Sutton, 2019) or PVC pipes (Eskew, 2012). The mount structure must be sturdy enough to carry the weight of the camera trap and ensure it does not move. If there is a nearby tree or pole, these could be ideal mounts. One of the biggest challenges when using camera traps is reducing the possibility of theft. To prevent theft, the camera traps can be placed within commercially available housing cases that can only be opened with a special key. These housings also protect the cameras from damage by animals. Most anti-theft cases are intended to be attached to trees or poles that cannot be removed. However, these are often difficult to find in the sea turtle nesting environment. Deploying the camera traps only at night may reduce the risk of theft (Shipman, 2019); however, this schedule provides limited data and requires regular installment and removal.

Camera traps are designed to be robust and weatherproof, however most of them are not built for a beach environment. It may be necessary to regularly clean the camera traps of sand. To prevent damage due to humidity, desiccation packs can be placed in the camera trap or within its casing (King, 2016). The casing should have seals that prevent entry of rain, dust, sand and insects etc.

Depending on the target predator, the camera trap must be installed at an appropriate height to ensure that the animal will fall within the detection range as well as the field of view of the camera. They can be tilted slightly downwards to avoid triggers due to sunrise and sunset. Additionally, unless required, the camera trap detection range should not include the ocean as this may lead to waves and tidal movements acting as triggers (King, 2016). This is important to make sure the memory card is not exhausted due to repetitive empty shots.

Data analysis

Camera trapping surveys often produce large amounts of data (still images or video) that are cumbersome to analyse. Using a PIR that senses movement can result in a high proportion of images that are empty shots due to detection of non-animal movement (false triggers) such as the movement of foliage. Many studies sort the images manually; however, emerging camera trap data analysis software that weigh pixel variations against the background to filter out images void of animals can be used to streamline the process of analysis (see Hobbs & Brehme, 2017; Wearn & Glover-Kapfer, 2017).

ETHICAL CONSIDERATIONS WHEN USING CAMERA TRAPS

In environments where there is a high degree of human activity, projects must consider the privacy of local residents. Steps should be taken to avoid non-consensual monitoring and surveillance. For example, local communities should be informed about the purpose, general location, and operation of cameras before traps are installed. Projects can also implement community-based conservation, compensating locals for regularly checking the camera traps, retrieving memory cards, and replacing batteries. Additionally, there must be a plan to respectfully delete any accidental images of people.

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PROTECTION OF *IN SITU* SEA TURTLE NESTS FROM DEPREDATION

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INTRODUCTION

Nesting turtles act as biological transporters of nutrients from marine to terrestrial ecosystems, where eggs and hatchlings eaten by terrestrial predators contribute to coastal food chains and nutrient cycles (see Bouchard & Bjorndal, 2000; Madden *et al*., 2008). Depredation of sea turtle nests should, therefore, only be of concern if the affected population is categorised as Threatened, if it is occurring at or has the potential to reach unsustainable levels, if the predator is introduced or reintroduced to the area, or if the increasing population of one predator is the result of control measures against another. Predator management may also be desired if local tourism relies on the presence of sea turtle nests.

A common strategy for protecting eggs and/or hatchlings from excessive predation is to immediately relocate clutches to a hatchery, a protected area enclosed by a fence to reduce animal entry. However, care must be taken to ensure that collecting, handling, and incubating eggs does not itself reduce the number of eggs that hatch (Phillott & Shanker, 2018). A viable alternative to moving eggs to a hatchery is protecting them in their original position. *In situ* protection reduces the potential risks associated with collecting and moving eggs if best practices cannot be implemented due to restricted resources. Nests would still require regular inspection by project personnel or local community members to ensure continued protection. While sea turtle festivals and other environmental education initiatives could continue, participants may need to walk further to reach the nest location.

At nesting beaches throughout the Indian Ocean and Southeast Asia (IO & SEA) region, hatchery programs are commonly and successfully employed to control predation rates. However, *in situ* nest protection and predator management strategies can also be highly effective, as proven by reduced nest depredation rates on the east coast of Florida, USA, from 95% to <10% (Engeman *et al*., 2005). Therefore, this paper reviews methods for *in situ* protection of sea turtle eggs and hatchlings from predators found in IO & SEA countries. While the discussed predators have been limited to those in the region, the strategies for protecting nests have been drawn from studies around the world so conservationists can consider the various potential options and determine what best suits their needs. Before implementing *in situ* nest protection, the animal/s predating on eggs and hatchlings should first be identified by analysing scats (Brown & Macdonald, 1995; Blamires, 2004), stomach contents (Hilmer *et al*., 2010; Engeman *et al*., 2019), tracks in the substrate, digging patterns used to expose nests (e.g., Drake, 1993; Tripathy & Rajasekhar, 2009; Gandu *et al*., 2013), visual observations (Tripathy & Rajasekhar, 2009), and/or camera trapping (reviewed in this issue by Kotera & Phillott, 2020). It is important to distinguish between animals that predate on eggs and hatchlings in undisturbed nests and those that scavenge eggs which have been exposed by other species in order to choose the most appropriate management strategy.

STRATEGIES FOR REDUCING DEPREDATION

Actions to manage depredation can focus on predator