


SEA TURTLE MONITORING MANUAL

A guide to selecting appropriate tools for basic sea turtle research and monitoring in the Pacific Region

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EUROPEAN UNION

30 YEARS SPREP PROE

Pacific BioScapes

The Pacific BioScapes Programme is a European Union (EU) funded action, managed and implemented by the Secretariat of the Pacific Regional Environment Programme (SPREP). The Programme contributes to the sustainable development of Pacific Small Island Developing States through the implementation of 30 focused activities taking place across a diversity of ecosystems in 11 countries that will address critical issues concerning coastal and marine biodiversity, and ecosystem-based responses to climate change adaptation.

The Western Pacific Regional Fishery Management Council has generously allowed the adaptation of its original black and white comic book *'Come Back Leatherback'* (illustrated by Gima Segore and written by Nicolas Pilcher). It has been coloured, rewritten and renamed *'Tuki and the Turtle'* by Carlo Iacovino at SPREP in this new edition for the Pacific BioScapes Programme.

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***Our vision:** A resilient Pacific environment sustaining our livelihoods and natural heritage in harmony with our cultures.*

AUTHOR'S FOREWORD

When the idea of writing a manual for tagging projects in the Pacific was proposed to me by SPREP my immediate thoughts were "Surely we don't need another sea turtle manual?" Given the number of extremely valuable and informative efforts that are in print already, how could a new booklet add value? What else is needed that would be of value to people in the Pacific region, even beyond, that would guide sea turtle research and monitoring efforts, and hopefully save some grief, effort, funds and angst in the process?

And you know what? I figured out that there was indeed a gap in the 'Turtle Home Improvement Section' that I could help with. There are many good sea turtle books out there. Some provide amazing details of a single species. Some detail extensive research into the many aspects of sea turtle biology. Others point to best practices in hatchery management. Or husbandry. Or even necropsies. Others are how-to manuals for tagging or deploying satellite transmitters. Some are a bit difficult to read, or a bit too technical. Others are far easier. There's quite a spectrum, and in the back of this book I list some of those very books, my reading favourite list if you wish, and provide links to how one might be able to get a hold of a copy.

So where does *this* particular manual fit in? What else is there that needs to be known?

Well, I hope the answer to that lies in these pages. I often get asked "Can you design a drone survey for us?" Or "Can I get some tags so I can start tagging turtles?" But often the tool (the drone, or the tag) comes before the research or management question, or before an assessment of resources, capacity, knowledge needs and time frames. What is important is what you *need* to know and what you *want* to know. You need to know when you need the information. And you need to know what resources (funds, boats, people, expertise, etc.) you have at your disposal.

In the following chapters I hope to guide you through some of these questions, sort of like a decision-making process, and hopefully lead you to the appropriate research tool(s) of choice. I will first start with a little scene-setting in Chapter 1 with some basic sea turtle biology. Not because you don't know anything about turtles, but to show you how this knowledge is important in the question-setting and research tool decision-making process. I will then bring you up to speed quickly on what we know about sea turtles in the Pacific region (at least until the time of writing!) and why this is so. Why do we not know more? What gaps could we be filling? After this we really get to the subject at hand, which is all about asking the right questions (Chapter 3) and choosing the right tools for the job (Chapter 4). Then we will look at what we can do with all our newfound knowledge, and how we can be part of a much more expansive process and contribute to global data sets in Chapter 5, and even our very own Pacific region turtle data set in Chapter 6.

This manual is not a summary of all that is known about sea turtles. There are already very good books and resources that do that. It is also not exhaustive about research and monitoring. Nor it is the global synthesis of all turtle research options. Advanced research into breathing rates and blood plasma and stable isotopes and hearing and endocrinology are a bit out of our scope. Here, we will deal with the basics that inform conservation and management. And by the basics I mean how many nesting turtles do we have; where are they; what threats do they face; and why this knowledge is useful. At the end of the day, when it comes down to it, these are the most important metrics you need to know.

Let's dive in and find out. I'm glad you're here with me for the journey.

Dr Nicolas J. Pilcher March 2023

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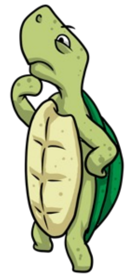
Photo by contributor StockSnap via Pixabay

CHAPTER 1: MARINE TURTLE BIOLOGY

Let's start with a little scene-setting information. What makes a sea turtle a *sea* turtle? To answer this we must look at turtles over an evolutionary time frame. Today's remaining sea turtle species evolved from some of their terrestrial cousins that decided to move back and live in the sea. Back then – and we're talking somewhere in the region of 100 million years ago - those stumpy tortoise legs were quite useless for oceanic swimming, so sea turtles had to evolve the large paddle-like legs that today we call flippers. Also, because they now lived in a salty environment, they needed to be able to get rid of excess salt.

Here's a fun side story to this salt-extraction process: to get rid of excess salt the turtles have glands behind their eyes which secrete the extra salt out in the form of a thick goo that looks like tears. The tears have several functions, but importantly they protect the eyes when they are open underwater, and from dust and sand when the turtles are on land. The thing is, the turtles can't 'turn off' the glands, and so it looks like the turtles are constantly 'crying' when they are out of the water.



And finally, with the large flippers and head that could not be retracted into the shell the way land tortoises do, they needed to protect the head with some extra bone material. These body changes differentiate them from their land cousins, and set them apart as *sea turtles* rather than tortoises (which is normally used for land turtles), or terrapins (normally used for freshwater turtles). But one trait they kept involves emerging from the sea to lay eggs, and that is how we come to see them most often.

SEA TURTLE LIFE CYCLES

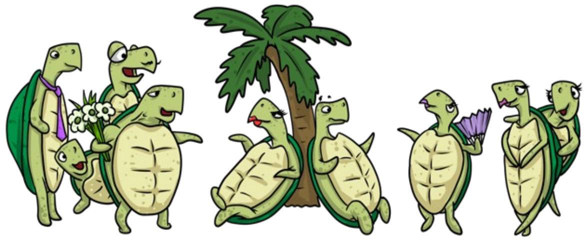
Maybe as a legacy of the long evolutionary process over a constantly changing planet, or just to make a sea turtle biologist's life difficult, today's sea turtles have really complicated life histories. Just when scientists think they have got it all figured out something else comes up and presents a new question or three. But let's see if we can at least lay out a generic life cycle. It goes something like this:

1 All sea turtle species undertake incredible migrations between nesting, mating and foraging areas, and the selection of these places has been determined over evolutionary timescales. As habitats opened up or were lost with rising and falling sea levels over thousands of years, turtles roamed farther and farther afield in search of the perfect combination. What is a beach today was submerged by about 1m just 500 years ago. Go back 10,000 years and the sea level used to be 20m lower than it is today! This tells us that sea turtles – which have been around for millions of years – have learnt to adapt to these rising and falling sea levels. One explanation as to why nesting areas are far away from feeding areas is that over these evolutionary timeframes some habitats were lost, and turtles needed to go further and further away to find either nesting or feeding areas. This is probably why some sea turtles in the Pacific move so far when we track them. For instance, a Green sea turtle tagged after nesting in French Polynesia moved all the way over to Fiji as her choice feeding area, some 3,000 km away. Even further still, Leatherback turtles that nest in the Solomon Islands can go all the way to California (USA) for dinner. That's a 9,000 km commute for a snack!

When it comes to understanding turtle biology, and maybe more importantly being in a position to do something about conserving them for the future, understanding the links between where turtles lay eggs (the nesting aeras) and where they spend their days feeding (the foraging areas) or what scientists term *habitat connectivity* is an important piece of turtle trivia.

Imagine this: if you were protecting sea turtles on your own doorstep but they were being captured at whatever place it is they also call home, then you still have not solved the conservation challenge. But armed with the knowledge of where your turtles move to, you are now in a position to develop projects with that other country and together ensure that 'your' – and 'their' – turtles survive.

2 Once males and females arrive at mating areas – which can be right offshore from the nesting beaches - they mate during a period of a month or two, although individual females are normally only receptive to the males for a couple of weeks. Male sea turtles usually mate with several females and, astonishingly, female sea turtles also (generally) mate with several males. This is quite a new concept to grasp: in sea turtles, fertilization of eggs is often by multiple males, likely as an evolutionary tactic to maximise genetic diversity and evolutionary survival. Imagine a male sea turtle had some kind of genetic disorder, and a female turtle only mated with that one male. That would mean all her offspring would inherit that same genetic disorder. But if a female mated with multiple males, and fertilisation of eggs was random, then there is a good chance that a large proportion of the eggs the female laid that year would be from other males that did not carry that genetic disorder. In the long run, this would ensure mostly healthy turtles made it through the system, and over the years sea turtles would become more and more genetically robust.



3 After mating, it generally takes a few weeks for a female turtle to lay her first clutch of eggs, and after this she return two to eight more times in the same season to nest. Normally the interval between each clutch of eggs (known as the *internesting interval*) is about two weeks, and traditional turtle tales across the Pacific figured this out many, many years ago.

A wonderful example of this is Palau's "Two Lovers and How the Turtle Cycle was Discovered". Search for it on the internet! It's a great story.

Importantly for us, however, is this concept that turtles lay multiple clutches of eggs in a single season, normally separated by about two weeks, which is as long as a female turtle needs to get the next clutch of eggs ready. For biologists trying to understand turtle reproduction, this number of clutches – known as *clutch frequency* – is an important metric. It helps us to figure out what is the total number of eggs laid in a season, and it is a measure of the total reproductive output for the turtles.

We will discuss this in a bit more detail in Chapters 3 and 4, but just keep this in mind: knowing how many clutches of eggs are laid on a beach is important. We could estimate this simply by counting how many tracks we see on a beach in the morning (this is known, amazingly, as *track counts*). But we need to keep in mind that not all emergence tracks lead to a nest – sometimes turtles turn back for some reason – so we also need to know how many of those tracks actually resulted in a nest – or a measure of *nesting success*.

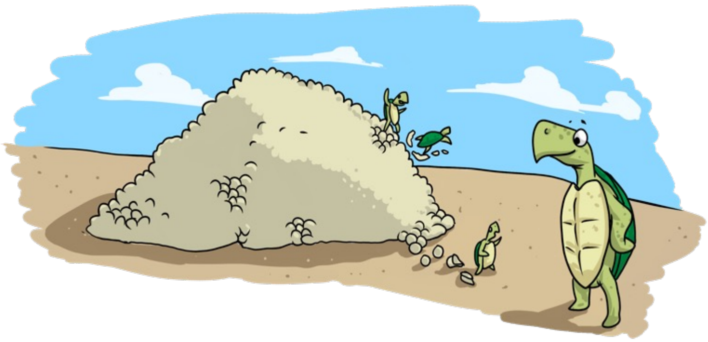
Knowing how many clutches of eggs a turtle lays in a whole season is also quite important because if we knew clutch frequency, we could do some calculations to determine the total number of turtles from the number of tracks and nests. For this, we would need to identify a turtle in some way, so that we know whether it is the same turtle coming back to lay eggs, and be in a position to figure out clutch frequency for our nesting turtles. Flipper tagging is one option to identify individual turtles.

4 Once a turtle has been active in a breeding season, it usually does not come back to lay eggs again for several more years. Male turtles – which do a lot less work during the breeding season – can come back after one or two years. But female turtles, which invest massive amounts of energy in creating the eggs, and then emerging on a beach to lay them, doing this over and over several times during one nesting season, normally need four or five years before they are ready to nest again. This interval between nesting seasons – known as the *remigration period* – is important because it helps us understand the total reproductive output of a turtle over its lifetime, and allows us to calculate the total number of adult females in a population. It also means that the turtles that nest this year are unlikely to be the same turtles we see nesting next year. And much like in the case of figuring out renesting intervals, we would need to individually identify a turtle through some kind of marking, so that we could recognise it when it came back to nest after a few years.

The interval between nesting seasons is largely governed by the amount of food available to a turtle in the intervening years. If there were two or three years of cyclones and bad weather, and food matter was scarce, it might take turtles longer to build up the energy supplies to be ready to nest again – resulting in longer remigration periods. But if food was plentiful and environmental conditions favourable, more turtles in a population could be ready to breed in any given season with shorter remigration periods.

5 Turtles lay lots and lots and lots of eggs in a breeding season. Lots of eggs. And those eggs turn into many many many hatchlings. Green turtle nests typically contain 80 to 120 eggs, and hawksbill turtle nests might contain up to 180! When you have lots of turtles, laying lots of clutches of eggs, the number of eggs and emerging baby turtles can be staggering. Here's one example: at Raine island, a nesting site in Australia, a good year can host 8,000 to 10,000 nesting green turtles. Each of these can deposit an average of 5 clutches, each with 104 eggs, that each result in 77 to 87 hatchlings. When you calculate all of this, it results in a staggering 3.1 to 4.3 million – yes million – hatchlings in just one season!

Knowing the number of eggs a turtle deposits each time she nests – known as *clutch size* – is another important metric we need to keep track of. If food resources were low, there's a chance turtles may lay fewer eggs, and a gradual but steady decline in clutch size could point to problems at the feeding areas. Of course, clutch size, like everything else, goes up and down a bit here and there. This is normal.



Ask a turtle biologist how many eggs a sea turtle lays and they will say 'oh, somewhere around 100' and they would be right. And if the number was 90, or 110, they would also be right. But if that number became 90, then 80, and then 70 and 60, in a downward trend, we would start to get concerned.

Another thing worth considering is that sea turtles don't just lay 100 eggs for fun. They do it for a good evolutionary reason: this is the number of eggs they need to lay for the population to persist over evolutionary time scales. So if a turtle emerged and laid only 10 eggs, this would point to there being something seriously wrong – maybe the turtle was disturbed and abandoned the nesting event. It is a rare event (and not at all normal) that a turtle would deposit an unreasonably low number of eggs after going to all of the effort of migrating, mating, egg-making, beach crawling, digging, chambering and egg-plopping.

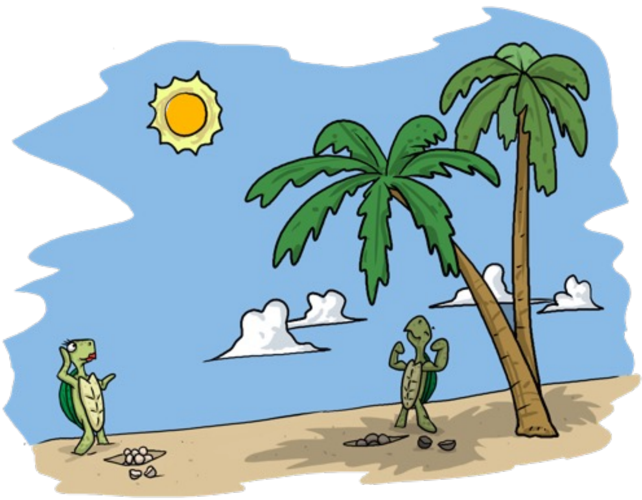
6 Sea turtle eggs take aproximately 45-65 days to incubate, known as the *incubation period*. Emergence usually occurs after dark when the sand surface cools. When incubation ends down in the depths of the sand, a baby sea turtle hatchling 'wakes up', 'stretches', and breaks out of its shell, disturbing the neighbouring egg, which also 'wakes up'. On and on this goes until the majority of the clutch are now scrambling around, upward, towards the beach surface. The hatchlings dig through the sand for two or three days before making their way to the surface, and 100 baby turtles have 400 baby flippers, which makes for a magnificent digging machine! But when the baby turtles get close to the surface they come to a halt if the sand is hot. Why? You might ask… If the sand is hot it means that the sun is still out, and it would still be daylight, so hatchlings could dehydrate or be seen by predators. So hatchlings wait for cool sands – after dark – to emerge and make their way to the water.

The number of emerging hatchlings from each nest, known generally as *emergence success* or *incubation success*, is another important metric to track turtle reproductive output. There are actually two measures by which this is tracked: *incubation* or *hatching* success, which is the number of hatchlings that emerge from the eggs down in the depths of the sand, and *emergence* success, which is the number of hatchlings that actually make it to the surface and run down the beach towards the water.

It is often the case that some eggs do not survive the embryonic stage, and some debilitated baby turtles don't make it out of the nest. For most practical purposes, the number of hatchlings that make it out of the nest (*emergence success*) is well worth knowing. When we total this up across our nesting beaches, this tells us how many baby turtles a beach is putting back into the oceans each year.

7 Once hatchlings emerge, they then crawl down the beach and head in an offshore direction using (primarily) light to reach the shore, then waves through the nearshore waters and finally magnetic fields for guidance and orientation as they reach offshore areas. While light is a primary cue on the beach, other things like beach slope, and the sound of waves on the beach also help guide turtles to the water. Notice how many natural cues turtles use to get them to the water: light, wave sound, wave orientation, beach slope, magnetic fields… Any sort of human interference in this can be quite catastrophic – like putting bright lights behind a beach that might attract baby turtles in the wrong direction. Bottom line: our actions should allow hatchlings to have as natural a sea-finding experience as possible.

Here's another interesting fact: hatchling sex ratios – the numbers of male turtles and female turtles - are governed by nest temperatures, whereby warmer nests produce higher proportions of female hatchlings. How about that? Temperatures in the nest during the incubation period are often a function of sand colour and nest placement, where nests in darker sands get hotter and incubate at higher temperatures, as do those deposited under the open sun. These nests are likely to produce more females. But if a nest was laid under the shade of a tree, where it would be much cooler, it likely would produce more male turtles. The reason this is important to us is that with climate change or egg handling in hatcheries, scientists are concerned that nests might get warmer and we will end up with more female turtles.



8 The baby turtles immediately swim nonstop for a day, and then maybe on and off for another four or five days, in what is known as a 'swimming frenzy' to get as far offshore as possible. This period is crucial for baby sea turtles, and any interference could lead to disastrous consequences for the turtles. For example, keeping sea turtles in plastic bowls to give them a 'head start' or a 'fighting chance' only means they use up the last of their energy reserves swimming around in a plastic tub. When they are released, they think they are 'already there' – offshore, safe, and without a need for any more swimming for a while. But really, nothing could be further from the truth, as these baby turtles just become prey to numerous coastal fish species. Remember: natural instinct and behaviour is everything for baby hatchlings, and we should do everything in our power to ensure hatchling emergence and offshore dispersal is as natural as possible.

9 After the swimming frenzy the baby turtles generally float on the surface among convergence zones and sargassum patches for several years until they come back as small 20-40 cm juveniles from oceanic waters to nearshore shallow feeding areas. Exactly what triggers this return to nearshore areas is largely unknown, but scientists think it is related to the amount of food available to the turtles. Out there in the big blue ocean they are opportunistic feeders, munching down on whatever prey happens to come by. But as they get older and larger, and reach roughly the size of a dinner plate (~35cm in length), the amount of food becomes limiting, and most turtles migrate to onshore areas where seagrasses and coral reefs and other shallow habitats provide the forage material they need to support their continued growth and development.. And finally…

10 These small turtles typically remain at one or even multiple feeding grounds for up to 20 or 25 more years while they go from being juvenile to sub-adult turtles, and until they finally reach sexual maturity and as adults undertake their own migrations to the mating and nesting areas, whereupon the cycle is repeated.

What is of note here is that these turtles are quite old when they first emerge on a beach to nest - maybe 20 to 30 years old or even older - and during that time they have had to avoid predators in the ocean (which is quite normal for a turtle), but also that they have been affected by human pressures all that time also (which is a lot less normal for a turtle).

It has been said over and over in turtle folklore that sea turtles return to the beach on which they were born. This might be so in a few cases, but for practicality's sake it is worth understanding that turtles return to the general region where they were born. How close? Well that of course varies, but it is normally in the region of a few hundred km. We know this is the case by studying sea turtle genetics, and to know more about this sort of thing in the Pacific region, a lot more work is still needed.

So there you have it. That's turtle reproduction and life cycles in a nutshell. If nothing else, you should now appreciate that there are many factors that govern turtle lives, from the distance between nesting and feeding areas, and how feeding controls the number of nesters; how nesters lay multiple clutches and that each of these clutches contains many eggs that produce many hatchlings; how there are natural cues that help turtles emerge from a nest deep down in the sand, and make their way down the beach and off into the ocean; and how turtle lifecycles are long, with several decades between emerging as a hatchling and one day returning to nest in the general region where they were originally born. You likely also appreciate now just how many bits of information go into understanding turtle life cycles and reproductive output: number of nests, nesting success, turtle identification, clutch frequency, clutch size, renesting intervals, incubation period, remigration intervals, and hatchling emergence success.

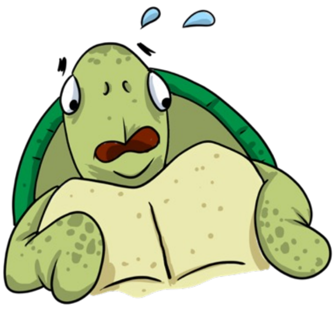
In Chapter 2 we will investigate why some of these metrics are unknown in the Pacific region, and then in Chapters 3 and 4 look into how we might solve this – as needed. But first a quick look at the threats turtles face to accomplish all of the life cycle we just described.

THREATS TO SEA TURTLES

Sea turtles face a multitude of threats over long periods of time, but this is not necessarily always a bad thing, so long as it is kept at natural levels. Turtles are evolutionarily prepared to suffer some level of mortality – if not the seas would be teeming with turtles! But it is worth noting that large sub-adult turtles and adults have a higher ecological value because they have reached a size at which they can reproduce, and the loss of these valuable individuals can have more of an impact on a population than the loss of, say, a clutch of eggs. From a turtle management point of view this is important, because the loss of a small number of eggs or hatchlings may be compensated by their prolific egg-laying in the short-term, but the loss of older and larger animals can have substantial negative effects on population size because it is the adults that are available to lay more eggs. Large turtles are very valuable!

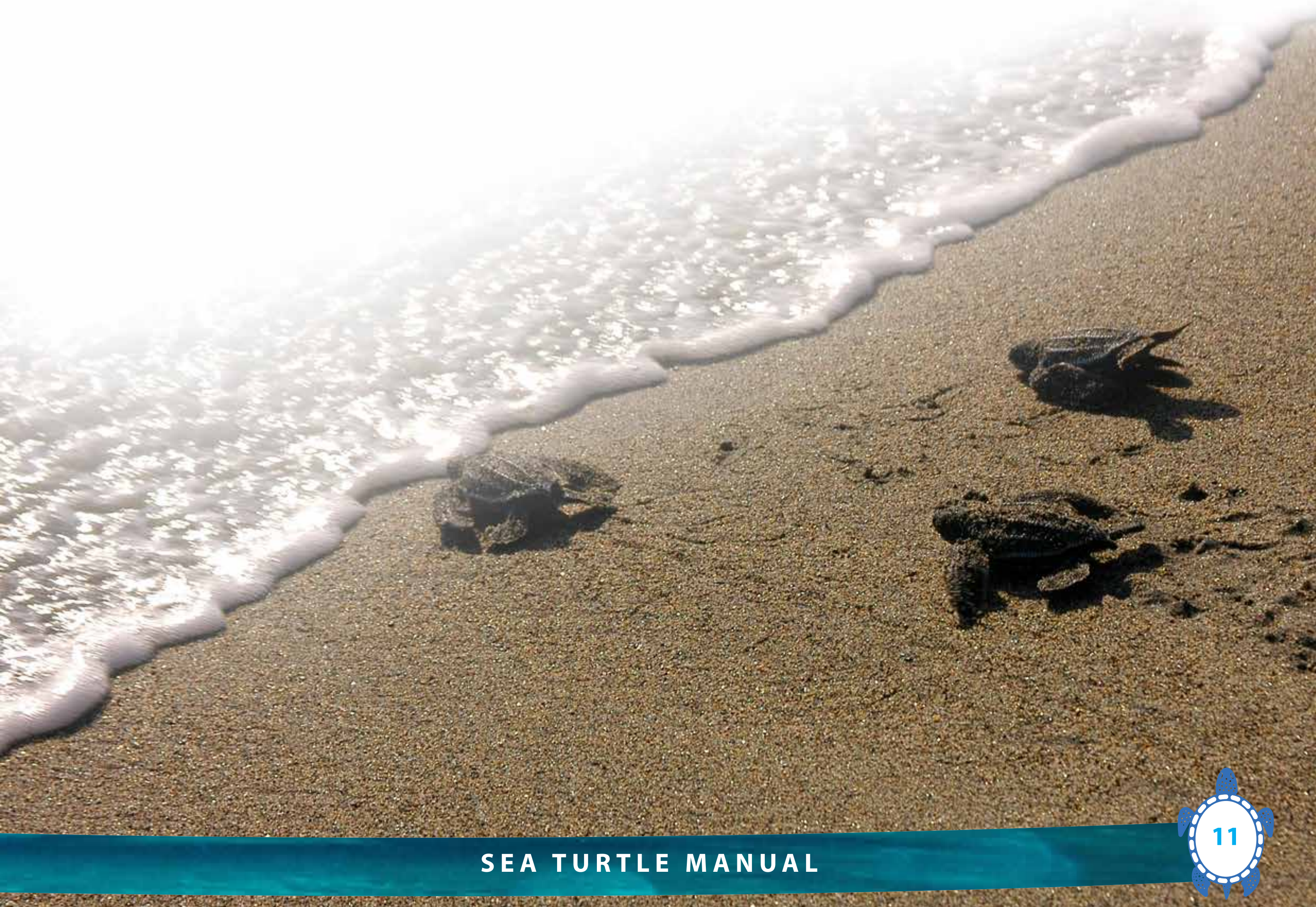
Threats come from a wide array of sources, be they routine biological threats (predation, disease), unexpected natural threats (storm damage, erosion, loss of habitat, climate impacts, etc.) and anthropogenic threats like captures in fisheries, vessel strikes, collection of eggs, pollution, lighting, ghost fishing, and also climate change.

What is important for us is to know what threatens sea turtles and / or their habitats, so that we are in a position to do something about it. But it is also important to know what is a real threat, and whether that threat affects turtles in your area(s).



For example, climate change is regularly presented as a threat to sea turtles, and indeed in many parts of the world this is the case. But is it the case in your neighbourhood? Do we know this for sure? I don't doubt for some places the answer to this will be yes. But in others the answer might not be so clear. Here's a practical way to think of this: if sea levels rise by 10cm and turtles nest further inland, does this represent a real threat to turtles? If there is no more beach available and nests are being washed away, then the answer to that is likely Yes!

But if the beach is extensive and turtles simply nest further up the beach, then chances are this is not the major threat you need to worry about. If nests are being washed away by more frequent storms, then climate-related impacts are surely to blame. But this does not mean we need to cool the nests, if temperature changes are not implicated. It is important to understand what actually impacts sea turtles, so that we can target conservation and management action appropriately. Some brief descriptions of the threats that impact sea turtles are presented in Annex I.



CHAPTER 2: CURRENT KNOWLEDGE OF MARINE TURTLES IN THE PACIFIC ISLANDS

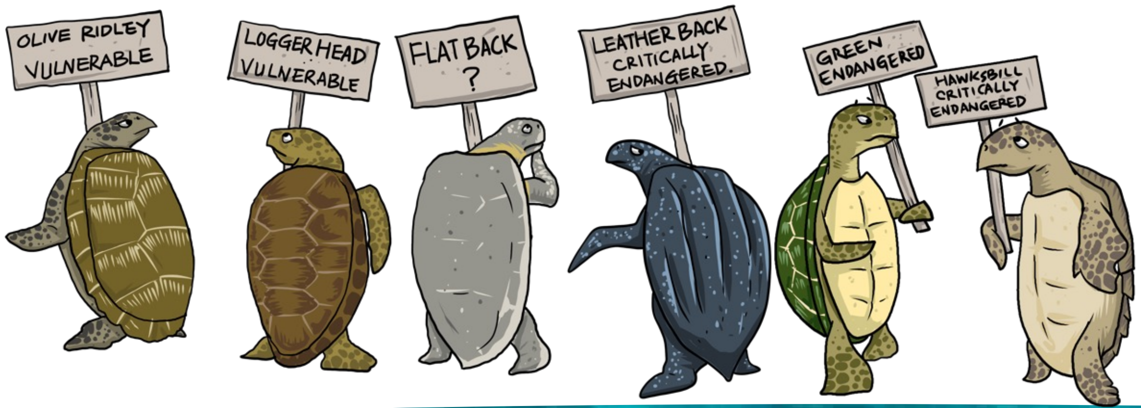
Sea turtles are cultural icons across the Pacific region, and are embedded in the customs and traditions of Pacific Island communities – featuring in myths, legends, songs and traditions. Turtles also have many other values such as for tourism, education and research.

Outside of this, sea turtles play a number of ecological roles that make them important to the planet and not just to humankind, which are usually less obvious to the casual eye. Because of their diets, sea turtles play valuable ecological roles in marine ecosystems, and act as what scientists call *habitat engineers*. This is a fancy term for saying that turtles modify the habitats on which they feed, that in turn helps those same habitats become more resilient and healthy.

Green sea turtles feed on seagrasses. They wander along the seabed cropping seagrass leaves and allowing new shoots and new growth to sprout upward. In the absence of the grazing the seagrasses would grow long and unhealthy, and be of less ecological value. Keep in mind these same seagrass beds are home to many important juvenile and commercial fish and shrimp species, so in many ways these 'sea turtle ecological services' that turtles perform are also of value to humans, because those fish become our dinner. Another example is demonstrated by Hawksbill turtles: As they feed on sponges, they break open the tough exterior walls that other species are unable to penetrate. This enables feeding by multiple fish species and controls sponge growth and cover, where it could otherwise compete with corals. And keeping coral reefs healthy is important to mankind because of coral reefs' role in fisheries – putting food on the table, and even larger oceanic and atmospheric processes like regulating the acidity of the ocean.

STATUS OF PACIFIC ISLAND SEA TURTLES

So let's take a quick look at what we know about sea turtles in the Pacific region. To start with, the Pacific Ocean is home to six species of the world's seven sea turtle species. The Green (*Chelonia mydas*); the Hawksbill (*Eretmochelys imbricata*); the Loggerhead (*Caretta caretta*); the Leatherback (*Dermochelys coriacea*); the Olive Ridley (*Lepidochelys olivacea*); and the Australian endemic Flatback (*Natator depressus*). We are just missing one, the Kemp's Ridley, which is restricted to the Gulf of Mexico and the coasts of north America.



By a very long margin, the Green and the Hawksbill are the two most common turtles in the Pacific, certainly as nesting and feeding turtles in Pacific Islands countries and territories. Because turtles spend most of their time at sea and only female turtles emerge to lay eggs, it is usually the number of female turtles in a population that we can count, and so we use this metric in determining how the population is doing. Of course, this means there must always be a certain number of males in the population, and countless sub-adults, juveniles and baby hatchlings. But the number of adult females is a useful proxy for total population size, and we will refer to this number frequently as we look at the status of populations across the Pacific, and also later on in Chapters 3 and 4 when we consider what we need to know, and how we can find that out.

Loggerhead turtles are abundant in Japan (2020's estimates point to some 9,000 adult female turtles) and there are smaller numbers in Australia (1,000 to 2,000 adult females), and even fewer nesting in New Caledonia. Juvenile turtles from the Japanese stock move as far as north America (e.g. Baja California, Mexico), and Australian / New Caledonian turtles go as far as South America (e.g. Peru). A large proportion of Japanese Loggerheads also take up residence in deep water feeding areas in the northeast Pacific. Although sometimes caught in fisheries, and infrequently seen at sea, Loggerheads are not that common in most Pacific Island Countries and Territories (PICTs).

The substantial Loggerhead turtle stock from Japan appears mostly well-off, save for bycatch in longline fisheries in the western and central Pacific, pound net fisheries in Japan, and in gillnet fisheries over in Baja California (Mexico). The much smaller stock that nest in Australia appears to be much more imperilled, as younger and smaller turtles are caught in gillnet fisheries off the coast of Peru and Chile.

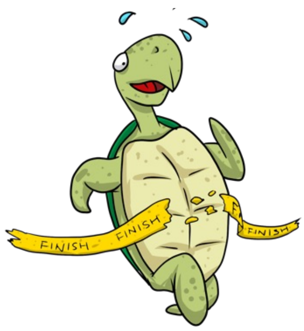
Leatherback turtles have a very small remaining population nesting in the eastern Pacific, and a larger but also declining nesting population in the western Pacific, in West Papua (Indonesia), Papua New Guinea, and the Solomon Islands. These turtles undertake incredible migrations across the Pacific to north America, or down south towards New Zealand. They are not known to nest elsewhere in the Pacific, and are only encountered as infrequent visitors (and captures) in Pacific Island Countries and Territories (PICTs) or as bycatch in the prolific longline and purse seine fisheries across the Pacific region.

Both the eastern and the western Pacific Leatherback stocks are Critically Endangered (the eastern and the western Pacific stocks), having crashed from historically high numbers. The eastern Pacific Leatherbacks are down to just about 100 adult nesters per year, and while the western Pacific Leatherbacks are more numerous (estimates of some 700 annual nesters) - they interact far more frequently with Pacific islands fishing fleets, and the long-term consumption of eggs, compounded by captures of adults for food and as bycatch in commercial and artisanal fisheries, means both populations are seriously in trouble. Of all species across the Pacific, this one is in need of the most help and conservation action.

Olive Ridley turtles are present but uncommon in PICTs. Most nesting occurs in the eastern Pacific, primarily in Mexico, and Costa Rica, then substantially fewer in Ecuador and Peru, and even fewer in El Salvador, Guatemala, Honduras, Nicaragua and Panama. While some turtles do extend their range westward into the Pacific, and some Australian olive ridleys move eastward, with some occasionally caught as bycatch in fisheries, they do not generally nest on Pacific islands, and are infrequently encountered by peoples of the Pacific. More recently there are quite a number of solitary nesting Olive Ridleys being found in the Philippines and Indonesia, which may also extend their migrations out into the Pacific Islands region.

Over in the eastern Pacific the Olive Ridleys have two nesting modalities: some beaches are home to what are known as solitary nesters, while a few select others host what are known as *arribadas* – a Spanish word for mass arrivals. During these arribadas, as many as one hundred *thousand* turtles may nest over a period of a few days. Yes, *thousand*! But the Olive Ridley turtles are so rare out in the Pacific Islands that in reality these large numbers have little bearing on how we manage threats and implement conservation action. Of course, any measure we introduce that reduces threats will reduce threats to the occasional Olive Ridleys, which can only be a good thing.

Flatback turtles nest exclusively in Australia and some foraging turtles are found in southern Papua New Guinea and Indonesia, but the species is coastal and does not venture eastwards out into the Pacific Ocean. It is likely that the north and east beaches in Australia host some 3,000 to 4,500 nesting flatback turtles each year, and threats have largely been addressed, so the various genetic management units in this population appear to be doing well.



As I said earlier, Green and Hawksbill turtles are by far the most numerous and common across the Pacific islands, and of these, the Green is far out in the lead. This is because Australia has some massive nesting sites (recall we discussed Raine island earlier) and there are also very large nesting sites in New Caledonia and the Philippines which bring the average number of nesters annually in the central and western Pacific region to about 24,000. However, if we discount the large nesting aggregations in Australia, New Caledonia and the Philippines, this number of annual nesters comes down to only about 3,000 females nesting annually across the rest of the Pacific, with about 450 to 500 of those up in Hawaii and Yap.

This means that the actual number of nesters across the Pacific islands is actually substantially lower than the Pacific Ocean total (excluding Latin America) – sometimes as low as ten or twenty nesters in a country per year.

When scientists look at the regional aggregations of Green turtles, given the large numbers that prop up the Pacific population, the conclusion is that these turtles are doing really well at a Pacific Ocean region level – and that while there might be some places in the Pacific where numbers are low and management is urgently needed, as a species they are not about to go extinct any time soon. There is an important distinction to be made, however: In American Samoa, the Cook Islands, Pitcairn, Tonga, Tuvalu, the Commonwealth of the Northern Mariana Islands (CNMI) and Guam, nesting Green turtles can be counted in only tens – and sometimes even less than that. These stocks cannot withstand any pressure or loss to nesting females whatsoever. So while the Green turtle is abundant at an oceanic scale, in many parts of the Pacific they are extremely fragile and probably highly endangered.

The story of the Hawksbill goes somewhat along the same lines, but at even smaller abundances across the region. The Pacific is home to some 4,200 annual nesters, but these are propped up by large nesting aggregations in Australia (~3,000), Papua New Guinea, the Solomon Islands and Vanuatu (~300 annual nesters each). Elsewhere the number of annual nesters is again – in most cases – counted in tens of Hawksbills per year. Given the extensive trade for Hawksbill tortoiseshell, and customary practices at a number of locations in the Pacific, the larger Oceanic scale numbers do not guarantee the long-term survival of Hawksbills and scientists have determined they are Critically Endangered across much of their range in the Pacific.

I mentioned just now that the Hawksbill turtle or Leatherback turtle nesting aggregations are mostly *Critically Endangered* in the Pacific region. But how do we get to classify a turtle species as being endangered? What does it take to actually figure out how well sea turtle stocks are doing and if they are going to go extinct? In the following section I hope to answer that question for you.

IUCN RED LIST STATUS AND REGIONAL MANAGEMENT UNITS

Among the most recognised assessments of sea turtle status (are they doing well, or badly, and if so, what is the risk of extinction?) are the assessments conducted by the International Union for the Conservation of Nature (IUCN) and published on their Red List https://www.iucnredlist.org. This assessment process objectively evaluates the trend in numbers of turtles, how much habitat they have, limitations to habitat use, whether the population is fragmented into smaller nesting groups, whether the population is genetically distinct, and a suite of other metrics to produce a risk of extinction assessment that is comparable across species.

In the past, these assessments were done at a global scale, which was a bit of a problem for sea turtles. That's because a sea turtle species may be doing well in one ocean basin and not in another, and so a global – overall – assessment was not reflective of the status of either of these populations. Take, for instance Leatherback turtles: in the Pacific the numbers have crashed and the population is on the verge of extinction. But in the Atlantic some stocks number in the thousands. So how can we interpret this? The North American stock is not about to go extinct while the Pacific stock may very well do so. With one population increasing and the other decreasing, would the average of the two trends make any sense to either of them?

The answer is 'Not really'. Sea turtles face different pressures at different levels in different places. Things like human consumption, bycatch in fisheries, climate change, marine debris, loss of nesting beaches. This means we really need to look at those turtles that nest and live in a particular region in order to provide a realistic assessment for just that region, and provide a more realistic assessment of populations at regional levels rather than global levels.

The MTSG recognised long ago that it was unrealistic to assess sea turtles at the global scale due to these vast differences in trends at different locations, and in recent years has conducted assessments at a level that is far more reflective of their range. This, more regionally-restricted assessment of extinction risk, is conducted at a level of Regional Management Units, or RMUs, and the most recent IUCN Red List of Threatened Species classified the six Pacific Ocean turtle species as follows:

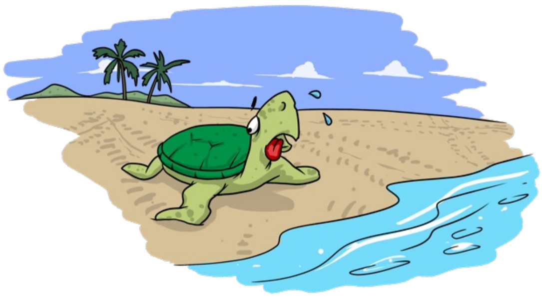
- Hawksbill: Critically Endangered (global; 2008)
- Leatherback: Critically Endangered (West Pacific subpopulation; 2013) and Critically Endangered (East Pacific subpopulation; 2013)
- Green: Endangered (global; 2004) and Least Concern (North Central Pacific subpopulation; 2019)
- Loggerhead: Vulnerable (all regional management units; 2015)
- Olive Ridley: Vulnerable (all regional management units; 2008)
- Flatback: Data Deficient (this does not mean that there is no data available, but merely that the data have not yet been compiled and assessed using IUCN criteria; 1996).

For sea turtles, the most common unit of measure (or metric) with which these assessments are made is the magnitude and trend in numbers of nesting turtles over time. If scientists don't know the number of actual turtles, sometimes they can interpret that from other data sets. For example, where scientists know how many clutches of eggs each species lays in each region, they can estimate the number of turtles from the number of successful tracks that get counted on a beach. If green turtles in the one place in the Pacific Ocean typically lay 4 to 7 clutches of eggs in a season, and a beach monitoring project counted 1,200 successful nesting events, this probably equates to some 170 to 300 individual turtles (1,200 ÷ 4, and 1,200 ÷ 7).

CHALLENGES IN ACQUIRING DATA TO UNDERSTAND POPULATION STATUS

The problem with trying to conduct status assessments in the Pacific Islands region is we don't always have all the information we need because of some very real limitations. In some places a lack of long-term monitoring data does not allow us to determine if the population is growing of declining. In others, some biological attributes remain unknown (e.g. clutch frequency) because it is expensive and logistically challenging to be on a beach for an entire season and record every single nesting event for every turtle. Let's take a look at some of the key metrics we discussed earlier (*italicised* in previous sections), and see what challenges might lie in getting hold of those data sets.

TRACK COUNTS Ideally, track counts tell us how many nesting attempts there were on a beach in a given night, and this is about the minimum one should count to be able to determine nesting abundance. If we add up the tracks over a season, we can determine the total number of tracks. When we couple this number with a figure for *nesting success* – how many tracks end up in a nest with eggs – we can figure out the total number of clutches deposited in a season. Of course, if we knew *clutch frequency* (look that up above!), we could also calculate how many turtles this represented. See how these are all interlinked?



The challenge, of course, lies in being able to count all tracks – or at least the majority of tracks – on a given beach for a whole season. Beaches might be remote, and costs might be too high to keep someone (or a team of people) on a beach for a whole nesting season. Weather is also a concern – we can't quite leave people on remote islands to deal with cyclones…

Beaches might be very far away from where people live, making the overseas trip dangerous. We might not even have enough people to spare to ask them to be out on an island for months on end.

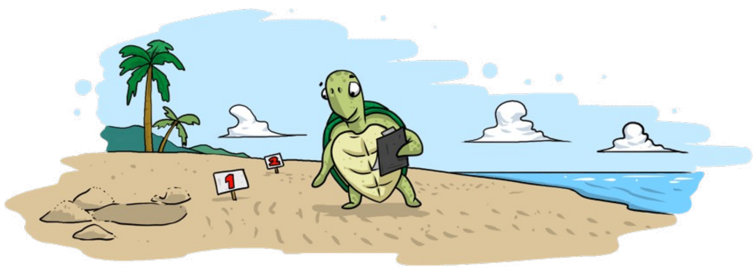
NESTING SUCCESS This is a little bit easier to estimate because we don't actually need to be on a beach for a whole season. Also, we don't need to assess the success of every single nest – once we have a sufficiently large sample we can use this as an average for a species at a certain location. What we need to do is get out on a beach for a number of nights – as many as practicable – and simply observe turtle nesting and see what happens. If eight out of ten turtle emergences end up in a nest, we have 80% nesting success. If six out of ten emergences end up in nests, then we have a 60% nesting success. The more nights and the more observations we make, the more robust this estimate of nesting success becomes. It does require getting to a beach and being there for some time, but it is nowhere near as complex as being on a beach for a whole season

CLUTCH SIZE Much in the same way as nesting success, we don't need to count the number of eggs in every clutch to make an estimate of the *average* clutch size for a season. We just need a good sample size from which we can derive an average clutch size.

We could spend a number of nights on a beach and count the number of eggs in as many nests as possible. The higher the number of clutches we counted, the more robust our estimate would be. Knowing the number of eggs in a clutch helps us later on when we want to calculate the total reproductive output for the season. In Chapter 4 we can discuss just how robust these estimates need to be.

CLUTCH FREQUENCY This is a hard one – probably one of the hardest of all metrics to figure out. This is because it requires observing nesting over an entire season, and also to be able to individually identify each turtle. As we learnt earlier, we need to be able to identify a turtle – either through flipper tagging, or painting on them, or etching on their carapace or even using facial recognition photographs – if we want to identify them when they come back to nest. We also need to monitor the entire nesting season, right from the start up to the very end, to record every nesting event by every turtle. Then we can add up the total number of times we saw each individual turtle lay eggs, and average these for a *clutch frequency* value for the whole beach that season. You can already imagine how complicated this is in terms of logistics and access to distant turtle nesting beaches, on top of needing to identify each turtle. Get there too late in the season, and you will have missed some nesting events that will make the overall estimate inaccurate. Leave the beach to early and the same thing happens.

These challenges notwithstanding, if we knew *clutch frequency* with a good degree of accuracy, we could then use our more basic track counts and nesting success information to translate the counts into a total number of adult female nesters for a season.



INTERNESTING or **RENESTING INTERVAL** This is quite an easy metric to calculate if we are already doing all of the work to determine clutch frequency – we will already have tagged the turtles and we will be spending all the nights on the beaches to 'recapture' them. The value of this metric lies in helping us predict when turtles are likely to emerge again to nest, and given start and end dates of a nesting season the possible maximum clutch frequency, but it also allows us to estimate things like how many clutches of eggs a turtle might have laid when we were tracking it, say, with a satellite transmitter. Here's a scenario: early in a season we deploy a transmitter on a turtle that just laid eggs, and she stays in the vicinity of the nesting beach for another six weeks. If we assume the internesting interval is two weeks, we could assume that she remained in the area to lay three more clutches of eggs. If we tack on the clutch she laid when we first saw her, this would be an *estimated* clutch frequency of four for this turtle.

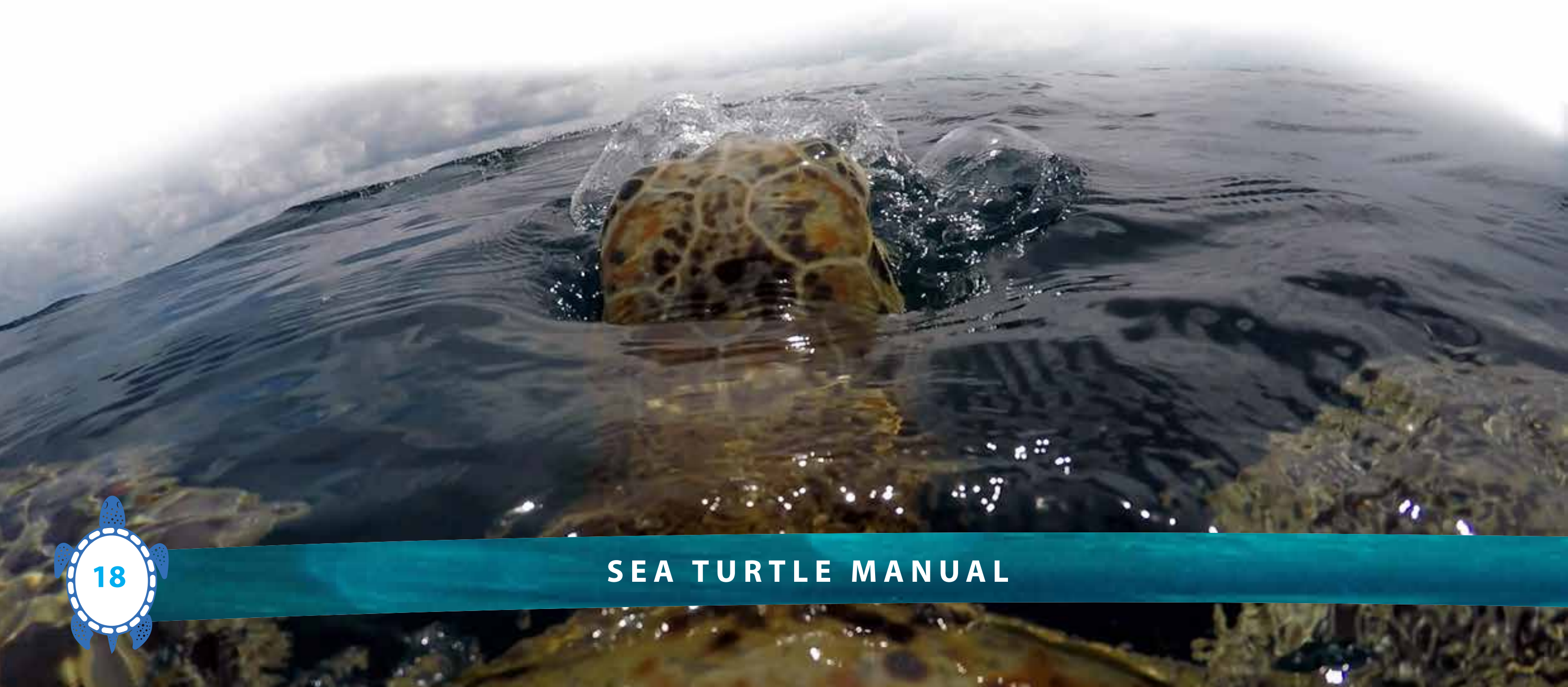
INCUBATION PERIOD While we also don't need to calculate the incubation period for every single nest, and a good sample of data points would suffice, assessing this metric is challenging in many areas in the Pacific. This is (again) because beaches are remote, logistics challenging and costs to get there high, and projects tend to focus their energies and resources on the nesting turtles themselves. But determining incubation period is also a massive challenge because it is hard to predict exactly when the hatchlings will emerge and we can't guarantee we would be on a beach when it happened. And we must be able to find that nest after a couple of months! All of these challenges mean it's an uncommon metric recorded across the Pacific. An emerging opportunity to determine incubation period comes when using temperature dataloggers, because these record a temperature spike when the turtles emerge (more on that in Chapter 4). However, one still has to actually find the nest where the loggers were placed and retrieve the data…

HATCHING SUCCESS As above, while we also don't need to count the number of hatchlings emerging from every single nest, and a good sample of data points would suffice, assessing emergence success is still challenging in many areas in the Pacific. Because it is hard to predict exactly when the hatchlings will emerge, we can't guarantee we would be on a beach when it happened. The nest would have needed marking way back when it was deposited, and that mark must have stood the test of time and multiple turtle nesting events since. And we must be able to find that marker after a couple of months. All of these challenges mean it's another uncommon metric recorded across the Pacific. We sometimes know how many hatchlings emerge from a nest if we randomly encounter one when wandering along a beach at the exact time the baby turtles emerge. If we are diligent and also dig down and try to reconstruct *clutch size* from the broken egg shells, we might be able to estimate emergence success. But again, this is not a very common metric simply because of the hit-and-miss aspect of being on the beach at the exact time of the evening when baby sea turtles emerge and rapidly crawl down the beach. Miss a hatching event by half an hour and you might never know it had happened!

REMIGRATION INTERVAL Even harder still to determine, because it requires being on a beach over multiple successive seasons – and usually for the entirety of every season on the off-chance a particular turtle would return, is determining how many years it takes a given sea turtle to come back to nest after her last egg-laying season. This needs turtles to be identifiable, and it needs a team to patrol beaches for so many days that it is unusual for this to be known for many turtle stocks in the Pacific. There are some places where this is known – such as Hawaii, Hatohobei in Palau, and the Arnavons Marine Protected Area in the Solomon Islands – but this is not common. Imagine having to deploy a team of monitors to a beach on a remote island in Tonga, for an entire season, through rain and shine and storms and cyclones, year after year after year, tagging each and every turtle that came up and recording each nesting event, to come with a remigration interval for the occasional turtle that called that island home.

And making things even more challenging, the remigration interval is often a moving target! What I mean by this is the number can keep changing the more data we acquire. Let's say we monitor a beach for four years and we see many tagged turtles coming back in the fourth year, and a handful in the third. We would estimate that the remigration interval was somewhere close to 4. But if continued monitoring that same beach for a few more years we might get turtles coming back after five years, six years or even longer. So the average remigration interval would keep changing the more data we collected. Only very thorough and long-term data series can really identify remigration interval with accuracy.

Hopefully by now you can see some of the challenges in assembling the metrics needed for accurate assessments – or counts – of sea turtle populations. As managers or conservation practitioners keen on advancing measures that protect sea turtle populations, these challenges should set the scene for how we formulate our research questions – the 'what do we want to know?' part – which we deal with next in Chapter 3. Once we have figured out what we want to know, then we need to use some filtering steps to best understand logistical constraints alongside capacity, to slowly go figuring out what we can do to get that information (Chapter 4).



CHAPTER 3: WHAT IS IT EXACTLY THAT YOU WANT TO KNOW?

So now comes the fun part. Figuring out exactly what it is that you want to know. As I have said earlier, I have been asked to help design drone studies, or to provide tags for tagging projects, but hopefully by now you have figured out that these are just the tools or study methods with which we acquire information. They are not the information themselves. For example, from Chapter 2 you should now be familiar with track counts, and also know that track counts don't require us to tag a turtle in the slightest. They are just counts of tracks on a beach. If you need to know how many turtles came to nest in a night this could be done easily by walking along the beach at low tide the following morning. Similarly, nesting success doesn't need us to tag a turtle. Tagging a turtle doesn't help it lay more eggs more successfully, or as I have often told people, 'tagging a turtle doesn't save it'.

But tagging turtles does help us identify which turtle is which. And yes, there can be multiple benefits to that. We can recognise turtles when they come back to nest, as we learnt earlier, in the same season or even after several years. We can also learn where they go. If a turtle swims from French Polynesia to Fiji, and someone sees and reports the tag and the new sighting, that movement record helps paint the picture of how turtles move around in the Pacific - the *habitat connectivity* we spoke about earlier.

I hope you now recognise that tagging on its own does not alter clutch frequency, internesting intervals or remigration periods – rather, it helps us quantify these metrics. It is a tool that helps us answer a question about something we want to know.

And that brings us to the crux of this chapter. What, *exactly*, do you want to know?

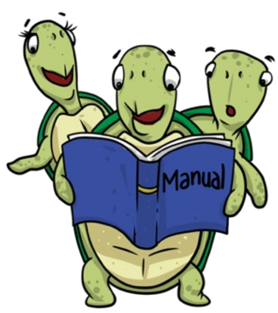
I am guessing you will have questions like "How many turtles do we have in my country?" "Is the number of turtles going up or down?" "Where are they?" "How many eggs do turtles lay?" "Where do they go?" "What threatens our sea turtles?"

When we look at bare bones of knowledge needs for turtle conservation, we are really left with three key questions:

1. How many turtles do I have? From this we can figure out if the numbers are going up or down;
2. Where are they? From this we know where to look, and where to implement conservation actions; and
3. What are the main threats? This lets us know what we need to change to conserve sea turtles.

Of course, a million research projects help inform these questions also, and expand our knowledge on sea turtle biology and ecology, but for basic turtle monitoring these are our key priorities. Given the interdependencies across these broad topics, we could narrow down our question by some broad headings such as Turtle Numbers, Reproduction, Habitats and Threats. And from there we might be interested in specific aspects of each, and the process would get refined from there until we know what exactly we want to know.

A useful way of approaching the question "what do you want to know?" is to also ask "why do you want to know it?" Indeed, very often these two are so interlinked that we can't pull them apart. A way I like to work through this is to first clearly articulate the *objective* of the study. The objective will often help define the question.



In Chapter 5 we will look at places where we can use the data sets we collect, and one of them is known as the SWOT Minimum Data Standards. We will get to that in a bit, but for now it is informative to know how their booklet describes this: "*Whether you are beginning a new sea turtle monitoring project or already have one under way, it is important to establish your project's goals and to revisit them regularly to make sure that the data you are collecting are sufficient*." I'd add to that that the data also need to be the *right* data to inform your question.

Here's an example: "My objective is to know how many turtles nest on my beaches so I can keep track of this over time" Another: "My objective is to conserve nesting sea turtles because they are valued by society and under legal protection" Perfect. Do we know where the nesting sea turtles are? If not, then a question might be "Where do sea turtles nest (or feed, or migrate to)?" – so that we know where we need to work. If we already know where they nest, a question might be "When do sea turtles nest at this location?" – so we know when we need to implement conservation action. Another question related to this might be "What are the threats to these nesting sea turtles?" – so we can devise solutions to the problem.

Notice that so far we have not come across drones or tagging or genetics. All we are doing at this stage is setting the scene and developing the *question*. And so now, armed with this notion, exactly what is it that you actually want to know? Figure 1 is provided below to help narrow down your ideas, starting with some broad categories and narrowing down the search in a second step.

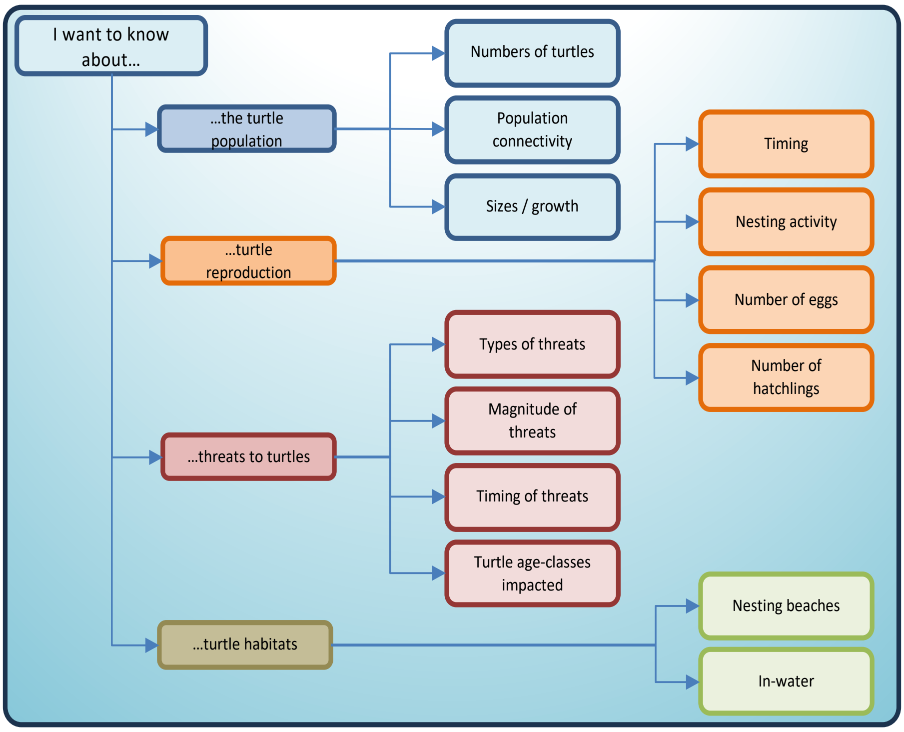
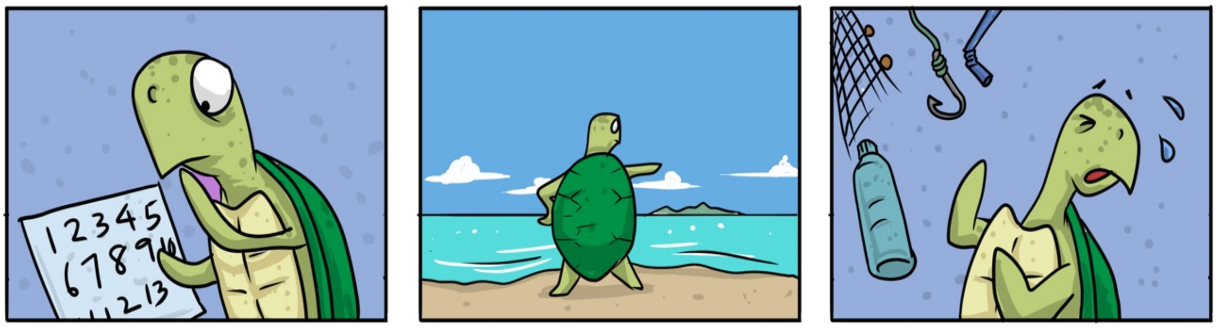


Figure 1: Sea turtle monitoring and research study categories to inform conservation and management.

Now that you know roughly what we are looking for, you can be a bit more specific: once you select for "I want to know about track counts…" or "I want to know about population connectivity…" you can then figure out something a bit more focussed. Some sample questions you might want to ask under each of these headings are presented in Figures 2 through 5.

Of course, there are multiple question and justification combinations. This manual does not presume to offer an option for every single study or monitoring option out there, nor describe every objective you might have. Here we are focussing on the three specific sea turtle management and conservation-related questions for which you are likely going to need information – number of turtles, location, and threats.



Hopefully these ideas will allow you to think through your question carefully and, if the specific question you have is not here, you should be in a position to determine the best course of action for your own information needs, based on the *process* we describe here. Just remember: the *objective* leads to the *question*, and the *question* leads to the *tool* or *study method*. Tools and study methods are discussed next in Chapter 4.

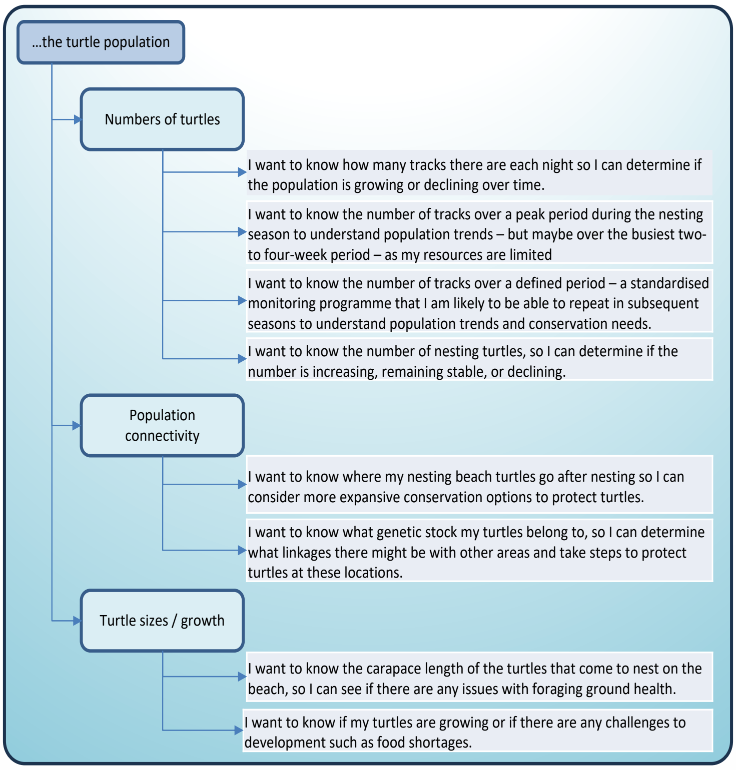


Figure 2: Specific sea turtle monitoring and research questions related to the turtle population itself.

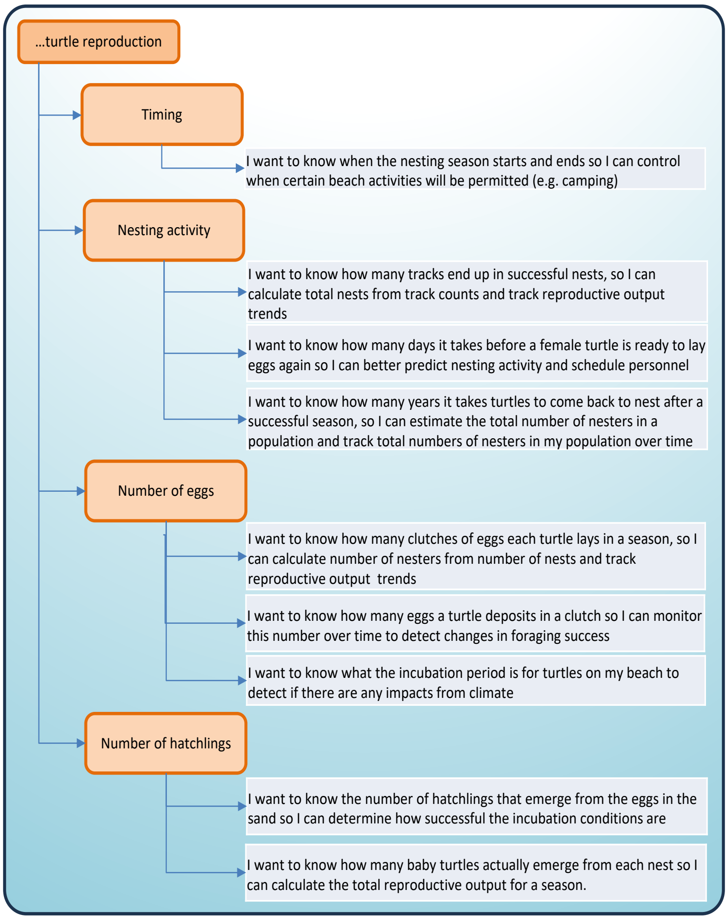


Figure 3: Specific sea turtle monitoring and research questions related to turtle reproduction.

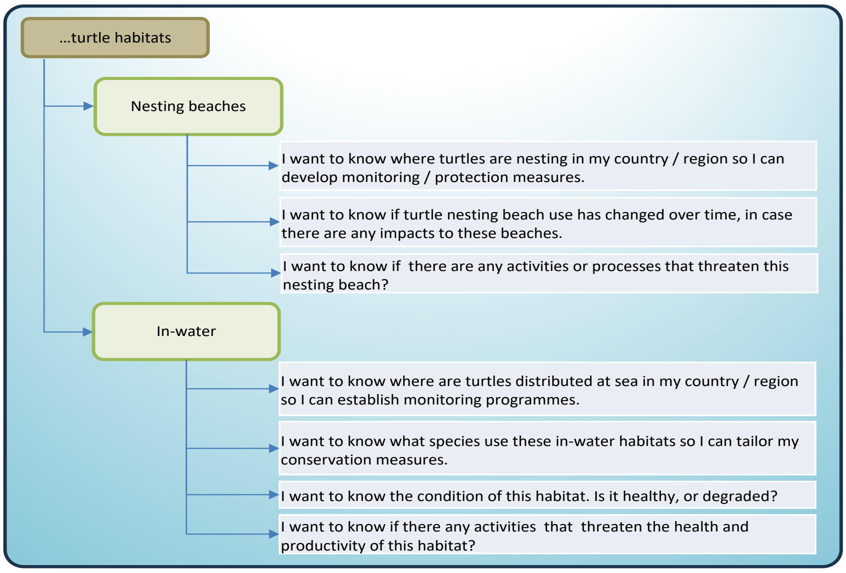


Figure 4: Specific sea turtle monitoring and research questions related to sea turtle habitats.

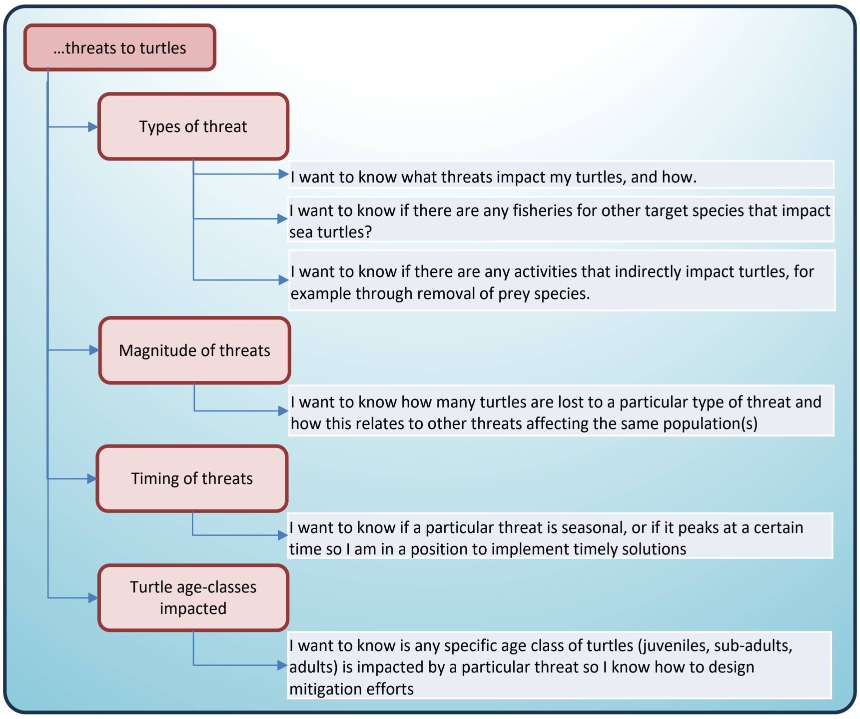
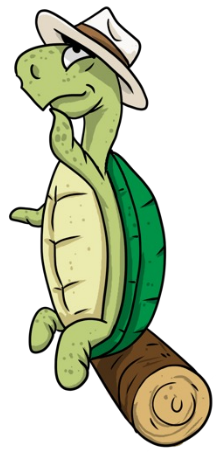


Figure 5: Specific sea turtle monitoring and research questions related to threats to sea turtles.

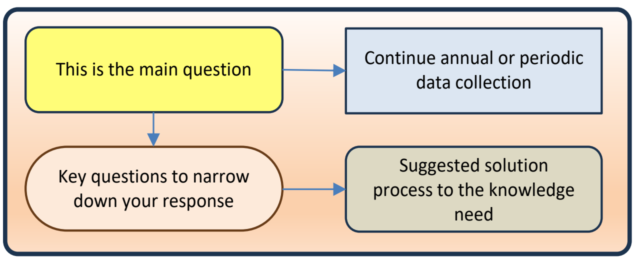
CHAPTER 4: APPROACHES TO SEA TURTLE RESEARCH IN THE PACIFIC ISLANDS REGION

By now you should be ready to get cracking on selecting the right tool for the job. You know the sorts of data you need to get, and you have a good idea of the limitations you might face in getting some of these, but you have also found out that you can use some neighbouring data as a proxy if needed. This chapter will take you on a process that gradually narrows down your tool and study approach based on what you need to know, and based on what resources you have available to you. Remember that that the study method or tool should be chosen based on the question you are trying to answer. Some key secondary questions to keep in mind when narrowing down the study method / tool choices are as follows:

1. What human resources are available? Do you have a small pool of people in the office, or do you have an extensive community network that can assist with data collection?
2. What expertise do you have available? Do you have trained scientists and data recorders, or do you need to get someone to assist with training and capacity building? Keep in mind the training might take time and cost additional funds.
3. When do you need the information? Do you need it immediately, or do you need time to get the resources in in place? For example, it might take some time to get a grant or a government funding allocation before you can implement some more expensive projects.
4. What tools are available to you? Do you have access to a boat for boat-based surveys or to get to distant island sites, or an airplane for aerial surveys, or a drone? Do you have tags and applicators, or GPS units? What is the lead time to getting these tools?
5. What will the project cost and what funding do you have available?



The way I have laid everything out in this section is to have a series of decision-making trees (Figures 6 through 12), and each final decision leads to a numbered Process. These are presented in colour-coded flowcharts and a sample of how to follow the flowchart is shown below. These Processes are then presented sequentially after all of the decision-making has been considered. It is important, as you go through these, to think of the secondary questions above and consider your responses based on your skills, resources and time-frames as you navigate each decision pane. We will start with counting nesting turtles, as this is usually a top priority. This section takes care of the "*how many turtles do I have?*" part of the knowledge needs for conservation and management.



While we are looking at nesting turtles, we will also take a short detour to look at reproductive output and turtle movements, given as these are likely two of the more accessible types of study to many research teams – and because much of the data is collected while we count turtles.

Of course, this makes the assumption that the locations of nesting beaches or feeding areas are known, but in case it is not, then the wider scale surveys for both nesting and in-water sites comes next, taking care of the "*where are my turtles?*" part of the conservation and management information needs.

Once we know where turtles spend their time in the water, we can take a look at some of the ways in which we can determine turtle numbers, in a way that would be replicable over time. This also answers to the "*how many turtles do I have?*" part but is specific to foraging and development stage populations of turtles, rather than those on the nesting beach.

Finally, we will tackle impacts to sea turtles and their habitats, as the third section in the trilogy of conservation and management needs on "*what are the threats to my turtles?*". Hopefully these key sections will guide you in a fairly straightforward way in selecting research tools and programmes that give you the most information with the best use of your limited resources, and provide you with the data to best understand trends in turtle numbers and status, and be in a position to implement conservation actions.

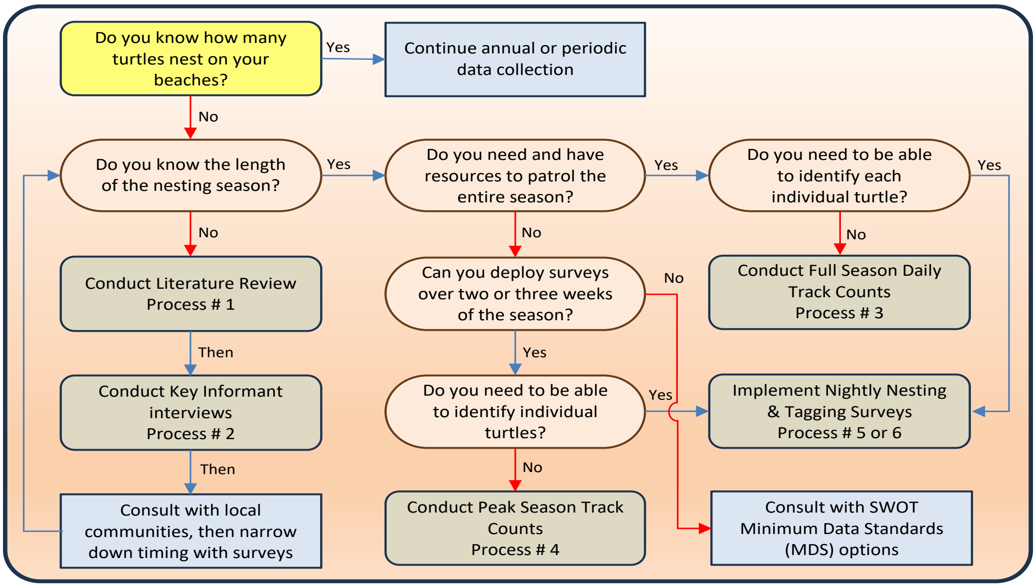


Figure 6: Decision-making steps related to the number of turtles.

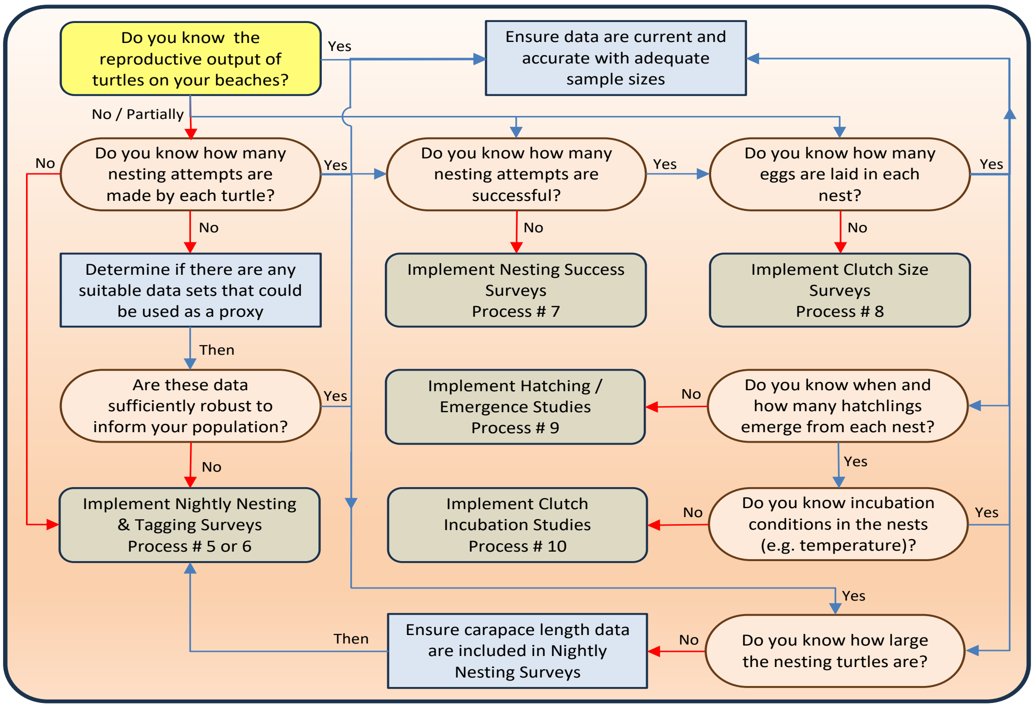


Figure 7: Decision-making steps related to the reproductive biology of turtles.

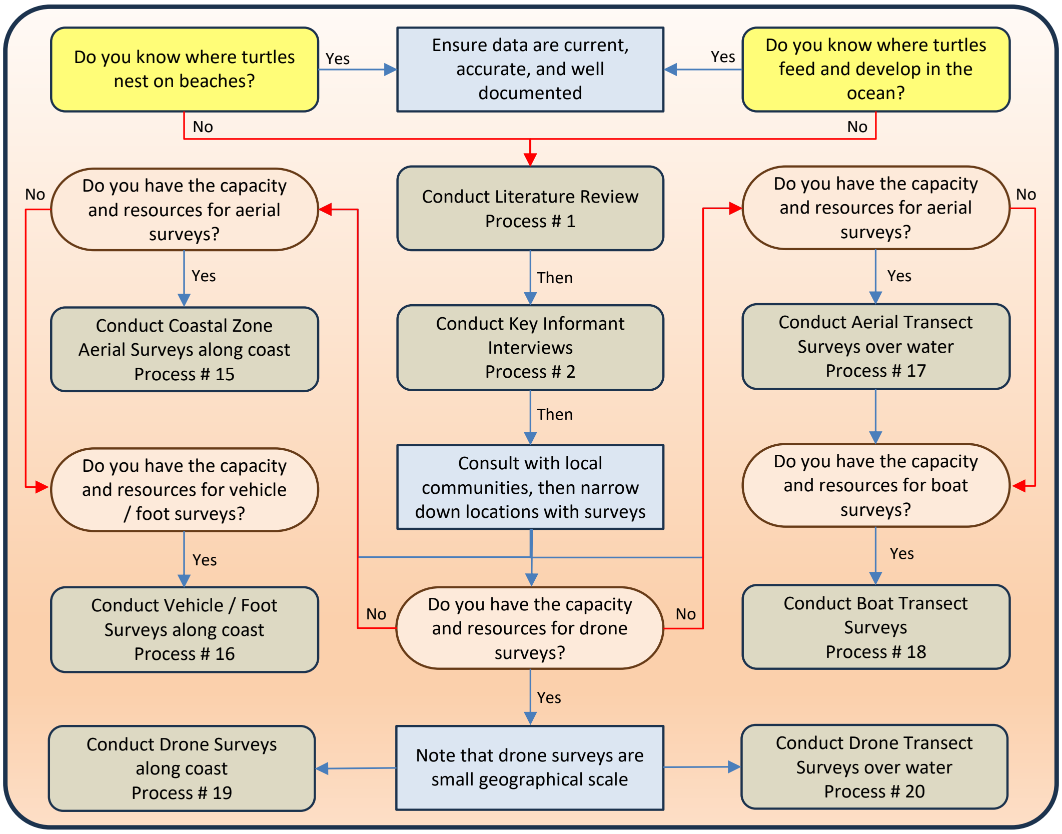


Figure 8: Decision-making steps related to the turtle nesting & foraging habitats.

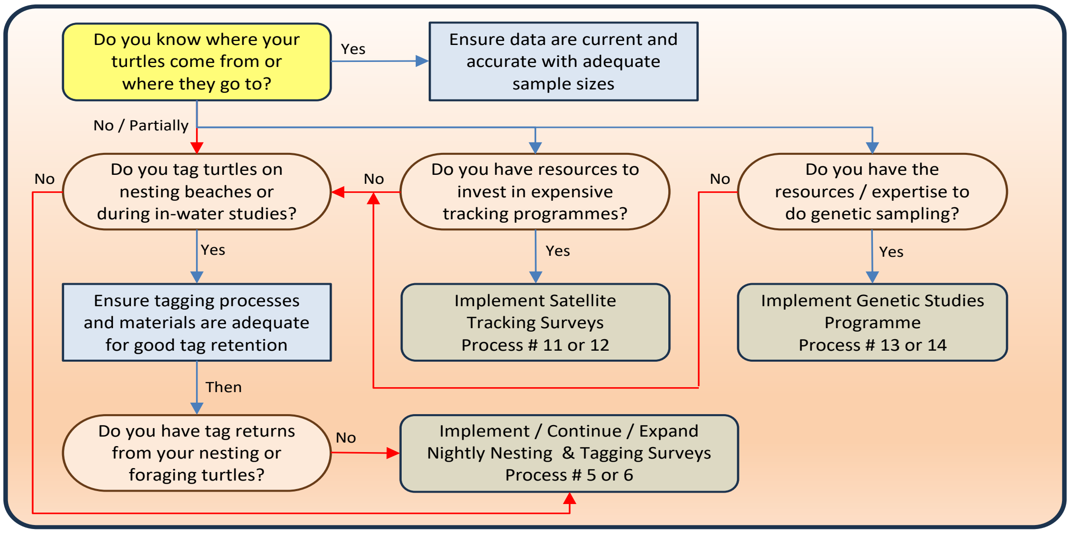


Figure 9: Decision-making steps related to turtle movements and dispersal.

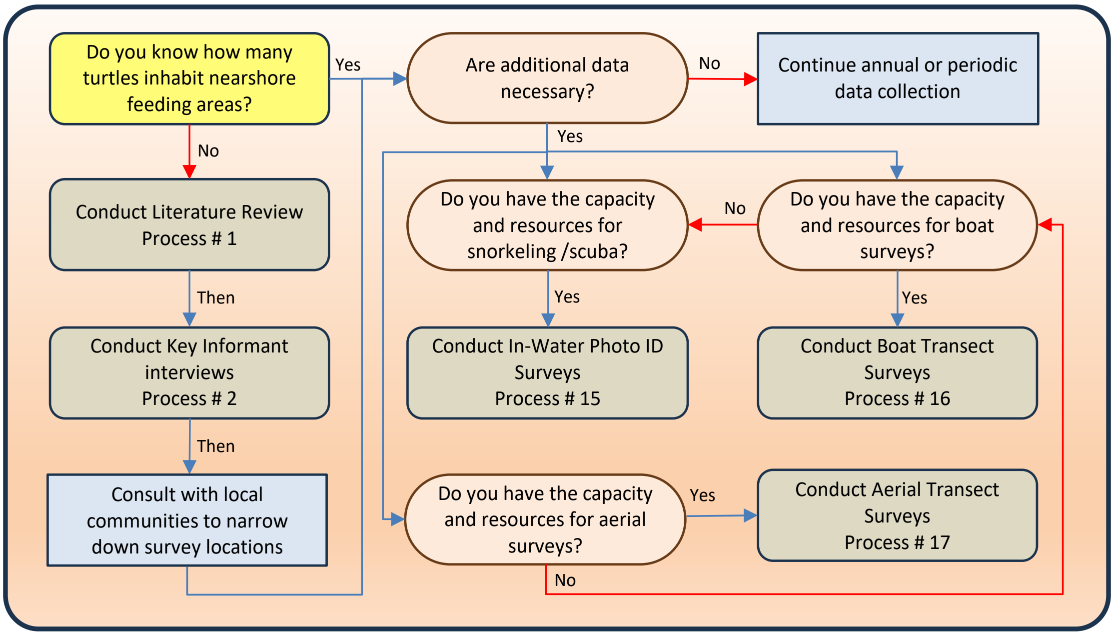


Figure 10: Decision-making steps related to determining turtle abundance in foraging areas.

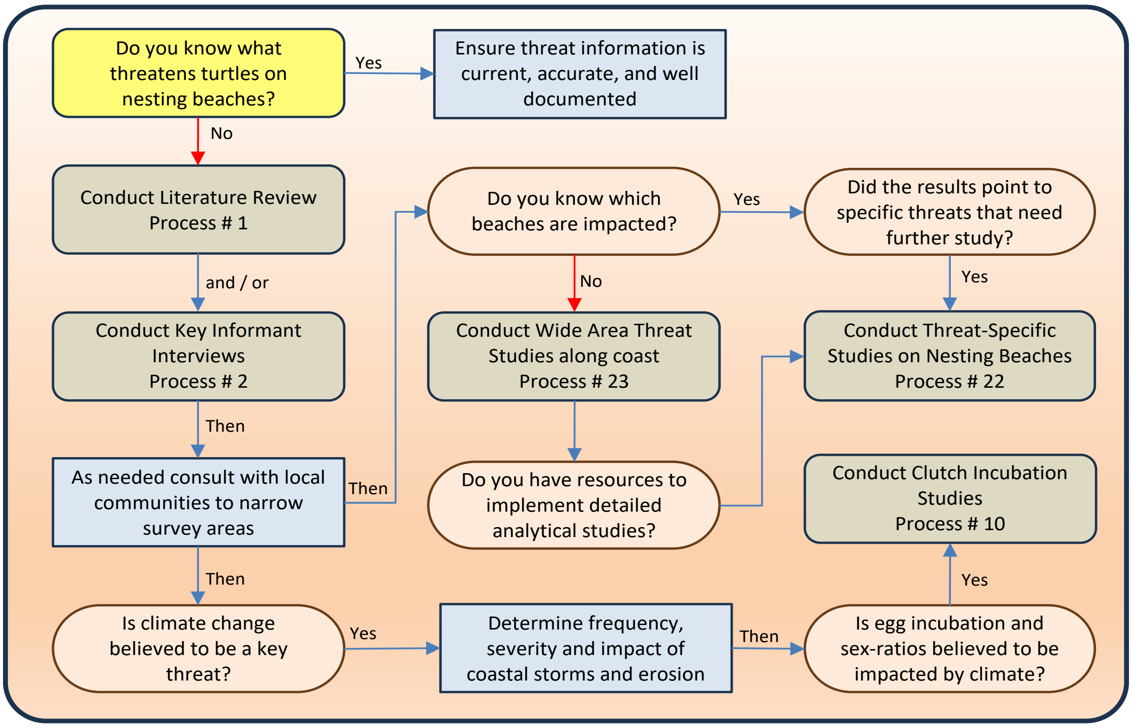


Figure 11: Decision-making steps related to threats to sea turtles on nesting beaches.

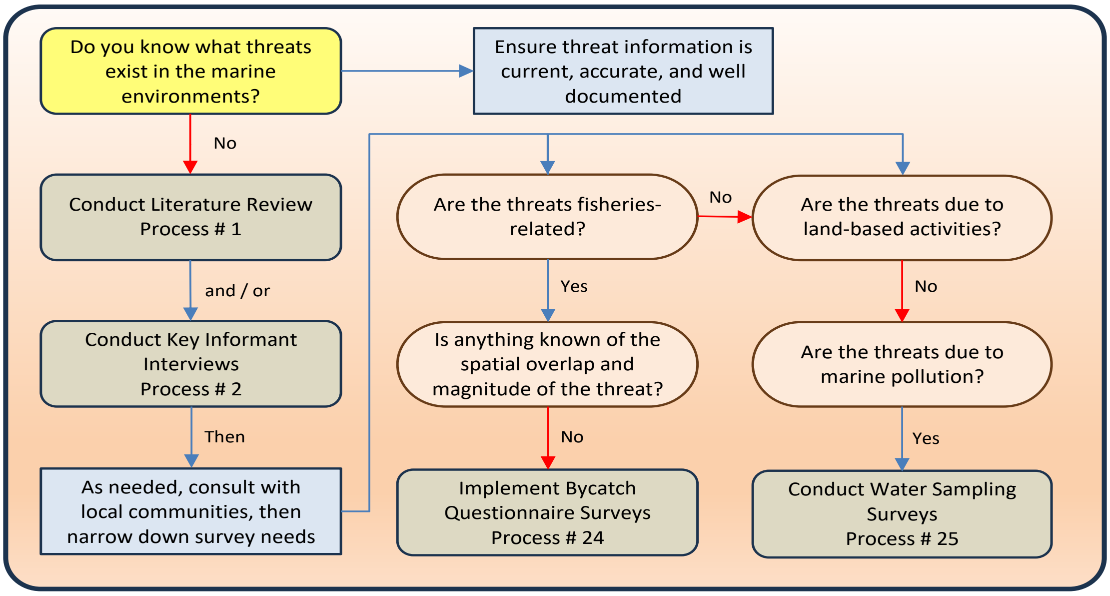
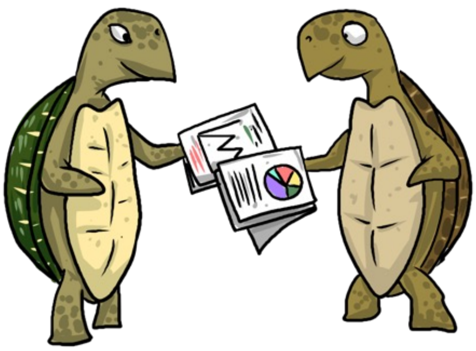


Figure 12: Decision-making steps related to threats to sea turtles in the marine environment.

As I mentioned right at the very start, the idea is not to present every single possible research or monitoring option on the table. Rather, my goal is to present you with some of the more common questions you may ask, and responses to those – and particularly questions that might resonate with your conservation and management needs: How many turtles do I have? Where are they? And what are the threats? The data that flow out of most of these studies can also feed directly into many global and regional assessments, and increase the overall value of your efforts.



If you have access to good modelling statisticians, your life might be made easier by using a combination of beach surveys and statistics. If you – like me – are the sort of person who likes to be out in the field, these methods are designed with you in mind. I hope the descriptions guide you in your research and monitoring, and also hope that they help streamline your work plans and allow you to make the best use of the resources you have. There are a couple of themes that are common to many of the research topics, and I touch on these briefly in the nest section.

OVERARCHING CONCEPTS

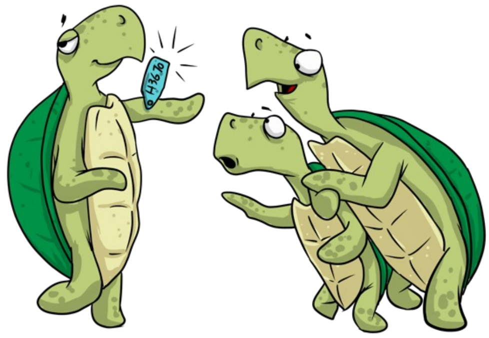
Just before we get started on exactly how one gets the job done, I would like to take a moment and reflect on some overarching issues that are applicable across multiple processes, and also some thoughts related to permits and ethical approvals, and on health and safety. These topics transcend many of the Processes I present below, and while they are bound to differ from country to country, the general concepts should be the same for everyone and everywhere.

A WORD ABOUT TAGGING…

Turtles are usually tagged to provide individual recognition in subsequent recaptures and to prevent re-sampling of the same individual. Tagging turtles is a useful research tool but is not a necessity for sea turtle studies. If the objective is simply to count turtles during a short field expedition, short-term recognition can even be achieved using spray paint to mark the carapace. This typically lasts about two weeks in the natural environment. So as we discuss tagging as it relates to identifying a turtle, I thought it was worth pointing out that there are many ways to identify a turtle - not all need to be flipper tags. But there are some advantages to different types of tags that make a discussion on tagging worth a brief detour here.

Flipper tags are visible. If someone sees them at a later date, they usually have some form of return address or contact that allows us to track down the team that originally deployed the tag. In today's world of internet connectivity and online tagging databases this is becoming easier and easier. A key downside to flipper tags is they don't last forever. They can fall off after a number of years (good tagging practices can lead to far longer retention times, but poor tagging practices can mean turtles lose tags nearly before they leave the beach!) and this means we might one day find what we think is a 'new' turtle, but that was previously a tagged turtle that we cannot identify. Another downside is one has to deploy a large number – and I mean a huge number of tags – to get returns that really start to paint a picture about turtle movements.

One tag return does not tell us much other than a turtle went from here to there. We don't even know if that was the final destination, because maybe turtle was captured half way through its journey. We don't know if this was a typical movement, or a movement practiced by a large proportion of the population. Australian researchers have deployed hundreds of thousands of tags by now, and yet there are less than 1,000 international tag returns... What then are the chances of getting meaningful returns if we deploy 30 tags on a beach one year?



The upside of course is that flipper tags are relatively cheap, and require only modest skills to deploy, and can help identify turtles for a few decades, and because of this they are a common tool used by researchers across the world.

There are other tags, such as PIT tags – this stands for Passive Integrated Transponder and sounds like it came from a Marvel comic – that mostly do away with the tag loss issue, but come with other drawbacks. A PIT tag is inserted with a large syringe into the shoulder muscle of a turtle and because it is internal it is very rarely lost. But to read the tag you need a special digital magic wand gizmo that costs around $1,000 and not everyone carries one in their back pocket. And also, because these tags are internal one cannot see them just like that. So if a fisherman catches a PIT-tagged turtle he would never know it, and therefore not report it.

Another emerging way of 'tagging' turtles is with the use of facial recognition. The scale patterns on the sides of a turtle's face normally do not change much over time and allow us to reidentify a turtle we have seen before from past photographs. And the great thing is we really don't need to capture the turtle in the first place. Or the second! We could take photos of turtles underwater or on a beach and check these against others in the future to track turtles through space and time. Here again, I am sure you can already see some challenges…

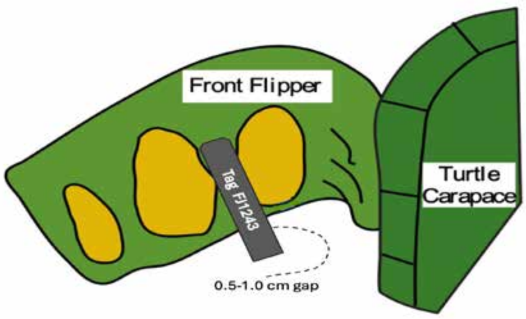
What if the photographs are not uploaded to a public site for cross-referencing? What if the person who 'recaptures' the turtle doesn't think of taking photographs? How would I recognise a turtle from its face when I'm out on a remote beach in Ulithi and don't have my laptop? Despite these, with the right programmatic design, there is ample scope for use of facial recognition in turtle research and monitoring. Just the other day I was suggesting this very tool to a team out in the Cook Islands…

At the end of the day, the choice of tag will depend on what exactly you want to know. Do you want someone else to be able to find your tags? Do you want to know remigration and renesting and clutch frequency at your site with a high degree of accuracy? Or do you want to know if turtles you sight underwater stick around or if they use multiple feeding areas. Do you need information over a large area? Over a short time-frame? Do you need it to be accessible to others? Do you need to know turtles by name, or simply by number of nesters?

In all fairness (to the turtles and to the resources incurred in a tagging programme), for a tagging programme to be effective there must be a commitment to future surveys and compiling data from tag returns. If used, tags should at least conform to the following characteristics: (a) They should be individually numbered and carry a return address; (b) They should be long-lasting (titanium or stainless-steel alloy); (c) They should be recorded in a master database, and then individual turtles should be linked to specific tag numbers; (d) They should not be used if they are heavily corroded or might be lost easily.

Turtles should be tagged on the proximal trailing edge of each front flipper to reduce the chances of abrasion, entanglement and tag dislocation. Tagging is a two-step process: (1) clamp the applicator so that the sharp point pierces the flipper and (2) apply greater force to ensure the tag point bends over and securely locks into rear of tag. Check carefully to ensure the tag is securely attached, and that the sharp point of the tag has looped through the receiving hole and curved into a locking position (it is possible – and undesirable - that the sharp point curves back under the receiving side of the tag, or outside of it, and this will lead to rapid tag loss). Try to leave a 0.5–1.0 cm gap between the trailing edge of the flipper and the rear edge of the tag when tags are applied to adult turtles, and up to a 1.0 cm gap between the trailing edge of the flipper and the rear edge of the tag when tags are applied to juveniles.

Some other pointers on tagging: Try to tag turtles when they have completed covering the nest cavity with the rear flippers to minimise the possibility of disturbing the turtle, causing her to abandon the nesting effort.



Tag turtles that emerge but fail to nest when they are returning to the sea, as they will usually return to nest at a later time or date. Tag number and placement (i.e. which flipper) should only be recorded after tagging has been completed successfully. Tags can break on application and must be discarded, and it is possible to forget to change the number if it is pre-recorded. Only the tag that is actually placed on the turtle should be recorded.

Finally, a reminder that tagging is just a tool. It does not save a turtle; it simply identifies it so that it can be recognised at a future encounter. Tagging projects need to consider if they plan on revisiting beaches and looking for their tagged turtles, or if the number of turtles they tag have a realistic chance of informing on such topics as migrations, remigration intervals, and renesting events. If these are unlikely, it is possible tagging is not the right tool for the job.

PRIMARY TAGS

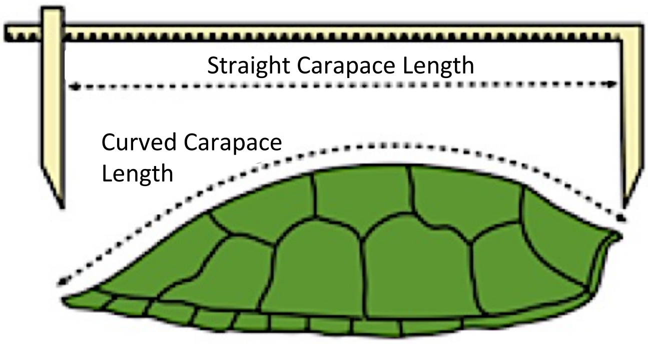
It is worth taking a few minutes here to go over Primary Tags in a bit more detail because it relates to how we store tagging data. By its very name you are right in assuming it is the first tag we ever apply on a turtle. Or at least one of the first, if we apply more than one tag (as in double flipper tagging, which is common). From a database point of view, the Primary Tag now becomes the unique turtle identifier for life – the turtle's name, if you wish – and even if the turtle were to lose that particular tag (provided of course that we could figure out which turtle it was through some other secondary tag), this is the identifier through which we would track every sighting record for this specific turtle. Think of it as giving a turtle a name.

Primary tags in practice: Let's say we tag a turtle with NC3476 on a left flipper. This becomes the Primary Tag, or the turtle's name, like calling her Freddy. On that day or at some point in the future Freddy (NC3476) might get a secondary tag on the right flipper. Let's say NC3480 for sake of argument. If we recaptured Freddy and for any reason tag NC3476 had been lost, we could still find her in the database via tag NC3480. But we would not start a new turtle life history record in the database with NC3480, would we? We already know this is turtle Freddy (NC3476) because these tags are linked, so even though she no longer carries that tag, this is the tag that we would look for in the system to identify Freddy. The turtle might get a new tag that day to replace the lost one, and become NC3490(left) / NC3480(right). But the primary tag would still be NC3476 in the system, and by this name we can keep track of the turtle through time. Of course, if she were to lose both tags, or only have the one tag and lose that one, we would not know that this was a previously-tagged turtle. But that is why we put two tags on, so that this rarely happens. I do hope this makes sense, because you will need to use Primary Tags in your data fields if you start a tagging programme.

SOME THOUGHTS ON MEASUREMENTS

Sea turtles are measured to provide an indication of general population characteristics, sometimes to determine the minimum size at maturity and at other times for subsequent re-measurement at later dates to enable calculations of growth rates. If measurements are needed on a nesting beach, then it is a good practice to wait for the turtle to finish laying eggs before collecting measurements. Whether working with adult or smaller turtles, it is a good practice to have two independent team members measure a turtle, because in the heat of the moment, busy on a boat or on a dark beach late at night, it is easy to make mistakes. Record these two measurements on a data sheet or tablet and make sure they are sufficiently aligned to give you an accurate size for the turtle. Remember that turtle growth is slow and measured in mm, so there is no point having coarse measurements to the cm that will not accurately reflect the turtle size. If you are going to the trouble of measuring the turtle, you might as well get it right. Also, consistency in measurement taking is critical for later comparisons and analysis.

Curved measurements are taken over the curve of the carapace with a fibreglass tape measure (± 0.1 mm). Straight length measurements are taken with callipers (± 0.1 mm) to record the straight-line distance between one point and another. Any barnacles or other organisms growing where measurements are to be taken should be removed with pliers beforehand.



DETECTION ERROR

The concept of error, and how to deal with detection issues and account for nests or turtles that are missed during beach surveys, or aerial surveys over water or the coast, is worthy of another detour here. Detection error can be a really difficult thing to deal with in normal turtle studies, and often some sophisticated modelling is required to account for detection error so that data sets are as realistic as possible.

Imagine that you want to determine the number of turtles nesting on a beach, but the survey teams miss a small percentage of turtles each night… would your end of year counts be accurate? And if not, by how much? Or if you miss a turtle during a night survey, was it one of the tagged turtles from earlier in the season, or a new turtle to your programme? Mistakes resulting from imperfect detection during research sampling can introduce errors into the data.

On a nesting beach, some errors include double-counting (two researchers count the same turtle), misidentifying turtles (we could mis-read the tag number, or transcribe the tag number incorrectly into our data sheet), or even overlooking turtles that were present during a night patrol but not recorded by the team. On a crowded beach, it is often the case that turtles get overlooked because tracks all overlap.

During aerial surveys, some common detection errors include nondetection (this is when we don't detect a turtle even though it is present), counting error (inaccurate counting of group sizes), and species misidentification (incorrectly identifying the turtle species). Nondetection errors can occur when a turtle that is there is missed by the observer, or because a turtle is unavailable for detection (e.g. under water). Counting errors can happen when observers either over- or under-count the number of turtles on a transect. If turtles are gathered in large numbers, it might be difficult to accurately count them from a fast-moving aircraft. Species misidentification can lead to un under-count of one species and an over-count of another, and is made worse by the speed of the aircraft and distance from the observer.

During coastal surveys, whether by airplane or drone, one type of error involves the number of nests prior to the aerial survey that were no longer visible. If you have the opportunity to record nesting on a stretch of beach for several days before conducting the aerial surveys, you would be able to determine what proportion of nests on the beach were present, but not detected by the survey, and correct for this error. A second type of error deals with the number of nests present (and recorded by ground teams), but missed by the aerial survey team. This is the one you need to minimise as much as possible. The last type of error involves the number of nesting events that occurred after the aerial survey. If you are not able to correct for these errors, it is likely your aerial survey will underestimate total nesting activity. In these cases however, you would have indicative data to which beaches were most important for sea turtles, and be in a position to focus efforts in these areas.

As we've seen when discussing turtle assessments, monitoring data are important indicators of turtle population status, but the data must be reliable. At the population level, there are two main kinds of conservation assumptions we could make: we would conclude a turtle population is threatened when in fact it is not, or we could conclude a population is not threatened when in fact it is – and you can see how problematic that could be. The challenge lies on collecting data that is as free of detection errors as possible.

THREATS EVALUATION

Threats to sea turtles and their habitats are addressed briefly in Chapter 1, and additional detail is provided in Annex I. There is also a Process on threats in the section below that goes into quite a lot of detail. But I thought it would be useful here to quickly put threats management into perspective, and briefly discuss the *relative impacts* of threats. Does a threat impact a very large segment of the population, or just a handful of turtles? This is a consideration to make when considering threats. Or is one threat an acute short-term threat while another is a more pervasive long-term threat?

The reason I think these are important considerations is because we might end up putting a lot of effort and resources into resolving a threat that has less of a population-scale impact, and overlook more important challenges turtles may face. You could think of it as a priority-setting exercise: First determine all the threats to turtles, and then determine the relative impacts of each. Are the impacts long-term? Do they impact many turtles or just a handful? Would the resources be better off spent solving one problem over another? There is no one single response to all these questions because threats and threat magnitudes – and also turtle population sizes – vary across the region. But rather than assuming a threat is going to doom a turtle population, it is worth being reflective and objective when approaching threat mitigation options.

PERMITS AND ETHICS APPROVALS

In most countries there are legal mandates that will require you to obtain a permit to undertake research on sea turtles. Often these are administered by natural resource-related government agencies, such as Departments of Conservation or Environment or Fisheries or Marine Affairs. You should conduct your own due diligence checks for permit needs before you start any sea turtle studies and make sure you meet the country's requirements. This is particularly the case if your team has foreign personnel, who often may require additional paperwork.

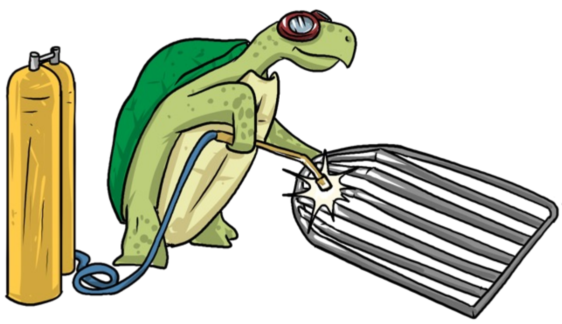
In many places, academic institutions require humane care for institutional use of (or research on) animals and have an Institutional Animal Care and Use Committee (IACUC) to review and approve research plans, regardless of the funding sources. IACUC approval is generally always required before conducting research involving field activities using wildlife when studies involve more than just unobtrusive observation.

There are also ethical considerations of conducting research – particularly if this involves people or sea turtles - and the publication of that data. For example, it would be inappropriate to make public the names of people from anonymous interviews, and any form of process that might harm a sea turtle would need clearance and possibly even participation from someone like a trained veterinarian. Any work with local communities should at a minimum adhere to the spirit of Free, Prior and Informed Consent (FPIC) of the United Nations Permanent Forum on Indigenous Issues, and be appropriate to local customs and cultures of the people among whom you work.

These considerations are typically governed by ethics boards at Universities, NGOs and government institutions. I recognise that a lot of this work will be implemented in remote locations by government agencies and NGOs that may not have ethics boards of their own, and that some countries might not have ethics approvals processes. Given this, and being respectful of human rights and animal welfare, it would be prudent to develop your own ethics statements and guidance process that reflect the ethics requirements of places like mainstream Universities or ethics approvals boards in other countries. Examples of these can be found online at key academic and government institutions, and many journals might also provide examples, as they very often require an ethics statement if you intend to publish data from your work.

HEALTH AND SAFETY

The studies I present in the following pages are extremely varied and it would be impossible to list all potential health and safety considerations for you and your teams. However, the mere mention of health and safety should give you an idea that this is a serious consideration in any study. A team I worked with in Papua New Guinea came face to face with a 4m crocodile. This is a real health and safety consideration! If you use ATV bikes for your work, they bring with them hazards such as speed accidents, burns and pinch points. Sunburn and dehydration are real concerns when walking beaches and doing surveys on land. Aerial surveys are inherently risky because aircraft fly at low speeds, close to the ground with little margin of error. Crossing large stretches of ocean to get to remote islands and nesting beaches is fraught with other risks.



At a minimum you and your team should develop a health and safety plan and a risk assessment for the work you are about to undertake. You should think of all the possible things that might occur, and develop appropriate responses and procedures to anticipate these and bring risks down as much as possible. You should know how to contact emergency first responders.

You should have backup plans to your backup plans, and you should always be in a position to call for help. At the end of the day, a health and safety plan is really only in place for you and your team, to make sure work is undertaken in a safe, considered manner, and so you come home safely when it is all done. Sea turtles will always need you and your teams to be able to do this work, and you should take all possible risks into consideration when developing your research plans in a way that you never run into trouble.

SEA TURTLE & HABITATS RESEARCH OPTIONS

As I have already mentioned several times, the idea of this manual was not to present every single possible research or monitoring option available to the planet. In the following tables we will take a look at some detailed descriptions of each of the most common survey methods used by science and management teams around the world to better understand how many turtles they have, where they are located, and what threats exist. There are also some brief notes on these top 25 questions, outlining some of the pros and cons of each different approach, listing some of the more basic tools you will need to get the work done, and then providing a set of sample references so that you can see how some of these methods have been used, and some of their limitations and values. Later on, in Annex II there is a list of published works where these tools have been used in the field. All of those citations should be easy to download from the internet, or by asking for help on public forum lists such as CTURTLE (CTURTLE@lists.ufl.edu). Copies will also be kept on a server with SPREP.

And now, let's get to the heart and soul of the manual – how to actually get things done!

STUDY PROCESS DESCRIPTIONS FOR 25 KEY SEA TURTLE STUDIES IDENTIFIED IN THE DECISION MATRICES

Process #1	Pros	Cons	Frequency	Tool(s)	Refs
(1) Literature Review	Internet connectivity means much data is available via online searches; Rapid; Inexpensive; Requires little prior skills	Older data may not be digitised and available online; Sourcing non electronic data time-consuming and challenging; Requires an understanding of what to look for	Once	Computer; Internet access; Personnel time	1, 2, 3, 4
Description					

A review of existing literature is quite a straightforward process and one that is often overlooked when starting out. In this case I am referring to background literature searches of what is already known related to the subject at hand. This is not to be confused with more academic literature reviews as dedicated studies. There are numerous ways to conduct a background literature search, and a lot depends on what you need out of the search. Do you want to find out something about your area? Or are you trying to exhaustively discover everything that has ever been published on a specific subject? These are two extremes of the same process.

As we have discussed above, a lot of the design of your search will be based on the question you are asking. Also, a literature search is a bit of a discovery process because as the name implies, it is a search and you do not know just how much you will find. A good rule of thumb I use is whenever I have exhausted my search, I keep searching a little more because there's surely a useful bit of information still left out there that I haven't discovered.

Literature searches should ideally start close to home and spread out from there. If you are looking to find out what is known about turtles in your area, the best places to look are right next to you. Consult with colleagues, consult with other government agencies, and consult with NGOs working in your region. Sometimes someone there will know of some past study that was done or some data that was collected and be able to point you in the right direction. Then expand your search to the vast repository of data that is available online.

Literature searches today are made easier because of the internet, but not everything ends up on the internet. Recall that earlier we discussed examples of studies that do not get published and therefore remain unknown. But the internet is the next best place to look after you have personally consulted with colleagues close to home. There are online search engines such as Google Scholar (https://scholar.google.com), Scopus (https://www.scopus.com/home.uri) and the ISI Web of Knowledge (https://mjl.clarivate.com/search-results) along with several others, and these are good initial search options. These sites tend to only look for published information, and because not all data and reports get published, it is useful also to use regular search engines such as Google, Chrome, Safari, Bing, Yahoo, and any others you are used to, in addition to the more scientific sites. Often unpublished reports might show up at these sites and not on the more scientific ones.

Then comes the art of getting hold of copies of reports and information you find on the internet. A lot of search engines will have links to file downloads, and these obviously are the best way to start. On other sites you might find a report but that report is not available via a download link. In these cases you have several options: (1) you can look at the title page of the report and see if the author's email is listed and write to them – that's the simplest way by far; (2) you can find out who was the author – or authors – and try to search for them personally on the internet. You could search for something like *first name, last name, email* and see what comes up. If the lead author is not listed, maybe try one or more of the other authors; (3) you could look at the authors' affiliations and write to those institutions directly to see if they can put you in touch with the author(s); (4) you can look on other search engines in case someone has uploaded a copy and it just happened that the first search engine you used couldn't find it; (5) you could send a request to public list servers (e.g. CTURLE listed above) and across chat groups to see if anyone has a copy.

Maps and charts can often highlight potential nesting areas. For example, mangrove-fringed coasts typically do not support nesting, but island habitats often do. Extensive shallow areas along the coast generally represent shallow muddy substrates unsuitable for nesting. It is important to ground-truth information taken from maps and charts as these are not always at a scale that can reveal specific coastal types.

The key thing about the literature searches is to approach them as a detective would approach solving a mystery case: you need to use key words to describe your search and get the most out of your efforts. There are bound to be ways of finding out what has been done previously, and you just need to be a bit creative in digging through piles of information to find the special bits you need. But you need to be focused and search for specific key words that help you narrow down your search. For example, if you type *sea turtle* into a search engine you are likely to get millions and millions of hits. My search engine just came up with "About 246,000,000 results" so there – millions of hits. But narrow that search down and it gets a bit easier. When I asked my search engine for *sea turtles Fiji* this is how many results it found: "About 36,500,000 results". Take that a step further and type *sea turtles Fiji foraging* and we're down to "About 822,000" results with the very first paper being "Soundscape of green turtle foraging habitats in Fiji, South Pacific". You should get the idea by now – be specific about the key words in your search, and you will (usually) get focussed responses.

Process #2	Pros	Cons	Frequency	Tool(s)	Refs
(2) Key Informant interviews	They provide additional insight on data that may have been gathered from other surveys and/or to complement the literature on a topic; They are conversations with experts who possess first-hand knowledge, experience and/or expertise on the subject matter under investigation; Information comes from knowledgeable people; Inexpensive and easy to implement; May explore other ideas and topics	Not appropriate if quantitative data are needed; May be biased if informants are not carefully selected; Can be susceptible to interviewer biases; May be difficult to prove validity of findings; There is a potential for the interviewer to unwittingly influence the responses given by informants; Systematic analysis of a large amount of qualitative data can be time-consuming	Once, follow-ups as needed	Access to local community members; Transport; Voice recorder; Notebook	5, 6, 7, 8, 9

Description

Key informant interviews are qualitative in-depth interviews with people who know what is going on in the area. The interviews could be a rigorous study, or even just a phone call to an 'expert' to get their insights and advice informally for background knowledge. The purpose of key informant interviews is to collect information from a wide range of people who have first-hand knowledge about the sea turtles in your area. Key informant interviews can be used to get information about sea turtle nesting or feeding in an area from a limited number of well-connected and informed community experts. The interviews can also provide input on motivation and beliefs of community residents on a particular subject, or to discuss sensitive topics, get respondents' candid discussion of the topic, or to get the depth of information you need.

Community experts, with their particular knowledge and understanding, can provide insight on the specific topic you are interested in – turtles - and might even give recommendations for solutions to local issues. Probably the most common technique used to conduct key informant interviews involves face-to-face interviews. Normally a trained practitioner will work with local community members to identify those people who might know the most about a subject, and speak to them and ask a set of structured and unstructured questions. Often these key informants (in our field of interest) are village elders, community or traditional leaders, hunters and sellers of turtle products, owners of businesses or traditional traders, and fishermen who spend their lifetimes at sea.

It is important to collect and review existing research data and reports (see Process #1) before determining what additional information needs to be collected from key informants, as the information you are looking for may already exist. Next, you need to identify the information you want to gather. Once you have drafted your primary questions, next determine what type of data is needed. For example, do you want to collect data on a community practice, on turtle nesting activity, on turtles at sea, or on something like bycatch? The type of data needed helps you identify the best people to interview. It is also important to carefully select the key informants. Remember key informants must have first-hand knowledge about your topic - sea turtles and threats they may face. Also, key informant diversity is important: if you only interview people of a particular background or sector you may end up with results that are one-sided or biased

You will need to prepare an interview tool (like a questionnaire sheet) to guide the discussion and make sure your questions are answered. The interview tool typically contains an outlined script and a list of open-ended questions relevant to the topic you would like to discuss. Begin with the most factual and easy-to-answer questions first, then follow with those questions that ask informant's opinions and beliefs, or topics that may be sensitive, such as turtle use and bycatch. End with questions that ask for general recommendations. Don't be afraid to ask probing questions during your interview, as these help to clarify informant's comments and get detailed information.

Finally, you need to compile your interview information to make sure that the data was collected efficiently, was of high quality, and was consist across interviews. Interviewers should be good listeners, have strong communication skills, be able to take detailed notes, be detail oriented, and comfortable meeting and talking to new people. For consistency it is wise to only have one or two designated interviewers.

This fantastic resource https://healthpolicy.ucla.edu/programs/health-data/trainings/Documents/tw_cba23.pdf Is a great source of information for designing and planning key informant interviews, and internet searches for *Key Informant Interview Methods* will yield many more such articles. These interviews can come in many shapes and sizes, and a lot depends on what information you want, and who you have the opportunity to speak to. However, a lot can be learned by asking the right questions of the right people, and these interviews can serve as a launching pad to many of your subsequent research and monitoring efforts.

Process #3	Pros	Cons	Frequency	Tool(s)	Refs
(3) Full Season Track Counts	Less manpower intensive than night-time saturation monitoring; Less costly than night-time monitoring; Provides a total number of nesting attempts per night; Can provide data on nesting success; On small / remote beaches may be done with a drone; Can provide spatial (GPS) nest location data	Does not distinguish by individuals; Cannot provide clutch frequency data; May not detect species differences; May not detect nesting success accurately	Annual	Foot patrols, ATVs or Vehicles	10, 11, 16, 20, 23, 33, 37,
Description					

Counting the tracks from nesters that emerged during the previous night is among the simplest and easiest measures of nesting activity. The counts can be done by walking, or driving an ATV or vehicle, or riding a horse along the beach. It takes one person (or two for added safety) and is normally conducted early in the morning before the high tide washes away the fresh tracks from the night before.

The premise of this survey is to simply count the number of up and down tracks from turtles that emerged at night to nest (and divide by two for actual emergences per turtle!). For added refinement, one could record the location of the tracks or the nests, as a way of providing a measure of spatial distribution of the nesting activity.

On the first morning of the survey, it is useful to 'cross out' any previous tracks so that these are not counted again the following day. Normally the research team uses a long stick to put a deep line all the way through the track. On the first day it might be hard to distinguish between the immediate prior night's nesting activity and older tracks, and -unless the team are extremely experienced - sometimes they use the first day simply to cross out all tracks so that the following day the counts are all of only new 'uncrossed' tracks.

As the research team progress along the beach, tracks are 'crossed off' or otherwise marked and a record is kept of the track event. As noted above, a GPS can be used to pinpoint the distribution of nests, although this is not a critical task. It does however help point to the areas of beach most important to turtles.

Turtle species can be identified by the gait and the width of the tracks, so that if more than one species uses a beach the activity can be attributed to specific species. Hawksbill turtles tend to be substantially smaller than Green turtles, and they move with an alternating gait (one flipper goes forward at a time). Green turtles are substantially larger and move with a synchronised gait (both flippers move forward at once). Therefore narrower tracks with an alternating gait might point to Hawksbill turtles, and wider synchronised gait comes from Green turtles. Leatherbacks are massive, and their tracks are something like 2m wide, so these are unmistakable. Loggerheads, another species that occasionally is found in the Pacific region as a nester, are as large as green turtles but move with an alternating gait. Wide tracks with alternating gait? Probably a Loggerhead. The challenge might come with Olive Ridley tracks as these are very hard to distinguish from those of hawksbills… narrow and alternating gait. But given there are so few Olive Ridleys nesting on Pacific islands is likely not a major issue.

A last thing that can be done during the track counts is to try and get a sense of how successful nesting has been. Once teams are comfortable interpreting nesting activity, the results of this sort of assessment can get more and more robust. But teams need to be able to distinguish between a successful nesting attempt and an unsuccessful one if they are to make any substantial contribution to this metric. If not, they could be counting unsuccessful nests as successful, which would have implications for total number of nest estimates later on. Recall that once we know the number of tracks, it is a simple calculation to determine the number of nests *if* we know how many tracks result in actual nests. For example, if we had 100 tracks, and we knew that on average only 65% of emergences resulted in nests, then we could estimate total number of nests in that instance as 65.

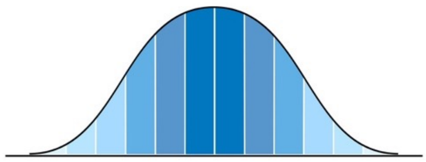
One option is to classify nests as 'successful', 'unsuccessful' and 'unknown' to account for the times a research team did not know the outcome of an event, and then only calculate the proportion of successful nests out of those where the outcome was reasonably well known. But a better option is to mark successful nests at night and come back in the day to look at the tracks and the digging activity to best understand what turtles do and what it looks like.

And that is as complicated as it gets. The teams simply progress along a beach in the morning before the high tide washes away fresh tracks, counting and crossing out tracks from the night before, and arriving at a total number of nesting attempts by species for each location. These track counts are a valid metric to be used in contributions to regional and global assessments of nesting activity.

Process #4	Pros	Cons	Frequency	Tool(s)	Refs
(4) Peak Season Track Counts	Less manpower intensive than night-time saturation monitoring; Less costly than night-time monitoring; Can provide data on nesting success; On small / remote beaches may be done with a drone; Can provide spatial (GPS) nest location data; if implemented correctly alongside periodic full-season monitoring) can provide statistically valid long-term data	Does not detect all tracks in the season; Tracks outside of the monitoring season can only be deduced from concurrent full-season periodic monitoring; does not distinguish by individuals; cannot provide clutch frequency data	Annual	Foot patrols, ATVs or Vehicles; Notepad; Camera; GPS; Tags and applicators; Tape measures	10, 12, 13, 23, 37
Description					

As the name implies, these track counts are the exact same thing as described above, but they are only counted during a specific period during the nesting season - typically during a two- to three-week period during the peak of the season. But the one key difference when using this approach is that it requires an understanding of what the nesting season 'looks like'. What I mean by this is that the team needs to know in advance if there is a peak season, and when that occurs and for how long it lasts. If not, how would we pick a peak monitoring period?

And take note that nesting seasons can all look quite different. In many areas turtles start to arrive in small numbers, reach a peak of nesting at some point, and then that nesting trails off (as in this graphic). Sometimes these 'seasons' can be more than six months long (a very flat curve), an in other cases only two or three months long (a very high and compressed curve).



If you already have an idea of when the peak nesting season occurs, you could sample only during the peak and be reasonably sure to encounter a large proportion of the season's nesters. This is because many 'early season' nesters would still be nesting, and many of the nesters at the time also comprise 'late season' nesters. The exact distribution of nesting activity varies by location, but normally the closer one is to the equator, the more consistent nesting is year-round with a less obvious 'peak', and the further away from the equator one gets, the more pronounced the 'season' is, and within that the peak nesting period.

There are several variations on the peak season or non-saturation monitoring. Teams can count tracks for a certain number of days across the season, or a set day per week (some good examples are explained in the SWOT Minimum Data Standards). But in all these cases a good statistician is needed to help you determine the total number of nesters (you also need other data such as tagging data), and provide comparisons between complete nesting seasons and peak nesting seasons. These analyses also usually require some concurrent full season surveys every four to five years to provide comparisons between 'peak season' and full season data.

While needing some good statistical skills is a requirement for this approach, the reduced amount of annual fieldwork might make this method attractive when access to remote beaches for long periods is a challenge.

Process #5	Pros	Cons	Frequency	Tool(s)	Refs
(5) Full Season Night Monitoring	Allows for collection of additional information such as nesting success, clutch sizes; Provides an opportunity for tagging, enabling future capture-mark-recapture studies; Extremely accurate Allows identification of individual turtles; Provided quality initial training, does not require highly trained personnel; Can provide clutch frequency data (important in understanding reproductive output)	Relies on substantial time and manpower investment (all - or at least Index - beaches need to be monitored for the entire season); Can be exhausting for field personnel; May need several teams in rotation	Annual	Foot patrols, ATVs or Vehicles; Notepad; Camera; GPS; Tags and applicators; Tape measures	10, 16, 37, 108
Description					

These surveys are really the heart and soul of most sea turtle monitoring programmes around the world. They involve having teams on the beaches at night, when turtles emerge to nest, to record nesting events, tag sea turtles, determine nesting success, and conduct all kinds of other studies. The vast majority of night time surveys on nesting beaches adopt these seasonal night time monitoring exercises, and gather a wealth of data. The downside to these surveys is that they are extremely labour intensive, and might not always be what you need to do to get the information you need.

For example, if all you needed to know is how many nesting events there were in a year, and track these numbers over time, there is probably no need for such a resource-demanding process. And this is a perfectly suitable measure of nesting activity. If, however, you also wanted to determine things like renesting intervals, clutch frequency, and other research aspects that were tied to the individual turtles, then these more intensive surveys might be just what you need. A lot depends on the question you need answered.

An understanding of reproduction and nest biology is a valuable tool for conservation and management of sea turtle stocks. Without this knowledge, well intentioned, but ignorant, conservation efforts can be detrimental to sea turtles. The nesting beach provides a narrow but important window for studying sea turtles, and night time monitoring can yield a wealth of data.

What do night time surveys entail? Well, to start with they take place at night, when turtles emerge to nest. Patrol teams usually are on the beaches from sunset until several hours after midnight, and patrol for the majority of the season, collecting data on species, date and time, measuring turtles, applying tags, assessing nesting success, sometimes counting numbers of eggs per clutch. Or marking nests, or deploying temperature data loggers, or a wide range of other activities to find out more about their sea turtles. As has been said often by now, a lot depends on the question. Some of the individual topics are dealt with in the following sections, but it is worth taking a moment here to address some of the basics, and also some issues related to tagging – as this is often one of the key reasons you might want to embark on night time surveys.

Timing: If the idea is to determine the total number of turtles using the beach(es) in a season, then you need your teams to be on the beach at the start of the season, and continue monitoring all the way up to the end of the season. This could be a long time, and might be a drain on human resources you can't afford. Other teams might have loads of volunteers, or community members, or staff even, that can spread the load and make it easier on a per-person basis.

Turtles typically nest at night. That is not to say a few turtles will not nest during the day also, and so it is worth patrolling the beaches occasionally during the day just in case. This is particularly so on overcast days or later in the afternoons when it is not so hot, as turtles generally avoid the hot sun and warm temperatures. If you are combining your night time nest patrols with daily track counts (see Process #3), this would be a good opportunity to determine just how many turtles you miss from day to day, and try to fill some of the blank times in between to catch those missing turtles.

What to look out for: Nesting turtles are wary of lights, and of movement. So people walking down or driving down a beach with lights on and swaying from side to side might dissuade a turtle from nesting. Normally beach patrols are done at the waters' edge, looking for emerging tracks from nesting turtles, and also keeping a watch forward for any emerging nesters. Once an emerging track is located, the team can slowly and 'stealthily' follow the track until the encounter the nesting turtle. At this stage they should assess what stage the nesting process has reached, and determine a course of action.

If the turtle has just emerged, and there are sufficient people to continue monitoring, then a team member could stay behind to carefully count the eggs as they are deposited, resulting in a confirmed clutch count. The team members can also score nesting emergences as being successful or not, as a measure of nesting success. And finally, they can interact with the turtle itself.

Process #6	Pros	Cons	Frequency	Tool(s)	Refs
(6) Peak Season Night Monitoring	Less manpower intensive than full-season monitoring; Less costly than full-season monitoring; If implemented correctly alongside periodic full-season monitoring) can provide statistically valid long-term data	Cannot detect all animals nesting in a season; Precludes population modelling as not all turtles are 'captured' by the monitoring programme; less robust data sets than from full season monitoring	Annual	Foot patrols, ATVs or Vehicles; Notepad; Camera; GPS; Tags and applicators; Tape measures	37, 109, 110, 111

Description

Much as in the case of Peak Season Track Counts (see Process #4), as the name implies these night monitoring programmes are also conducted only during the peak of the nesting season, or during specific defined periods that can be used in mathematical modelling to provide a picture of the entire season. In many projects they are conducted during a two- to three-week period during the peak of the season, and as with the track counts, they rely on the assumption that many 'early season' nesters are still nesting, and many of the nesters at the time also comprise 'late season' nesters. These surveys are really only useful when a substantial amount is known about the nesting populations so that the peak period can be established, and so that data can be extrapolated using mathematical models.

Most of the same data sets that are made possible during the full season monitoring can also be collected during peak nesting surveys. One of the key exceptions to this is clutch frequency, as female turtles are only counted over a short period and it is not possible to count *all* nesting emergences per tagged turtle in a season. But there is no reason why nesting success and clutch counts cannot be established, or why turtles cannot be tagged and measured. A lot depends on what is needed from the research programme.

Finally, as in the case with track counts, these data need the attention of a good statistician or modelling expert to help extrapolate from the peak counts to season estimates.

Process #7	Pros	Cons	Frequency	Tool(s)	Refs
(7) Nesting Success Studies	Relatively low cost; Need not cover the entire season; Can monitor a short period over a subset of the nesting habitat; Requires only simple observation skills; Not overly time consuming and can provide a robust estimate of nesting success at a greater regional level	May not be representative of all nesting habitats if these differ substantially; Requires monitors who can assess nesting success without disturbing turtles; Requires a certain degree of academic rigour in the design and implementation, rather than simply counting tracks	Once, with periodic updates	Foot patrols, ATVs or Vehicles to access beach; Notepad; GPS	10, 100, 101, 102, 103, 104
Description					

The purpose of this type of study is to determine how many nesting attempts result in actual nests by monitoring a subset of nesting events. As we have discussed earlier, you can count tracks on a nesting beach as a measure of nesting activity. But not all emergences (tracks) end up as nests. This is because sometimes turtles are disturbed while attempting to nest, or they do not find a suitable place to nest. They might wander along a beach trying to nest several times but end up returning to the sea, and this sort of event would be considered an unsuccessful nesting attempt.

These studies are typically conducted with a subset of beaches, or along a portion of a beach, or with a subset of turtles on a beach, during a defined period. The key requirement is to standardise the sampling protocol and then keep to it in the field, so that you end up with a robust and defensible measure of nesting success. For example, you may decide to determine nesting success for all turtles that emerge one week on a particular beach, regardless of the nesting outcome. You might find that seven emergences out of ten result in an actual nesting event, for a 70% nesting success rate. Or you might find a lower or higher rate, depending on how 'suitable' the nesting environment is for sea turtles.

These surveys need not cover the entire nesting season, but need to be sufficiently robust and structured to provide reliable nest success information that is representative of the location and the nesting season. Normally one or more observers establish with complete certainty whether a nesting emergence results in a nest by waiting on a beach for the turtles to emerge, and then following the turtles individually until they either lay eggs or return unsuccessfully to the sea. This is not the same as estimating the success of a nesting event by looking at the nest the following day: nesting success studies require actually being there and seeing the turtle lay eggs in order for the attempt to be scored as successful.

It is often useful to mark the successful emergences somehow and revisit those the following day, to get a good 'feeling' for what a successful nesting attempt looks like. These observations can be used to estimate nesting success from day time track counts, but are really no replacement for actually observing the activity at night when the turtles actually emerge.

Some examples of how a survey like this might be structured is to plan to track a minimum of 30 actual emergences over a certain period to determine if they are successful; or to track all emergences on a certain beach for five nights at different times in a season, or to track all emergences on only a certain portion of beach for some defined period of time. It is also useful to spread this effort over time, and try to encompass different environmental conditions (e.g. full moon and new moon) so that the nesting success proportion is as realistic and accurate as possible.

Process #8	Pros	Cons	Frequency	Tool(s)	Refs
(8) Clutch Size Surveys	Relatively low cost; Does not require specialised equipment, and is not required for every single clutch on the beach; An adequate sample size that is representative of total nesting events will suffice	Requires having people on the beach and that they wait with each turtle until it starts to lay eggs, and who are in position behind the turtle to carefully count the eggs until the clutch is complete	Once, with periodic updates	Foot patrols, ATVs or Vehicles to access beach; Notepad; GPS	10, 16, 34, 39,
Description					

As a measure of reproductive output, this is one of the more important metrics you can collect on a nesting beach, after track counts and nesting success, and involves determining the exact number of eggs deposited by a subset of female turtles on a nesting beach over the season. Knowing how many eggs is inside each clutch can tell us a lot about overall reproduction in sea turtles, and being able to track this metric over time also allows us to determine if turtles are getting enough food to be in a position to develop and deposit the typical hundreds and hundreds of eggs in a season.

Sometimes people try to get clutch size estimates when they excavate the nests after the hatchlings have emerged, but it is more accurate to do this as turtles deposit the eggs, rather than during nest excavation, because counts of broken shells may not provide exact numbers of eggs. That is not to say that excavation estimates are not a good idea – in the absence of anything else, this is a great way to find out how many eggs might have been deposited and estimate hatchling production. On remote beaches, where access is a challenge, if you were to run across an emerging bunch of hatchlings, excavating the nest would give you a good idea of the original clutch size. If this is indeed how you determine clutch size, then it is important to understand that it is a close estimate, and not the exact number of eggs, simply because as hatchlings crack open the eggs and emerge, the egg shells typically break into pieces and reassembling them into perfect eggs is a massive challenge.

It is usually a good idea to get counts for around 10 to 15% of nesting activity, to derive an estimate of clutch size on a beach where there is quite a lot of nesting, so that it is representative of the overall population. On a beach where there is less nesting activity, it is a good idea to increase this overall sample size (beyond 10-15%) so that the results are reflective of what actually happens on the beach. For example, if you only get 20 nests in a year, counting the number of eggs in only two of them might not be as representative of the overall population, and you might want to increase the proportion of the total population upwards, maybe up to half of all nests. I don't want to get into a detailed discussion on statistical power and sample sizes, but it should be fairly obvious that if you have 1,000 nests and you establish clutch size in 100 of these, the average value is likely to be quite representative. But if you only have 10 nests and only count clutch size in one nest, this is unlikely to be representative of all nesters.

This survey work can be (and usually is) combined with nesting success work (see Process #7), as the survey teams are already on the beach watching carefully to see if each turtle lays eggs. If the turtle does lay eggs, it is only a slight amount of extra work to stay there and count the number of eggs in that clutch. This sort of work is also normally a standard part of night time nesting beach work (see Process #5) as you would already have teams working on the beaches, tagging turtles, determining nesting success, and counting eggs deposited into each nest.

If you knew the total number of tracks, and you knew nesting success and clutch size, you could estimate the total number of eggs deposited in a season by: # tracks × nesting success (%) × avge. clutch size.

Process #9	Pros	Cons	Frequency	Tool(s)	Refs
(9) Hatching / Emergence Studies	Relatively low cost, only requires investment in time and resources to accurately mark the nests; Does not require specialised equipment or personnel	Requires being able to mark nests in such a way that they are found after two months of incubation, and multiple other nesting attempts, possibly in the same location; Requires being on the beach both when eggs are laid and again a few months later when they hatch; Subject to disturbance by other nesters, loss of the markers, depredation, and simply not being able to find the marker when needed	Sub-sample of nests, annually	Foot patrols, ATVs or Vehicles to access beach; Notepad; GPS; nest markers, potentially the use of RFID chips that are placed in the nest to aid in relocation	10, 38, 105, 106, 107

Description

As a last measure of reproductive output on a beach, it is useful to know how many live hatchlings make it out of a nest and down the beach to start their lives in the ocean. There are two types of counts that science teams usually conduct, and one of these involves determining the number of eggs that hatch and produce live hatchings (down in the depths of the nest), and the other one is determining the number of hatchlings that emerge from a nest (up on the beach surface). The difference between these two counts is simply any hatchlings that emerge from the eggs but for some reason or another do not make it to the surface of the sand. Sometimes they are weak and debilitated, other times they may get stuck on some obstruction. It is not unusual for only a subset of eggs to reach embryonic success, and therefore the teams need to be able to count the number of eggs that were infertile (often these are clear or translucent when a light is directed through them) and also the eggs that did not reach full term (dead embryos). It is a great day when these emergence and hatching success are the same, because it means that all hatchlings that made it out of the eggs also made it to the surface, but it is likely that 5% to 15% of the eggs may not survive into hatchlings. When values are lower than this, it is likely there is a problem with incubation.

Most survey teams typically count emergence success - as this is what truly matters in terms of reproductive output – what proportion of eggs result in hatchlings that become part of the turtle population. Some teams determine hatching success as a way to measure the suitability of the incubation location / material / conditions. But at the end of the day, knowing how many hatchlings make it out of a nest and into the ocean is the metric that contributes to estimating total reproductive output.

Normally nests are marked as they are deposited, and are dug up following emergence to determine hatching success. When teams are conducting full season or peak season nest monitoring, they are in a position to mark the nests so that these can be found a few months later when hatchlings are expected to emerge. But there are multiple challenges in this process. To start with, you need to be able to mark the nests in a way that you can definitely find it a few months later, after many other turtles have been on the beach moving sand around, and after storms might have obliterated any original beach shape. Some people do this by marking the nest with a wooden, numbered stake, recording the GPS location, and then making this location more accurate by triangulating the marker in relation to some non-moving structures (trees or bedrock features are a good choice). GPS location data is rarely more accurate than about 5m, which means that re-locating a marker using only GPS information would place the marker point in a circle with a 5m radius, or some 75 sq m! Other teams use expensive real-time kinematic (RTK) GPS data, which can be accurate to around 10cm, but this technology is exorbitantly expensive.

However, today there are new technologies that might help with nest relocation in the form of RFID chips: you have likely heard of people tracking their luggage as it gets lost in the airline industry using chip-based devices, and these days this technology is finding its way into sea turtle research. There are now devices on the market that can be detected using the Bluetooth reader on a smart phone, and some of these devices can be quite innovative, sending nest temperature and other information. The benefit of this new technology is that once you know the general location of the nest, the Bluetooth reader on a mobile electronic device can be used much as one would use a metal detector to narrow down the location of the actual nest.

Emergence success is usually best determined by being present when the nests hatch, but this is often quite impractical – especially if you do not have a team monitoring the beaches each day during the hatching and emergence season. Baby hatchlings making their way across a beach are usually the first clue that a nearby nest has emerged, for which no original clutch size data are available. It is also usually possible to collect all hatchlings that emerge from a nest (unless they are penned in), as they crawl rapidly to the sea, and there may be multiple emergences from one nest over several days. Imagine a scenario where your team finds a few hatchlings on a beach, but where the majority emerged the evening before…

It may therefore prove necessary to excavate the nests. At this point, much as in the case of establishing clutch counts (see Process #8), you have to estimate clutches size from egg shell fragments, and determine emergence and hatching success from these estimates.

At this point you are well on your way of knowing pretty much all you need to know in terms of reproductive activity and output for turtles on your beaches). Following on from clutch counts (see Process #8), if you knew or could estimate emergence success you could calculate total reproductive productivity by # tracks × nesting success (%) × avge. clutch size × emergence success (%).

Process #10	Pros	Cons	Frequency	Tool(s)	Refs
(10) Clutch Incubation Studies – A. Incubation temperature	Relatively low cost; Can be deployed as sea turtles lay eggs; Once deployed the loggers require little maintenance; Drops in temperature as clutches emerge assist in determining incubation period; Can record temperatures outside of the nesting season to help understand temperature limitations to nesting	Easy to lose if accurate data are not available for nest (or logger) location; High location accuracy involves RTK GPS which is extremely expensive; Requires up-front calibration for realistic data	Once for spot checks, annual for ongoing monitoring	Temperature data loggers (e.g. iButton, Tinytag, HOBO)	10, 24, 32, 40, 54
Description					

In the past, temperature was recorded in turtle nests using an old-fashioned mercury thermometer, or with sensors attached to cables that allowed research teams to get periodic readings of the temperature inside of a turtle nest during incubation. Today technology is so advanced that there are numerous data loggers on the market that can record temperature, humidity, and various other parameters, miniaturised circuits and batteries that can last an entire nesting season. Some examples of these include Hobo (www.onsetcomp.com), iButton (www.ibuttonlink.com), and TinyTag (www.geminidataloggers.com). These loggers can be programmed to collect information at regular intervals, and are often set to collect temperature data on an hourly basis.

By deploying accurate and calibrated temperature data loggers in clutches to determine temperatures throughout the incubation period you will be able to find out if nests are experiencing lethal temperatures, whether they are producing more female than male hatchlings (if you know a few other things, like incubation period and regional pivotal temperatures). In some cases, you can also determine when the hatchlings emerged, because often the temperature in the nest experiences a sudden drop as all of the hatchlings depart.

As you can imagine, retrieving these loggers is extremely important, because you need to download the data at the end of each season. The same challenges apply here as they did in the hatching success studies, with regards to marking nests and being able to find them again at the end of the season (see Process #9).

Some research teams place on logger inside the middle of a clutch of eggs (you have to be on the beach when the eggs are being deposited in the nest by the turtle…). Other teams place multiple loggers in one nest – with one on the top, one or more in the middle, and one at the bottom. A lot depends on what you want to learn. Other teams place loggers in the middle of the clutch, and also loggers in similar depths of sand but with no eggs. The difference between the records of these two loggers can then be used to calculate metabolic heat – the amount of heat given off by the eggs and embryos as they develop.

But for most practical purposes, team want to know what the temperature is inside of a nest to better understand the incubation environment in which the eggs develop. Some of this is linked to concerns over climate change and increasing temperatures in nests – and what this might mean for sex ratios of the emerging hatchlings. Other concerns may be linked to human activities – for example if eggs are moved to a hatchery, one would want to make sure the temperature regimes were similar to those the eggs might experience under natural conditions.

Finally, a thought on sample sizes: these loggers are not necessarily cheap (costs can range from around 30 to 200 USD each depending on quality and the number of sensors, memory size and battery capacity) so figuring out how many to use in a study is important. Without going into a discourse on statistics and sample sizes, suffice it to say that a single logger is unlikely to be representative. Normally teams might deploy loggers in five to ten nests on a less active beach, and ten to twenty (or even more) on a more active beach. They also are likely to vary the location of the loggers so that some are far up the beach, some in the middle, and others down closer to the sea. Again, a lot depends on the question at hand – do you want to know the overall incubation environment, or is there a reason you might want to know differences in different environments along and up and down the beach?

Armed with incubation temperature data, you would be in a position to determine if nests were incubating outside of normal ranges, whether storms and inundation events cause lethal temperature shifts, estimates of the proportion of male and female hatchlings being produced, and be in a better position to figure out what might be affecting embryonic development inside the nests.

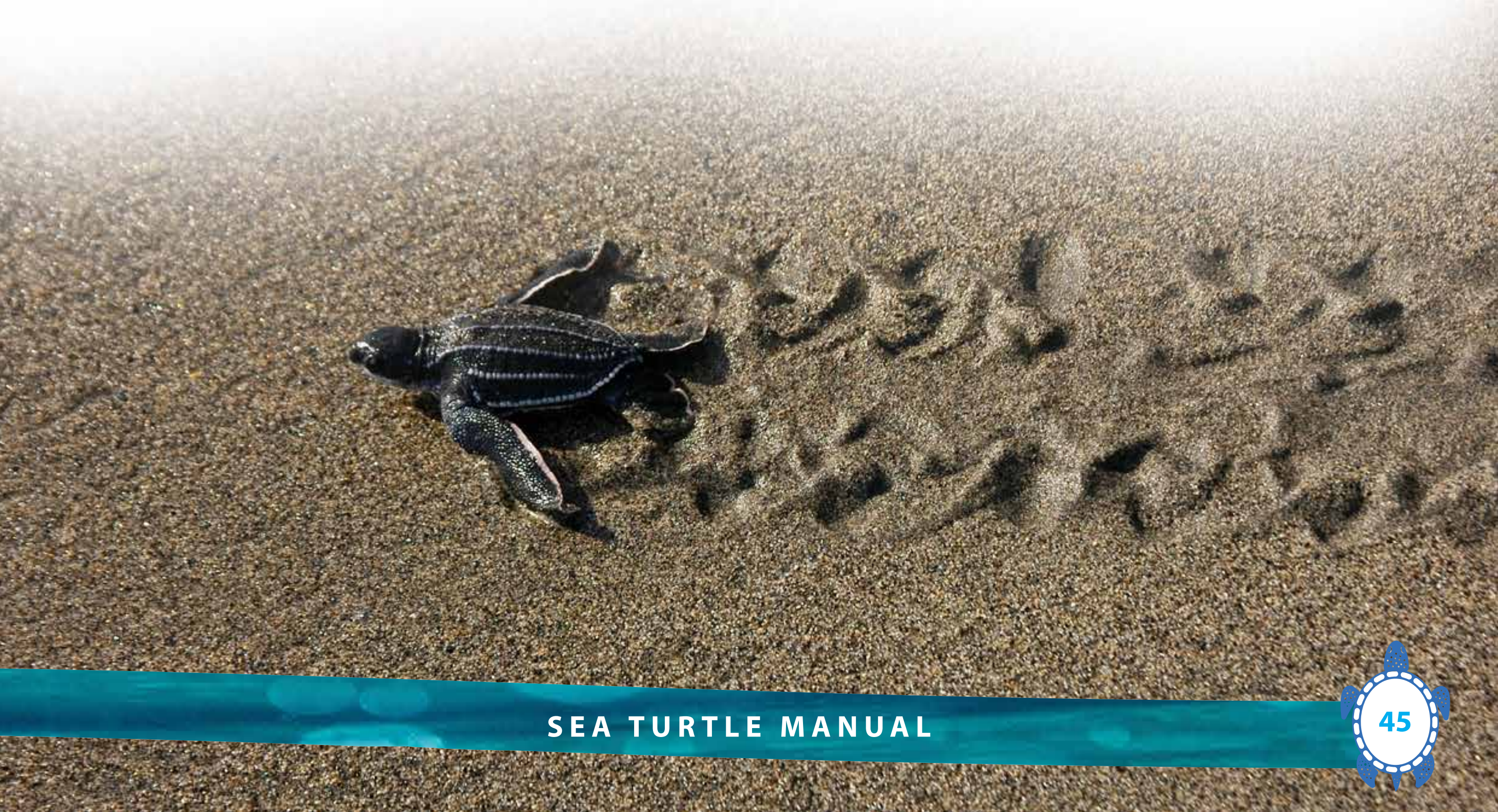
Process #10	Pros	Cons	Frequency	Tool(s)	Refs
(10) Clutch Incubation Studies – B. Sex ratios	Does not require sacrificing sea turtle hatchlings; Is relatively simple when incubation period and temperature are gathered via nesting beach monitoring efforts; Provides a 'quick and easy' estimate of offspring sex ratios and potential impacts of climate	Because pivotal temperatures vary across the globe for each species, the pivotal temperature from one place is generally not directly applicable to another; The output is only an estimate and not completely realistic until controlled incubation temperatures provide accurate pivotal temperature data	Once for spot checks, annual for ongoing monitoring	Temperature data loggers, beach monitoring programmes that provide accurate information on incubation periods	24, 96, 97, 98, 99
Description					

As we have seen earlier, temperature determines what proportion of turtle eggs become male or female turtle hatchlings. It is important to be able to assess the sex ratios of sea so that the conservation implications of skewed sex ratios can be considered. The challenge is that determining the true sex of a hatchling sea turtle can really only be done by sacrificing hatchlings or using occasional dead hatchlings found in the nest. Their sex can then be determined by careful morphological examination of the gonads or by histological examination (looking at the cell structure). Given the endangered status of sea turtles, sacrificing small hatchlings is rarely an option, and so indirect methods of estimating sex ratios are necessary.

A different and less intrusive approach involves the use of Predictive Equation Studies. One way to do this is to use the temperature of nests (or of the sand at nest depth with corrections for metabolic heating) to diagnose sex, rather than using gonadal histology. When data on sand or nest temperatures for a beach are not available, incubation durations may be used to predict sex ratios of emerging hatchlings. Given it takes a few days for hatchlings to get from egg to the beach surface, these few days need to be subtracted from the time from egg deposition to hatchling emergence to arrive at incubation periods.

Both of these approaches rely on information that relate temperature to sex ratio, which are obtained from laboratory experiments. These experiments tell us what the pivotal temperatures are (the constant temperature yielding 50% of each sex) and transitional ranges of temperature (those ranges of incubation temperatures that produce both sexes). Using the laboratory data, the temperature of nests in the field may then be converted into sex ratios for those nests. In cases where the pivotal temperatures are not known, as is the case for much of the Pacific region, we can often rely on proxy data from the closest nesting locations for which this may be known (e.g. Australia).

Once we know the incubation temperature, and incubation duration, and have either real or proxy data on pivotal temperatures, it is a fairly simple process of using a formula to predict the sex ratio of hatchlings. Of course, there are multiple challenges in studies such as these, and these are linked to sample size, knowing exactly when hatchlings hatched (rather than emerged), and having access to pivotal temperatures that are representative of the region in which you work. But they do eliminate the need to sacrifice hatchlings and for careful laboratory studies, and so these are very often used to derive *indicative* estimates of male and female hatchlings produced on a beach.



Process #10	Pros	Cons	Frequency	Tool(s)	Refs
(10) Clutch Incubation Studies – C. Incubation duration	Relatively low cost, only requires investment in time and resources to accurately mark the nests; Does not require specialised equipment or personnel	Requires being able to mark nests in such a way that they are found after two months of incubation, and multiple other nesting attempts, possibly in the same location; Requires being on the beach both when eggs are laid and again a few months later when they hatch; Subject to disturbance by other nesters, loss of the markers, depredation, and simply not being able to find the marker when needed	Sub-sample of nests, annually	Foot patrols, ATVs or Vehicles to access beach; Notepad; GPS; nest markers, potentially the use of RFID chips that are placed in the nest to aid in relocation	112, 113, 114, 115, 116
Description					

A last important metric when studying egg development in sea turtles involves the study of incubation duration. As we have seen above, predictive equations rely on knowing incubation periods, but there are also practical uses of this knowledge, in that teams can predict when nests might hatch and be present for hatchling emergence. Incubation duration should not be confused with the time from egg deposition until the time turtle hatchlings are found on the beach, because hatchlings take several days to reach the beach surface after emergence form the eggs.

As with hatching success studies (see Process #9), determining incubation periods involves marking nests on the day they are deposited, and monitoring them during the incubation period, paying particular attention to the days leading up to the expected hatching. Sometimes a small conical depression will appear in the sand as the clutch of hatchlings is about to emerge, providing a visual cue. Sample size is once again important, and the greater the number of nests that can be practically monitored, the more robust your estimate of incubation duration will be.

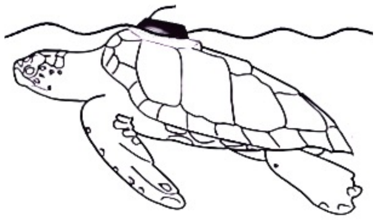
As noted above, the use of temperature data loggers can help with this estimate because there are drops in temperature as the eggs hatch and hatchlings emerge from the nest. As technology improves and becomes cheaper, it is likely that most estimates of incubation period will be derived from temperature studies rather than requiring people to be on the beach when hatchlings emerge (a major challenge in the Pacific region due to the remote location of nesting beaches, costs and logistical constraints).

Finally, the combination of temperature data derived from loggers and incubation period calculations also allows very accurate estimates of temperature during the middle third of incubation (when sex is determined) and to establish transitional temperature ranges. These data can help paint an accurate picture of incubation conditions, and allow for better interpretation of potential impacts of climate change, and human impacts.

Process #11	Pros	Cons	Frequency	Tool(s)	Refs
(11) Satellite Tracking Studies – Post-nesting using Argos-linked data	Provides relatively accurate (+/- 1 km) accuracy of movement paths; Enables pinpointing the foraging area with relative accuracy; Depending on transmitter duration, may provide return migration data; Depending on when tags are deployed in the season, may identify internesting habitat extent; Provides excellent visibility and public awareness opportunities via online maps, press releases, social media and web-based platforms	Accuracy of Argos data is low, so precise movement data are not available; Behaviour states can only be inferred by changes in movement patterns; Requires multiple deployments over several years (to account for interannual differences) to get a general understanding of linkages; Relatively high cost	Once, dependent on sample size	Argos data satellite transmitters	10, 26, 42, 95
(11) Satellite Tracking Studies – Post-nesting using GPS linked data	Provides extremely accurate (+/- 50 m) accuracy of movement paths; Enables pinpointing the foraging area with high degree of accuracy; May identify mating areas; Depending on when transmitter is deployed in the season, may provide estimates of clutch frequency; Can identify internesting habitat extent; Provides excellent visibility and public awareness opportunities via online maps, press releases, social media and web-based platforms	Requires multiple deployments over several years (to account for interannual differences) to get a general understanding of linkages; Higher unit cost than Argos tags but similar tracking costs	Once, dependent on sample size	Fastloc GPS satellite transmitters	27, 41, 94, 95
Description					

In these tracking studies, female turtles that have completed nesting are equipped with satellite transmitters that relay signals to ground stations that are then forwarded to you and your research team, and allow for the identification of habitat linkages, and also the actual movement patterns between nesting areas and foraging areas.

Normally this work is done at night, when project teams patrol the nesting beaches in search of nesting turtles. Preference should be given to turtles which have already laid eggs, so that egg-laying behaviour is not compromised. Following nesting, turtles are usually restrained in some way so that the transmitters can be affixed, and most teams build boxes out of wood with no top or bottom for this purpose.



Next comes the attachment of the transmitters. There are numerous manuals and published protocols on transmitter attachment but the two most common involve the use of either epoxy glues or fiberglass resin. Each come with a set of advantages and disadvantages related to availability, drying times, a 'mess' factor, and personal preferences. With both methods, the attachment zone needs to be sanded with rough sand paper to make it abrasive, and then cleaned with alcohol and a cloth several times.

A surgical-grade elastomer rubber-like compound can be used as a base between the transmitter and the turtle, as the transmitter is flat and the turtle shell is rounded. The transmitter is then affixed to the centre line of the carapace at its highest point, slightly overlapping the front-most scute, so that the antenna breaks water when the turtle surfaces to breathe. The most popular satellite tag manufacturers (e.g. https://wildlifecomputers.com, https://www.lotek.com) provide manuals and even attachment kits with each transmitter to make life easier for researchers.

Tags need to be pre-programmed so that they can collect information at the right times and so that they can distinguish when the tag is out of the water, but again the manufacturer guidelines are very good at explaining these processes. What is important is that the transmitters are securely fixed to the turtles, are turned on prior to deployment (my personal number one rule of satellite tracking!), and that careful records of the entire process are maintained so that turtles can be distinguished individually.

Satellite signals are then available from a service provider (usually a company called Argos - www.cls-telemetry.com) and come in two forms: Argos positions or GPS positions (often called FastLoc). The difference in the two lies in the accuracy of the data. Argos data are based on the acquisition by a satellite of several signals sent by the transmitter. These data are inherently of poorer accuracy because they rely on signals being sent over large distances (from a turtle to a satellite!) and on the movement of the satellite. If a turtle breathes at the surface for five to six seconds as the satellite passes overhead this results in a high-quality signal. But if the satellite is emerging over the horizon when the turtle is on the surface, the angle of incidence is low and the accuracy of the data decreases. Similarly, if the turtle dives when a satellite comes overhead or surfaces as one is departing, the contact is insufficient for an accurate fix. While data can be accurate with lots of high quality-signals we typically think of Argos data being accurate in the 500m to 1,000m range.

FastLoc data on the other hand relies on a miniaturised GPS sensor inside of the transmitter. As the turtle surfaces, the sensor uses GPS to figure out where the turtle is, and send this information to the satellite. This FastLoc data can be accurate to 5-10m instead of 500 to 1,000m.

But as you can already imagine, FastLoc transmitters are substantially more expensive than simple Argos data units. The choice, as you can already imagine, depends on what your question is to start with. Do you wish to know generally which way turtles move across the Pacific, and generally which route they take, or do you wish to know where turtles live in a particular bay, or if they come back to nest on the same beach time and time again? If the question is more about general movement patterns, it is likely that the cheaper Argos solution is more than sufficient for your needs. But if you need detailed location data that is extremely accurate, it is likely that FastLoc is the option for you.

Once you have downloaded the data from one or more turtles, the next challenge comes in interpreting that data. There are some powerful modelling tools available if you have access and the right skills, but 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.

All points that are received after tag deployment and before a purposeful departure point from the nesting site can be categorised as internesting (the period when turtles may be laying additional clutches of eggs). Within these data sets, each approximate two-week block during of internesting behaviour could be considered a subsequent nesting event based on known internesting interval for sea turtles. 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 error and variation than Argos data.

The location data on feeding areas can be used to develop maps of important turtle habitat, and science processes usually narrow down these sites via "home range analyses" which involve the delineation of the areas in which an animal conducts its "normal" activities. These analyses focus on Home Ranges, which can be likened to "areas traversed by a turtle in its normal foraging, exploratory, and development activities" and Core Areas, or "those areas where turtles spent over half of their time". Occasional forays outside of these areas, perhaps exploratory in nature or as flee reactions to predators, do not get considered as part of the home ranges or core areas. Being able to map these areas allows us to be in a better position to protect them in some way, or restrict activities that might impact sea turtles, and this is a key reason why tracking studies are done in the first place.

To end this section, it is worth keeping in mind some thoughts on sample sizes and data interpretation: One track from A to B does not tell us much about a population. It tells us a lot about that particular turtle, but it is not until we have a robust sample size that we can start to make inferences on where turtles go after they finish laying eggs, or where they come from. Another thing to consider is what the 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 that signals were lost along the way and that this could not be established? 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.

Process #12	Pros	Cons	Frequency	Tool(s)	Refs
(12) Satellite Tracking Studies – In-water, using Argos-linked data	Provides relatively accurate (+/- 1 km) accuracy of movement paths; Enables pinpointing the nesting area with relative accuracy; May identify mating areas; Depending on transmitter duration, may provide estimates of clutch frequency; Can identify internesting habitat extent; Provides excellent visibility and public awareness opportunities via online maps, press releases, social media and web-based platforms	Requires labour-intensive captures of turtles either via rodeo captures or netting; Accuracy of Argos data is low, so precise movement data are not available; Behaviour states can only be inferred by changes in movement patterns; Requires multiple deployments over several years (to account for interannual differences) to get a general understanding of linkages; Typically requires linking to laparoscopy studies to select turtles in breeding condition; Relatively high cost	Once, dependent on sample size	Small dedicated catch boat, or small fishing boats with large-mesh nets (500m - 2000m long, 2-3m deep), Argos data satellite transmitters	10, 30, 89, 90
(12) Satellite Tracking Studies – In-water, using GPS-linked data	Provides extremely accurate (+/- 50 m) accuracy of movement paths; Enables pinpointing the nesting area with high degree of accuracy; May identify mating areas; Depending on transmitter duration, may provide estimates of clutch frequency; Can identify internesting habitat extent; Provides excellent visibility and public awareness opportunities via online maps, press releases, social media and web-based platforms	Requires labour-intensive captures of turtles either via rodeo captures or netting; Requires multiple deployments over several years (to account for interannual differences) to get a general understanding of linkages; Typically requires linking to laparoscopy studies to select turtles in breeding condition; Higher unit cost than Argos tags but similar tracking costs	Once, dependent on sample size	Small dedicated catch boat, or small fishing boats with large-mesh nets (500m - 2000m long, 2-3m deep), Fastloc GPS satellite transmitters	30, 85, 89, 91, 92, 93
Description					

The concept of satellite tracking has been clearly described above. This study also answers the same connectivity questions as above for post-nesting turtles. Turtles are equipped with satellite transmitters that relay signals to ground stations that are then forwarded to the research team. The most important distinction in this case is that the tracking is done 'in reverse' whereby we track turtles to their nesting areas, rather than from the nesting beaches back to the feeding habitats. Sometimes we track turtles simply to determine the size of their feeding areas, and are not focussed on the long-distance movements.

The additional challenges with deploying transmitters on sea turtles in feeding areas is that they need to be caught first! It is relatively easy waiting for the adult female turtles to finish laying eggs on a beach, but it is quite another challenge to catch the turtles on a coral reef or a seagrass bed. There are really three main ways of getting this done: using passive nets and waiting for turtles to swim into them, using active beach seines that circle the turtles and then bringing them to shore, or using what is known as rodeo captures – where a team member jumps from a boat to capture the turtles in shallow water. The turtles can also be captured by hand by free divers in reef areas, but this takes quite a bit of skill and agility, and brings with it a few added dangers. Let's take a look at each of these methods in turn:

In shallow waters it is possible to capture turtles from a small boat. Turtles are chased until they tire and slow down, at which point a diver jumps or dives into the water slightly ahead of the turtle to catch it. This method, known as rodeo capture, takes quite a lot of practice. It carries inherent risks through jumping from a moving boat including collisions, propeller cuts and hitting the seabed or the turtle with great force. It should only be attempted when the boat driver is extremely competent and the diver is a very good swimmer. An advantage of rodeo captures is that it allows the research team to sample other life stages, and also male turtles. A key disadvantage, however, is not knowing whether the turtle you capture is about to undertake any sort of migration.

Net captures are somewhat more straightforward. Nets can be set in ports or bays where there are shallow water areas in which turtles rest. If turtles are known to be present in tidal creeks, nets can be set across the creek mouths at high tide and the turtles are captured as the tide falls. A passive net is one that is set and then the research team then simply wait for a turtle to swim into it. Normally the mesh size is quite large – more than a hand's width – so that fish can swim through without getting caught, and that only large things like turtles get caught. This method requires the research team to be present at all times watching the float line on the net for any sudden activity that might point to a turtle being entangled. At this point the team can quickly get to the turtle and disentangle it so that it can be tagged. A downside to net captures is that they require the turtles to be actively moving from one place to another so that they get entangled in the net. If the turtles are not moving across the area where the net is set, you might wait for hours and hours for little to happen.

In some parts of the world this passive nature of net captures is overcome by using active beach seines. In these cases a net is pulled out from shore, moved along the nearshore shallow area, and pulled back in to actively capture any turtles that might be in the area. Some nets measure hundreds of meters in length and are pulled by boats from offshore areas onto the beach, over shallow areas where turtles are feeding. Other nets are smaller, and are pulled by a few people moving deliberatively to encircle areas where turtles might be feeding. The nets generally do not harm the turtles as they can still surface to breathe and, working with the fishermen, the team can wait on the beach and collect any turtles that are herded along by the nets. After this it is a simple case of picking up the turtles and processing them on the beach. This method is also non-selective, and can capture turtles of varied life stages and both males and females. The downside once again, is that it is not possible to determine which of these turtles might undertake a migration to a nesting area.

Here is the main challenge if you want to track turtles from feeding areas back to nesting areas: From a nesting beach it is a relatively straightforward process to select a turtle and deploy a transmitter. We know that the turtle is an adult female, and that when she finishes laying eggs for the season she will return to her feeding area. But in feeding areas we can capture large turtles, but they might not be turtles that are ready to migrate any time soon. When we revisit the sea turtle life cycle, we know that only adult male and female turtles that are ready to breed undertake breeding migrations. Therefore the requirement (if the objective is to determine long-distance movements) is to find adult female or male turtles that are in breeding condition. That is, the in-water capture teams would need to know that turtles were in breeding condition so that they could be tracked when they migrated to nest. To do this the team would need to be able to identify which turtles were adults and, among these, which were reproductively active. This is far trickier and not something that is done by many research teams around the world.

Sea turtles do not breed every year nor do they do so year-round. Females normally breed every three to five years, while males breed a bit more frequently – on the order of every two to three years. However, the satellite transmitters normally only last around 12 months on average. If your 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 importantly, that it would migrate to nest that year, and therefore your project might not get any migration data or be able to link feeding and nesting sites. To overcome this, some extremely qualified teams use a small surgical procedure called laparoscopy to determine the sex and also the age class of the turtles, and if they are 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 fibreoptic light supply to look at the reproductive organs. Once the sex and reproductive condition are determined, the turtles can be selected for tracking. But very few people are qualified to undertake this procedure, and so in-water captures are rarely used as a way of catching turtles to determine the migration routes. Instead, many satellite tracking projects that target turtles in feeding areas are used to map the extent of the feeding areas, so that these can be managed and protected.

Lastly, in-water tracking studies can also be used to understand movements and survival of turtles that are the result of bycatch in fishing activities. Some research teams put transmitters on these sea turtles to see if they survive, so that they can better understand the impacts of capture in commercial fisheries. Other teams use the data from these bycaught turtles to understand their movement patterns at sea, with the goal of developing no-fishing areas so that the turtles don't get caught repeatedly. These tracking studies carry another level of complication because the crews of the vessels need to be trained in transmitter attachment and deployment, or a science team member needs to be on board in the event a turtle ends up in the net.

As you can see, a lot of this depends on your objective and it is extremely important to narrow this down at the beginning of your work, because satellite tracking is not inexpensive, and you want to maximise the data that comes out of your investment.

Process #13	Pros	Cons	Frequency	Tool(s)	Refs
(13) Genetic Sampling Programme - Nesters	DNA extraction and sequencing are standard procedures that can be done in many local laboratories; Primers exist to amplify DNA strands; Gene banks exist which enable tracing of natal origin; While not cheap, genetic analysis is far cheaper than extensive satellite tracking; Collection of samples on beaches is straightforward, either through cutting a small tissue sample or using a biopsy punch	Sample analysis requires specialised laboratories and technical skills; If not well preserved, samples may not provide sufficient DNA material; Incorrect assumptions during analysis can lead to incorrect assignment of foraging population; If laboratories are not equipped or capable, may require export permits to send the samples to other countries	Once	Biopsy punch or scalpel, vials, preservative; DNA analysis laboratory, computing skills	10, 80, 81, 82, 83, 84

Description

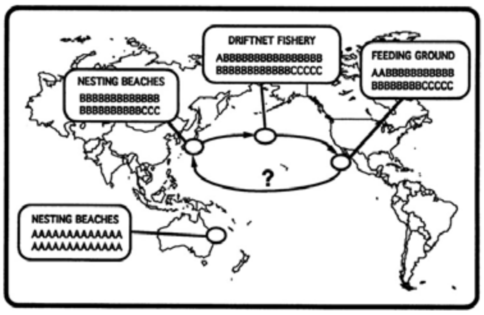
The genetic fingerprint of turtles is unique in different nesting areas and this enables genetic studies that can tell us where turtles came from. As we found out earlier in Chapter 1, the mitochondrial DNA that is passed down matrilineally can be used to define nesting areas, typically in the range of a few hundred km. When we encounter a turtle in a feeding area, or as bycatch from a fishing boat, we can use the DNA signature of that turtle to find out where that turtle originated from – so long as that area had been carefully documented. Once we know the genetic signatures of our nesting beaches, we are also in a better position to link feeding and nesting stocks, and defining geographical conservation units that make sense from a practical conservation viewpoint.

This is what this section is about. If we did not know the genetic signature of the nesting beaches in Tonga for instance, and we found a random Tonga turtle in a feeding area in Fiji, we would not be able to assign that turtle to the Tonga population because the DNA signature would be unknown. The analysis of tissue samples taken from nesting turtles can be used to define a nesting area, so that population linkages with feeding and migrating turtles can be better established.

The way in which this is done is we collect a small tissue sample from each nesting turtle, store it in a preservative solution, and get it analysed in a genetics laboratory. Normally we would wait until we had a substantial sample size (upwards of 50 and up to around 200 in large nesting sites) but even small samples (less than 10) can be used to characterise the nesting stock. This is because the genetic signatures are all going to be quite similar. It is a good idea to establish a relationship and agreement with a known sea turtle genetics laboratory up front, because the analysis can be expensive and likely needs to be incorporated into larger geographical studies.

Tissue samples can be acquired by using forceps to pull at the soft neck or flipper tissue, which is then cut off by using a unique and sterilised scalpel blade. There are also single use biopsy punches that can be used to do the same thing, and the choice of method is more a researcher preference rather than any specific benefit of one over the other. The scalpel blade method however is far cheaper than the biopsy punch method. Samples can be stored in small sealed vials in super-saturated salt solution, or in 98% ethanol, and even in special preservative chemicals such a RNAlater®. A lot depends on what you have available, with super-saturated salt being the easiest to prepare – simply boil water and add salt until no more can be dissolved. As the liquid cools, excess salt will precipitate out of the solution, and the remaining liquid will contain as much dissolved salt as it can take (super-saturated). Once the samples have been collected and preserved, they can be stored in a cool place or a refrigerator until such a time as analysis is called for.

When the samples are analysed, the laboratory will be able to define your population by the unique signature of haplotype frequencies, and these can be compared with known signatures – either assigning your turtles to a known genetic stock, or creating an altogether new genetic stock. The haplotype frequencies is a way of describing what proportion of different DNA segments your turtles have. These haplotypes are internationally coded and recognised, so that you might have 30% of this, 20% of that, and the balance some other haplotype. Sometimes the genetic stocks are quite complex and other times they can be quite simple. What is important however, is that the signatures become quite unique and help differentiate different genetic stocks.



In this graphic, the haplotype frequencies of the Australian and Japanese beaches are shown, and as you can see they are vastly different. The Australian loggerhead turtles all have AAAAAA haplotypes while the Japan turtles all have BBBBB and a few C haplotypes. When turtles are captured in fisheries in the north Pacific, researchers found that they belonged to the Japan stock simply by looking at the haplotype frequencies. This work was pioneers by a group of scientists led by Dr Brian Bowen way back in 1995 and is a great way to see how haplotype frequencies can be used once we know the genetic signature on the nesting beaches.

Two important points to keep in mind when sampling sea turtles for genetics: One, you need to make sure you mark the vials extremely carefully and clearly, in a way that the labels will not be lost when they are handled, or kept in a refrigerator where they will get damp. Marking the vial and the cap with indelible ink that defines the turtle ID code is one way to do this. Some people affix labels and put cellophane tape over these that will keep the labels intact when handled. Two, you need to make sure you do not sample the same individual more than once. The easiest way to do this is to tag the turtles you sample, and use the tag number as your sample ID, and ensure you only sample new turtles as part of your genetics sampling programme.

Lastly, you need to understand that all sea turtle species are listed under the Convention on International Trade in Endangered Species (CITES) and that all samples need a permit if they are to be shipped internationally. For this reason, it is far more preferable that the samples be analysed in your home country – Universities and accredited laboratories should be able to do this for you. It is also a great way to build skills and capacity among local research teams. Failing this, you will need to work with your counterparts to get an import permit into the country where the samples will be analysed, and an export permit from your country. Only armed with copies of both of these permits can the samples be legally shipped from one place to another.

Process #14	Pros	Cons	Frequency	Tool(s)	Refs
(14) Genetic Sampling Programme - In-water	DNA extraction and sequencing are standard procedures that can be done in many local laboratories; Primers exist to amplify DNA strands; Gene banks exist which enable tracing of natal origin; While not cheap, genetic analysis is far cheaper than extensive satellite tracking; Samples can be collected as described above; Multiple Stock Analyses (MSA) used to identify proportional rookery contributions to the foraging stock are relatively straightforward with sufficient training and guidance	Sample analysis requires specialised laboratories and technical skills; If not well preserved, samples may not provide sufficient DNA material; Incorrect assumptions during analysis can lead to incorrect assignment of natal origin contribution to the foraging population; If laboratories are not equipped or capable, may require export permits to send the samples to other countries	Once	Biopsy punch or scalpel, vials, preservative; DNA analysis laboratory, computing skills	10, 75, 76, 77, 78, 79, 86, 87, 88
Description					

By default, there is far more data on nesting population genetics than foraging population genetics simply because of the logistics of sampling in-water turtles. As we learnt above with satellite tracking (see Process #12), a lot of effort needs to go into sampling foraging and development stage turtles at sea. We need boats, and nets, and large research teams and a lot of time and effort to capture turtles. Once the turtles have been captured however, the actual tissue sampling and storage and eventual physical processing of the samples in a laboratory is the same as with nesting beach studies. The same sampling protocols apply, and the same CITES restrictions are in place. The only difference comes in the assignment of turtles to different nesting stocks, and this is normally a mathematical and modelling exercise.

But when we do get the opportunity to sample in-water sea turtle populations, we can learn a lot about where their nesting beaches are, and where they originally came from. It is quite possible to have multiple genetic stocks living in a single foraging area, and that each of these stocks goes back to its own nesting areas when the time comes, with little intermixing among stocks. Fiji is a good example of this, where recent work showed that about 72% of turtles originated from American Samoa; 17% of turtles were from New Caledonia and 7% were from French Polynesia. The combined contributions from the Commonwealth of the Northern Mariana Islands (CNMI)/Guam and Marshall Islands were minimal with an estimated mean of 1%.

In other places, the stocks are quite unique to specific feeding areas. Recent work along these lines in French Polynesia revealed that the genetic makeup of turtles form the Leeward and Windward Islands of the Society archipelago was significantly different; and that turtles from French Polynesia Island groups were genetically different from all other identified Pacific management units, with a weak differentiation between American Samoa and Leeward Islands. The mixed-stock analysis for the French Polynesian mixture revealed an exclusive contribution from the French Polynesian rookeries, with negligible input from the other Pacific populations. That is, this study demonstrated that turtles in French Polynesia come from French Polynesia and not from elsewhere. Similar linkages have been found for Hawaiian green turtles, that forage around the main Hawaiian Islands but nest up in French Frigate Shoals to the NW. But as we saw with Pacific loggerheads (see Process #13), turtles in the northeast Pacific off the coast of the US belong to the Japanese genetic stock. One thing that you might have noticed is that in Fiji they encountered turtles of French Polynesia, but in French Polynesia they only encountered turtles from French Polynesia. This tells us that French Polynesia turtles roam into other countries and territories, but this does not happen the other way around.

As you can see, genetic studies in feeding areas can answer some really interesting connectivity questions, and also can tell us a lot about turtle origins (and where they go back to after nesting). However, for us to know this with any degree of certainty, sample sizes from in-water studies need to be substantially larger than for nesting beaches. This is because there may be turtles from multiple stocks, and we need to be able to identify clearly in each of these stocks that these differentiations exist. For example, if we sample 50 turtles and only one of them has a signature that is not like the others, there will be insufficient information to determine where that turtle was really from. We would need another 50 samples of that particular haplotype frequency to be in a position to conclusively determine population of origin. Typically, mixed-stock analyses of turtles in feeding areas require samples of 150 to 300 turtles, and the Fiji study I mention above looked at 150 turtles and the French Polynesia study looked at 204 turtles. But the results were really useful in determining where turtles were from and the linkages between nesting and foraging stocks.

Process #15	Pros	Cons	Frequency	Tool(s)	Refs
(15) Coastal Zone Aerial Surveys	Can cover extremely extensive areas in relatively short time periods; Can allow for species identification and size estimation; Provides robust spatial distribution data; Cost-efficient compared to boat surveys	Expensive; Permits and aircraft availability may be problematic; Requires trained observers; Requires special analytical skills	Once	High-wing aircraft, preferably with low cruising speeds, minimum four-seat capacity	10, 67, 70, 71, 72, 73

Description

In many areas the lack of a broad geographical perspective has hindered population assessment and conservation efforts, and when little is known about nesting activity and sites along large stretches of coastline, aerial surveys can be one of the fastest and most practical ways to document beach use and nesting habitat. The more we know about where turtles nest and in what numbers, the more we can do about targeting conservation efforts at those areas. To solve this knowledge gap, aerial surveys along coastal areas can inform us about 1) which nesting beaches are used by individual females within a season and by the population as a whole, 2) the total number of nests at each site, and 3) number of nests into a total adult female population size when we know other female reproductive behaviour.

One major downside of these powerful surveys of course is cost, and in many parts of the Pacific, another key challenge is having access to the right aircraft that is able to survey very remote habitats. There are several other limitations that need to be thought of when considering aerial surveys to identify nesting habitat: Is there an aircraft available? Is it airworthy and does it have a good safety record? Are there any landing strips where it could land to refuel? Is the right kind of fuel available in remote areas? Can the aircraft fly for long periods so that it can return to base to refuel? Does it have the capability to land in remote areas in case of emergencies? Does it have emergency locator beacons? Is the design such that the observer would see what they were looking for? For example, aircraft with low wing designs are unsuitable for aerial surveys because when you look out of the window all you see is the wing and not the coastline. Bubble windows where the observer can extend his/her head out further from the aircraft fuselage and see more are preferable to flat windows. Twin engine aircraft are typically safer than single engine aircraft (not always but this is usually the case). Many smaller aircraft use a fuel called Avgas that is unavailable in many areas. Larger or more advanced aircraft may use the same fuel (JetA1) as commercial aircraft making life a bit easier in terms of fuel availability. All of these things need to be considered when selecting the right platform for aerial surveys. And of course, at the top of the list is cost. If you charter an aircraft to fly over potential or presumed nesting areas, you will need to cover the costs of ferry flights (when they bring the aircraft to you and fly it back home afterwards). You will need to cover air crew costs during overnight stays. You might need to pay for security if the aircraft remains on the ground overnight at a remote airstrip. Normally the actual operations of the aircraft are charged by operational hour, so when the aircraft is actually flying you pay, and when it is on the ground between flights you do not pay. But the hourly costs are designed to take all of this into account, and a cheap option might cost only USD 300 per hour, while more expensive options might cost USD 1,500 to USD 2,000 per hour.

From a more operational perspective, these aerial surveys are typically conducted along the coastline so that observers can count turtle tracks or evidence of nesting: Aircraft are required to fly low, at an altitude of just 150–200 feet (~45–60 m) and quite slow, at 90–100 knots (~170–185 km/hr) air speed. The aircraft needs to fly over water parallel to the coast at a distance that allows good visibility of the beach. Flights need to be conducted during morning or late afternoon hours when the sun angle is low, to maximize visibility of nests and tracks. In this manner, it is often possible to distinguish amongst turtle species from the size and shape of the tracks. It is useful to have more than one observer count the nesting events, so that these can be compared and resolved at the end of the flight. In addition, it is a good idea to have a third observer collect GPS data for each nest.

If you are able, it is a good idea also to ground truth the aerial survey data to make sure the estimates are as accurate as possible. One way to do this is to have a team count nests along a clearly described portion of a beach that is nearby, and later compare these counts with the counts from the aerial survey. Then the aircraft can proceed to more distant areas and those counts can be corrected for any error between actual counts and aerial survey counts.

One last comment on aerial surveys: in areas where nesting is extremely intermittent there may be no real advantages of using aerial surveys because they might not detect the infrequent nesting. For example, if a beach only experiences one or two emergences per week, these might not happen on the day the aircraft flies overhead and you would not count them, and therefore not learn anything new about this habitat. In these cases it is often best to start with literature reviews (see Process #1) and key informant interviews (see Process #2) before embarking on ambitious and expensive aerial survey work.

Process #16	Pros	Cons	Frequency	Tool(s)	Refs
(16) Coastal Zone Vehicle / Foot Surveys	Low cost; Useful in identifying beaches over wide coastal areas; Can identify previously-unknown areas	Depending on wind and erosion it is not always possible to distinguish species, or age of tracks; sometimes different season nesting pits are counted as single season activity; does not always clearly identify species	Once	Foot patrols, Vehicles; Notepad; Camera; GPS	10, 68, 69, 72, 74

Description

A somewhat less costly but more resource-demanding way of achieving the same result as the aerial surveys along the coast is the use of cars, boats and people. But whichever form they take, these surveys have the same objective as the aerial surveys: to document nesting over large coastal areas where little is known.

They typically involve inspecting beaches on foot; assessing nesting numbers (number of tracks) and species (via the track gait) and sometimes nesting success (depending on age of evidence). Normally one plans out the survey to determine what areas can be reached by car, and which need to be covered by boat and on foot. If the nearshore area is sufficiently deep, it is often possible to have a boat run close to shore and have the observers use binoculars to look for nesting activity. In other cases it might be necessary to drop observers at one end of the beach and collect them at the other end, with them walking along and collecting data on nesting events. The physical presence allows collection of quite accurate data, but comes at the disadvantage of taking a long time to complete. If the team are being transported to a beach by car, the car can collect them at the other end much as the case with boats. But if there is no access at the other end, the observers will need to walk all the way back before being taken to the next beach. I am sure you can see how labour intensive this is, and how the higher cost of the aircraft might be offset by the duration and costs of getting a few people to many beaches over a very large area to determine nesting distribution.

Photo: SPREP/Carlo Iacovino

Process #17	Pros	Cons	Frequency	Tool(s)	Refs
(17) Aerial Transect Surveys	Can cover extremely extensive areas; Can allow for species identification and size estimation; Provides robust spatial distribution data; Cost-efficient compared to boat surveys	Expensive; Permits and aircraft availability may be problematic; Requires trained observers	Periodic as resources allow	High-wing aircraft, preferably with low cruising speeds, minimum four-seat capacity	10, 18, 35, 61, 65
Description					

Aerial surveys are the backbone of many standardised sea turtle at-sea distribution and abundance projects, but as we noted above, they come with a high price tag, have numerous requirements related to fuel, safety (in this case particularly because the aircraft is operating over water, often far from shore), local airstrips, aircraft availability and suitability, and in the case of marine abundance and distribution surveys, also require some pretty sophisticated data analysis, and standardised data collection methods. It is not as simple as just jumping on an aircraft and heading off to count turtles.

An emerging consideration is the use of high-resolution cameras versus actual observers. As gimbals and camera equipment become cheaper and the image resolution improves exponentially, there is a real potential for this technology to replace observers on flights. But you have considerations of data analysis after the flights (the use of Artificial Intelligence (AI) is speeding this up somewhat but is not yet perfect) and also the storage requirements for the imagery. Each flight could result in thousands and thousands of images that need to be analysed and stored, requiring hundreds of terabytes of memory space. An advantage is these records are there for future examination, and a permanent record of what was seen. Hybrid versions with both human observers and camera systems might be the interim solution until storage and AI systems become more widely available.

When surveys are conducted over water there are some inherent challenges to counting turtles: If the wind is strong and waves are breaking into white caps, it will be impossible to count turtles accurately. Research teams rarely conduct surveys in a sea state that scores 3 or more on the Beaufort scale. Glare is another consideration, and if an observer is looking down at the water straight into the glare from the sun, the turtle count will again not be accurate. Timing of the surveys and alignment of the survey transects that minimise glare are key considerations. Observer fatigue is another factor: The surveys may be long, and the observers are required to be paying attention nearly the entire time the aircraft is in the air – if you turn your head just for a few seconds you might miss one or more sea turtles! Another thing to consider is animal behaviour: Sea turtles spend a lot of time submerged, so an aerial survey is unlikely to find them all on the surface waiting to be counted. Research teams need to account for this detection error when calculating total numbers of sea turtles in an area. Water clarity may also play a role in determining just how far into the water an observer might be able to see. In clear waters this might be several meters, but in murky water it might barely penetrate the water surface. In some cases, these detection errors can be compensated for by using appropriate correction factors, derived from knowledge of turtle dive behaviour. But it is rarely possible to correct for environmental variables, such as sun glare or sea state. Another important type of error in aerial turtle surveys is observer bias, which can be associated with skill, training, and experience of the observers. Some of this bias can be estimated by using multiple observers and systems to quantify any differences in detectability among observers – for example the NOAA teams out of the US and the James Cook University teams out of Australia typically use four observers, with the front two separated from the rear two with a curtain, and then they compare the detection capabilities by each pair of observers. Lastly, the design of the surveys (the actual the that the aircraft will fly) is extremely important. Surveys are usually conducted perpendicular to bathymetric lines rather than along them. The distance between survey lines needs to provide equal coverage probability across habitat types so that there is an even distribution of flight time over all areas. High-winged aircraft are used for these surveys to maximise vision when looking downward. Surveys are usually conducted at altitudes between 500 and 700 ft (150 to 200 m) and at no more than 90–100 knots (~170–185 km/hr) air speed. Finally, the timing of the surveys is also important? Not only at a seasonal level, but even from a time of day perspective. When are turtles active? When we might find them at the surface more often? As you can see, aerial surveys are complicated, require specific aircraft operating within specific flight parameters, skilled teams of observers, careful planning, and are subject to the vagaries of weather and animal behaviour, not to mention extremely expensive.

From an operational and design viewpoint, aerial abundance and distribution surveys are typically conducted along straight-line ‘strip transects’ that are spaced sufficiently apart to minimise counting of the same individuals. Transect line orientation can vary, with some teams using a V-shaped approach and others using a U-shaped approach. The idea is to cover a substantial portion of the ocean, but also not ‘double count’ the same individuals if they are swimming from A to B. The surveys require a degree of standardisation of the transect width, or be in a position to record the angle of inclination to each of the sightings (observers carry inclinometers with them and use these to record the angle between the aircraft and the sighting). This is because the surveys are a ‘sample’ of the ocean, and if you want to extrapolate to larger ocean areas, you will need to know the area you have covered during your flight. If we know the area each observer can ‘see’ out of either side of the aircraft, and we know the distance the aircraft has travelled, we can calculate the extent of the surveyed area. This area can be determined by standardising the field of view, or by calculating detection probability from the sighting frequency and angles of inclination data (this is a complex mathematical process). Some ways to standardise the width of the transects include marking the windows in an aircraft and counting sightings in between the markers, or fixing reference poles to the exterior of the aircraft. Observers need to be able to determine sightings fall within a certain demarcated zone for them to be counted as a ‘detection’. Of course, all animals get counted, regardless of whether they fall within the strip transect, but the ones inside of that transect can be used to calculate abundance estimates. If precise abundance estimates are required, observers need to be able to see 'straight down' and usually include an observer lying flat in the belly of the aircraft looking straight downward.

So you have decided aerial surveys are the way you want to collect abundance and distribution data, have planned ahead and secured the right survey platform, selected and trained your observers, and have gone out and collected loads and loads of information at great cost. Now comes the even harder part, which is the calculation of overall abundance estimates from the raw data. The raw data can be indicative at best, but it needs to be carefully processed for it to be an accurate representation of abundance and distribution. Mathematical corrections need to account multiple sources of bias or 'detection probability'. The data need to be corrected for instances when animals are present in the search area but are not available for detection (availability bias). They also need to be corrected for perception bias, when some animals potentially visible to observers are missed. And finally, they need to be corrected for environmental bias, where glare and sea state might impact the ability to detect a sea turtle. Sometimes the weather and glare are included or pooled with the availability bias to simplify data analyses.

There are very good modelling packages available to help with the analysis of aerial survey data, but as with anything related to computers, the quality of what goes into the formulas is what guides the quality of the results from the analysis, and your methods and planning need to be spot on to get the best results. Whether this is done via modelling or through mathematical formulas, it is important to have a good statistician and modeller be involved in the data analysis and interpretation.

Photo: Steve Bolton, Wiki Commons

Process #18	Pros	Cons	Frequency	Tool(s)	Refs
(18) Boat Transect Surveys	Can cover substantial areas; Allows for occasional 'close encounters' that confirm species presence and diversity	Sub-surface turtles are not seen or counted; Turtles may not be close enough to the boat to be sighted; Observer fatigue is an issue after long observation periods; Data not as robust as aerial surveys	Periodic as resources allow	Seaworthy vessel, preferably with a high deck for greater visibility	10, 60, 62, 63, 64, 65, 66
Description					

Surveying breeding sea turtle populations at sea can also be done by observers aboard boats. Often referred to a 'distance sampling' these boat-based surveys estimate turtle abundance in an area by measuring turtle density along a representative sample of transects, from a boat, over a pre-defined survey area. Turtle density is then multiplied by the overall size of the surveyed area to derive an estimate of population abundance at a greater regional scale.

We need to make a number of key assumptions to ensure that (1) the turtle density we measure in a sample of transects is representative of the overall survey area, and (2) turtle density is measured accurately in the samples. These assumptions are as follows: One, transect lines are distributed in such a way that average turtle density in the sample is representative of turtle density in the wider region. We can make sure this is done by placing lines randomly throughout the survey region. If we were to bunch all of our lines over a reef area, this would only be representative of turtles in reef areas. If we want an overall number of turtles, we need to distribute our sampling across all areas and all depths. Next, turtles on the vessel track line are detected with certainty. This assumption is often not met in sea turtle surveys because of availability bias (turtles are underwater and unavailable for detection) and perception bias (observers missed the turtles). If we do not meet this assumption, our data will only generate a *minimum* abundance estimate. Third, turtles do not move before distance and bearing from the vessel have been established and recorded. Field protocols need to be developed to ensure that observers search well ahead and to the sides of the vessel, so distance and angle can be recorded before turtles have a chance to respond to the presence of the boat. If turtles are attracted to the boat, density estimates will be positively biased. If turtles avoid the boat, density estimates will be negatively biased. Lastly, distances are measured without error. If observers overestimate distances, then density estimates will be negatively biased. If observers underestimate distances, then density estimates will be positively biased.

Boat surveys are cheaper than aerial surveys, but are slower, cover a much smaller area, may disturb animals on approach, and tidal conditions in coastal areas may make access in boats difficult. The area that can be surveyed with these techniques is rather small, and external factors such as visibility, habitat type and turtle shyness can all negatively affect abundance estimates. With low survey platforms, sea turtles surface fewer times within an observer's field of view than would be the case for observers working on ships with higher viewing platforms or in aircraft. Lower platforms also mean that observers cannot search as far ahead of the vessel as they could from a higher platform and, consequently, observers may first see a turtle after it has already avoided the boat. As you can see, boat surveys also have problems when standardising monitoring efforts, and observers may vary in their observational abilities and data-collection accuracy. Detection ability also decreases substantially with boat-based surveys, because the observers are looking sideways for turtles in the water column rather than from a top-down perspective. A turtle that is 100m away and just under the surface might not be visible to a boat-based observer but would have been clearly seen from an aircraft. An additional challenge is that this method is really not that suitable when there are low turtle numbers, because the detection error is sufficiently high to make any extrapolation into regional abundances inaccurate.

The operational concepts of boat-based surveys are similar to those of aerial surveys. They require a team of observers to be on the lookout for turtles, and sightings then get recorded on data sheets for subsequent analysis. Observers are usually placed to the front and to each side of the boat, and need to record the bearing and an approximate distance from the boat, species and size range (normally in standard categories such as small, medium and large). Standardising distance from the boat can be improved with the use of range-finding binoculars or range-finding cards, but the act of bringing binoculars up to the eye can also lead to losing sight of the turtle. Boats need to travel relatively slowly (normally < 15km/h) and preferably have an elevated platform to increase detection of sea turtles. Some important data fields that need to be maintained are the type of boat/engine, the number and position of observers, the route, direction and speed, and the time of day. Analysis of the data from boat-based surveys is similar to that of aerial surveys and needs to account for detection errors and biases, and would benefit immensely from having a qualified- statistician / modeller on your team.

Process #19	Pros	Cons	Frequency	Tool(s)	Refs
(19) Coastal Drone Survey	Relatively low-cost study of in-water populations of turtles in small areas (e.g. restricted bay, reef lagoon); Once programmed can be easily replicated; Requires little prior experience once trained; May allow for identification of size classes and species; Provides long-term photographic records that can be archived for future revision	Limited to very small geographic areas; Requires high resolution camera system (=>18MP); Limited to battery capacity and flight endurance; Not suitable in strong winds; Subject to predator bird attacks in coastal areas	Periodic, based on research question	Man-portable drone (e.g. DJI Mavic Pro 2)	14, 15, 23, 29, 60,

Description

The emergence of, and advances in, drone (also referred to as unmanned aerial vehicle - UAV, or unmanned aerial systems - UAS) technology over the last decade have started to have a large impact on survey methods that can be used to detect turtle abundance and distribution. The use of drones in coastal surveys for sea turtle nesting or other occurrences such as turtle strandings can reduce costs, simplify methods, enhance data acquisition and create a permanent visual archive of actual and potential nesting habitats. Large-scale nesting beach assessments are typically conducted along the coastline so that turtle tracks or evidence of nesting can be counted and located. Nesting beach start and end points can be determined from drone imagery, and it is often possible to distinguish amongst turtle species from the track shape and dimensions. Surveys can also target more logistically difficult to access, even dangerous areas (imagine areas with crocodiles…) to record data that would otherwise remain elusive. Nesting turtles can even be identified on the beach at night using a drone equipped with a low-light optical or thermal camera.

Drones allow you to collect of data on turtles and their habitats over larger areas than can be achieved by surveys on foot or by boat, in a fraction of the time. Some important considerations in selection of drone platforms for survey work include the drone type (fixed wing or rotor), endurance (how long the battery lasts), navigation software, and camera resolution. Fixed-wing drones are more complex than multi-rotor drones, requiring constant forward motion to remain airborne and a larger area for take-off and landing. But fixed-wing drones have longer flight times compared to multi-rotor types although technology is improving to the point that multi-rotor drones can stay in the air for much longer than they could in the past, and this is only likely to improve over time. There are advantages and disadvantages to each type of platform that are linked to training and skills, endurance, ways in which they land and take-off, flight control software, ability to remain stationary, and a lot depends on the purpose of the survey.

Drones these days come with a wide array of sensor options. You can have standard colour images and video, in various resolutions, you can have infrared heat-sensing sensors, radar sensors and light detection and ranging (LiDAR) sensors to generate 3D models and create topography maps of your research area. If your objective is to simply map nesting events along a stretch of coastline it is likely that video or imagery will suffice. You could programme the drone to take images with a certain degree of overlap so that there is entire coverage of a stretch of coast. Or you could programme it to record video of the same stretch of coastline, with the disadvantage that freezing the frame might result in an image that is hard to decipher. You could also use LiDAR to map the shape of the beaches in 3D, and track the beach shape and availability of nesting habitat over time. If you wanted to fly at night and collect information on nesting turtles, these would show up clearly when using an infrared sensor. A lot depends on the objective of the study.

Drones can be operated directly by the operator, or can be deployed to fly pre-defined and pre-programmed routes via navigation software. Some drone companies produce their own programmable flight operations applications, and there are also various third-party ones available on the market. Many drones are capable of relaying live video feeds from the camera back to the pilot's controller (although this is often distance-dependent), creating a first-person view of the flight.

There are also significant considerations related to the legality of drone use. It is becoming more and more common that a licence is required to operate a drone, and most licences do not allow operation out of line-of-sight, or at altitudes greater than 140m (500ft). Drones also cannot generally be flown over inhabited areas due to safety concerns. Drone operator licences usually require lessons and some form of examination, and are linked to the type of drone being operated. You should check carefully the legal requirements for drone use before operating them as part of a research study.

A great aspect of drone surveys is that the imagery you collect can be maintained over time, providing a reference that you may check time and time again. The data that are gathered can be reviewed by multiple researchers to obtain consensus on what is recorded, and can be archived for future reanalysis. And this brings up an important point about data storage: Drones generate large amounts of data. Massive amounts of data even. Each high-resolution image can be 5 to 10MB in size. When you collect 1,000 of these in a survey, data storage becomes a real consideration. You will need massive amounts of computer storage space to accommodate the immense amounts of data that are generated through drone surveys.

Process #20	Pros	Cons	Frequency	Tool(s)	Refs
(20) Over-water Drone Survey	Relatively low-cost study of in-water populations of turtles in small areas (e.g. restricted bay, reef lagoon); Once programmed can be easily replicated; Requires little prior experience once trained; May allow for identification of size classes and species; Provides long-term photographic records that can be archived for future revision	Limited to very small geographic areas; Requires high resolution camera system (=>18MP); Limited to battery capacity and flight endurance; Not suitable in strong winds; Subject to predator bird attacks in coastal areas	Periodic, based on research question	Man-portable drone (e.g. DJI Mavic Pro 2)	15, 21, 29, 31,
Description					

With similar objectives to aerial surveys of abundance and distribution, drone surveys over water are a far cheaper alternative, but cover far smaller areas. These surveys can capture abundance of turtles over small areas, and can consist of multiple surveys per year to detect abundance changes. Some drones can be launched from boats allowing you to get to remote areas in the boat, and then deploy the drone for more detailed surveys. Being able to launch from a boat also means you can conduct boat-based surveys and drone surveys at the same time and collect different types of information – or validate some of your boat-based survey findings.

Surveys can be pre-programmed and follow straight-line transects, much like the transects in aerial surveys but on a smaller scale and over smaller distances than boat or aerial surveys, to collect similar data to abundance surveys described for aircraft (see Process #17) and boats (see Process #18). A great advantage of pre-programmed surveys is that they can be replicated identically during each subsequent survey. With pre-programmed surveys it is often as simple as uploading the programmed flight from the controller to the drone, and pressing Start. The drone will take off, conduct the survey, and land again while you can devote time to monitoring flight progress and safety. Surveys that require more than one battery are also accommodated by these programming systems: You set the drone going, and when it decides it only has sufficient batter power to return to base it returns, you change the battery and press Start again, and the drone will continue where it left off. They are quite incredible…

Drones can be programmed to take photographs or record video, and one advantage with photographs is that the user can select the amount of desired overlap between images. If you are trying to create a photo-mosaic of the area, overlap (forward and rear and laterally) is important so that you do not miss any of the area in question. When you end the drone surveys, the visual data need to be reviewed by one or more individuals, and turtle observations can be georeferenced from the video or from the still images. Abundance estimations can then be carried out as per standard aerial survey methods. While overlap is not necessary for some surveys, the ability to programme that overlap is one of the strengths of drone applications. Unrelated to abundance studies, an additional advantage of drone surveys over water is the ability to study turtle behaviour. Rotor-type drones are particularly useful for their ability to hover and capture images over time or video, allowing you to record mating behaviour, or interactions with other marine species (e.g. sharks) or even the behaviour of a turtle after it is released following a bycatch event. If it is not already obvious, a key consideration when deploying drones over water is that if they crash, your drone is pretty much lost. One feature that is common to rotor-type drones that are flown over water is a Return-To-Home button or function. As the name implies, if you press this button the drone will return to the point from which it took off. But if you are on a boat, even if it is at anchor, it is likely moving slightly, and the drone is unlikely to find the 'home' spot it was looking for. Splash. If you purposefully fly the drone to the maximum battery endurance range you run the risk of a battery drain if a sudden wind gust picks up as the drone is on its way home. Splash. If you are not sufficiently familiar with the drone and press the wrong button… Splash.

In the section on shore-based drone surveys (see Process #19) we discussed the immense amounts of data storage that are required. With sea-based surveys this is no less the case, plus there are added challenges. Someone needs to sift through the imagery and detect the turtles you are looking for. Some surveys can generate thousands and thousands of images, and each of these needs to be inspected visually by one of your team. While Artificial Intelligence (AI) systems are evolving, there are challenges to interpretation that defy even super computers. We can all imagine what a silhouette of a turtle looks like from above, and we would be looking for something like that in an image. So would the AI system. It would be something somewhat oval, with flippers sticking out to the sides, and a head pointing out from the front. But what about a turtle that had just dived as the drone was overhead, and all we get to see is the downward-facing tail end of that movement? That is more of a challenge, but no less of a turtle. And if we would struggle with identifying a turtle in this position, imagine how an AI system would struggle also. AI systems are 'taught' what a turtle looks like from above by being fed with many different turtle images, and it tries to find those shapes in the survey images you submit to it. But this means you would need to submit a wide range or images of turtles in all kinds of 'poses', and you would need to have been able to recognise that was a turtle in the first place, so you could submit the image to the AI system! At the moment, most teams still rely on human observations and reviews of images to assign turtle detections to an image.

Another consideration is altitude. The higher you operate the drone, the greater the field of view from the camera, but the lower the resolution of the turtles you are trying to capture. Even with top-end drones with high resolution cameras, operators rarely use drones above 60 m and usually surveys at half of that altitude (30 m) produce images that can be used to distinguish between species and size classes. But this means that the lateral field of view is reduced, and you need to run more transect lines to capture a representative sample of your survey area. This will increase your flight time, and the number of batteries you might need to use for the survey. Drone technology is evolving rapidly and the functions that are available to sea turtle researchers are constantly improving. Good drone specialists keep abreast of these changes and would be in the best position to advise you on what to use based on your research question. At the end of the day, there is no substitute for experienced drone pilots and survey designers, and you would wise to engage someone like this on your team before embarking on surveys so that you get the very best out of your efforts, and don't lose your drone in the process.

Process #21	Pros	Cons	Frequency	Tool(s)	Refs
(21) In-Water Photo ID	Is a cost effective, non-invasive technique that can easily be used to monitor turtles without disturbing them; Is a good way of involving 'citizen science' in research and monitoring; requires little training and expertise; several online platforms exist to upload data and maintain 'databases' of sea turtles	Requires similar photographs of the same side of a turtle's head; does not account for detection error or missing turtles; does not always account for levels of effort; requires uploading photographs to the internet, and allowing a database to search for potential similar turtles, and then requires manual review	Periodic, based on research question	Scuba diving or snorkelling equipment, sports-type underwater camera, computer and internet access	44, 45, 46, 47, 48

Description

Photographic identification (Photo-ID) of sea turtles is a scientifically, non-invasive and proven method of "tagging" turtles by using the distinct facial scale patterns, which are much like fingerprints in humans. Like a fingerprint, each sea turtle's facial scales are distinct and don't change over time. These natural markings and colour patterns can remain stable over several life history stages. Photo-ID is quickly becoming an efficient tool for identifying specific turtles and long-term monitoring of sea turtle populations in feeding areas, and more recently on nesting beaches. From a practical point of view, field experiences so far have indicated that Photo-ID may be more suited for underwater images rather than for images taken on the beach as sand may obscure parts of the head.

Researchers are finding that taking photographs of the facial scales is easy, and does not require tagging with flipper or internal tags. Indeed, this technique can also be used to quantify the period of tag attachment and tag loss, and thus assist in the correction of errors in flipper tagging studies. Photo-ID is a great alternate tool when catching turtles in the water is a challenge, or when research teams do not want to add greater stress by using physical tags in an already stressful situation when a turtle is captured.

The way it works is as follows: Researchers take photographs of the left and right sides of the turtle's face. While one image might be sufficient, there is greater matching accuracy when both images are collected. These are then uploaded onto a computer, and entered into one of various software packages. There have been several evolutions of computer identification packages (in the past this was done manually by sifting through hundreds of images), but these are improving to the point that facial recognition is nearly is as good as flipper tagging, which comes with its inherent tag loss challenges. One such package is HotSpotter (www.cs.rpi.edu/~cralljp/) which compares and scores combined keypoint locations to rank animals in a database for potential matches. In essence what the system does is act like one of those CSI movies when they do facial recognition with criminals: it takes the image and then runs through all the other images in its databank until it finds a close match, and offers this up to the research for final confirmation. You can even set a limit on the number of matches the system returns, so that only those closest to the original will be displayed.

Of course, the better the images and the more consistently these are taken, the better the chances of finding a match. Some key considerations include ensuring photos are captured at consistent angles and preferably under comparable lighting conditions, or that post-processing manual manipulation of images (e.g. for lighting and contrast) are done in such a way that they do not lost the essence of the original. Images can be taken by multiple people, under highly variable underwater conditions, different image qualities and resolutions and angles, but with very minor manipulation these can be effectively used in the HotSpotter system.

Today there are new evolutions of this process in the works. Top-down photographs are being used as a way to identify turtles captures in fisheries, and which are only photographed from above (not all bycatch events are brought onto the boat, so the photographer will always be above the turtle looking down). If the animal is too large to bring aboard the vessel it also may be necessary to capture the image while the turtle is in the water. Photographs of scute patters on flippers are also being used, and are claimed to be even more accurate than facial recognition.

A great advantage of using Photo-ID for turtle work is that it can extend to the general public, invoking a degree of citizen science into your work. The participation of scuba divers is also a great opportunity to collect images over time and across a broad range of locations, allowing continuous and long-term studies. As photographs are taken by members of the public, these can be used to detect presence-absence patters, residence period, and even behaviour. And while flipper scute patters might be more accurate, most members of the public enjoy taking pictures of turtles' faces, so the facial ID approach is likely to have a greater role with members of the public.

Process #22	Pros	Cons	Frequency	Tool(s)	Refs
(22) Threat-Specific Studies on Nesting Beaches	Provides exact magnitude of impact to turtles, by species; May provide information on impacted age classes; Results can be effective communication tools in developing mitigation action; Provides the 'evidence' managers and governments need to effect change	Often the studies are time-consuming and costly; Requires specialist researchers with advanced understanding of sea turtle biology and ecology; Requires replicability and be sufficient to detect changes or impacts at a statistical power of 0.8 or greater	Once, follow-ups as needed	Variable and subject dependent and thus vary widely; For instance, impacts of climate change may require temperature data loggers; Impacts of lighting may require field arena trials or hatchling fan studies at impact and control sites;	10, 17, 19, 36, 43,

Description

These types of surveys typically focus on impacts of one threat at a time (e.g. global warming, predation, habitat alteration). They require detailed planning, use of controls, development of hypotheses and (often) intensive field research to detect impacts to turtles - often at different life stages. And in the most recurring theme of this manual, a lot depend on exactly what you need to study, and why. I have often had people want to shade turtle nests, or implement some other temperature-control measure, without first determining if temperature is indeed an issue. So it is important to follow through the hierarchical process of first determining what problem exists, investigating this a bit further, and then doing something about it. This section relates to the 'investigating this a bit further' part, and focuses on some of the most prevalent threats to sea turtles on nesting beaches. It is not an exhaustive description of each threat, but it should give you an idea of what the threat is, and how to approach your investigation.

Predation – Predation on nests, eggs and hatchlings is a common problem in many parts of the world. Common predators include domestic and feral dogs, pigs, lizards, foxes, racoons, rats, crabs, and a variety of birds. Many of these predators have an exceptional sense of smell and they are very good at locating nests under the sand. They can consume eggs and hatchlings and can be responsible for massive loss of reproductive output in sea turtles. Many of these predators are introduced on remote islands so that even these sites are not spared the devastation.
Complicating matters, introduced-predator strategies to mitigate particular nuisance species can introduce species that impact turtles, through which predation on turtle nests can increase. Certain predator removal strategies (e.g. raccoon removal) could result in drastic increases in secondary predator abundances (i.e. ghost crabs), in turn intensifying predation of sea turtle nests.

There are multiple methods to establish predator impacts, from beach walks simply to look for visual evidence (tracks, disturbed nests, eggs or dead hatchlings strewn around the beach); to camera traps, movement sensors and night-time infrared camera surveillance. A common denominator across all of these studies however is standardisation of effort and accurate record-keeping. With visual assessment on beaches, it is important to count both predated and undisturbed nests. Camera trap surveys need a measure of effort across different beach sectors and timeframes. It is important to make sure that at the end of the study you are in a position to report on average number of nests impacted, and within these impacted nests, what level of predation was evident. For example, a fox might dig in to a nest, but might not disturb the entire nest, which can be reburied and which will often successfully hatch later on. Once you have an idea of the degree of impact, you can prioritise management intervention actions to do something about it.

CLIMATE IMPACTS

As global warming takes a stronger hold on the planet, and climate change leads to increased Severity and frequency of storms, temperature extremes and sea level rise, sea turtles are impacted in numerous ways. Researchers have already detected changes in sex ratios of hatchlings from beaches, deformities to hatchlings due to temperature extremes, loss of foraging habitat, changes in the timing of nesting, and shortening of nesting season – among many other impacts.

Of these, possibly the one impact that receives the most attention is changes in temperature profiles on nesting beaches which has the potential to lead to skewed sex ratios of emerging hatchlings. There are many others of course, but this one particular threat crops up most often because it is something that people can tangibly feel - we know when it is getting hot. But to address this potential challenge, we should not get too far ahead of ourselves… There are many places in the world where temperature is not an issue, and so we should not jump to conclusions that temperature is the main problem we face everywhere. Indeed, sea turtles have roamed this planet for long enough to have undergone multiple changes in temperature, so we should not discard the potential for them to be acclimated in some way. That is not to say all populations are going to remain free from any climate and temperature challenges, and therefore it is important to take a moment and consider how we would approach a better understanding of this problem.

To start with, we would need to know what current nest temperatures are, and see if these have changed historically. We might not have historical data on nest temperatures, but there are some clever ways around that. We could measure current nest temperatures (see Process #10), and also record ambient air temperatures. Data on ambient air temperatures have been collected for decades, and so we should be able to correlate current nest temperatures with current air temperatures, and then take a look back in time to see what air temperatures were in the past, and calculate what nest temperatures might have been in the past. This would be a first step: establishing if there have been any substantial changes to temperatures.

Next, if you determine there have been changes and that this might be leading to skewed sex ratios, you could use incubation temperatures and duration (see Process #10) to estimate what current sex ratios of emerging hatchlings are, and what historic sex ratios might have been. If you have access to pivotal temperature data for your region, this makes life easier, but if not, you can use a known proxy for the same species under similar environmental conditions.
Detailed studies involving incubating eggs at various temperatures and sacrificing hatchlings and establishing sex ratios for your beaches, or laparoscopic investigations of turtles on feeding grounds, are likely not options given the resources and skills required, but if this is deemed an absolute necessity, you should work with science teams that have these specific skillsets to arrive at the most accurate results for your project, and that lead to carefully considered management decisions on mitigating climate impacts. Importantly, we do not want to be rushing into mitigation options without knowing if we have a problem in the first place.

HABITAT LOSS OR DETERIORATION

Rapid coastal development threatens the future of many beach and dune ecosystems. The gradual loss of plant life on nesting beaches can lead to wind-driven dune erosion, leading to a loss of nesting habitat. Construction of residential and commercial buildings, major industries and other 'grey' infrastructure, even coastal armouring and erosion controls all lead to a loss or degradation of nesting habitat. Beach nourishment by depositing sand on a beach to replace what has been lost to erosion usually puts salt-laden sediments on beaches, which are not adequate for embryonic development, and generally have less shear resistance and longevity than natural beaches. Beaches can be polluted by runoff from inland activities. Introduction of non-native species of vegetation can degrade nesting habitats, and alter temperature regimes on beaches. All of these impacts lead to decreased reproductive potential in sea turtles.
As with all of the threats we have considered so far, this one also needs to be studied in a systematic and standardised manner. It is of little use to simply look at a beach and think there might be a problem. If we want to be able to make change happen, we need to be in a position to record, document and carefully detail just what level of impact these activities have, so that we are in a position to solve them.

This normally starts by having baseline information and some form of controls. If you want to document beach loss, you could inspect historic and current satellite maps, or even resort to the time function on Google Earth, and rewind the clock to see what beaches used to look like in the past. Importantly, this would allow you to carefully measure past and present beach areas, and know the precise extent of beach loss, and be able to use this knowledge to argue for increased beach protection. Drone surveys (see Process #19) can also help in developing topographic maps for nesting areas, and these can be monitored over time for changes in beach shape and structure.

To assess impacts of beach alteration or other impacts, it is useful to have a control site where the impacts have not yet occurred, and which is similar in nesting activity and other influences, so that the control site can be considered natural while the study site is considered the impact site. Some large industrial developments that have the potential to impact turtles sometimes have monitoring projects on their beaches and also at reference sites that are used to detect changes due to the industry itself. Once you have a control or reference site, you should set up your study in such a way as to count turtles or determine nesting or hatching success at both sites, so that you have a way to compare your impact site with what might have happened under natural conditions.

LIGHT POLLUTION

Lighting is a major threat to turtles and receives special attention due to the specific nature of impacts. Turtle hatchlings are attracted to bright horizons, and adult turtles are deterred by lights. To a hatchling on a beach, an artificial light source appears bright because it is relatively close by, and the resulting glare makes the direction of the artificial source appear overwhelmingly bright -so that hatchlings ignore other visual cues and move toward the artificial light no matter where it is relative to the sea. As coastal development continues, and industrial installations are co-located with turtles, misorientation of hatchlings and decreased nesting is inevitable. When hotels, industries and homes have bright lights behind the beach, hatchlings get attracted inland instead, and are frequently lost to predators and dehydration. Adult turtles also avoid bright beach sectors when selecting a nesting spot, which in many countries is comprises all of the available beach. There are numerous solutions to light management, and there is an urgent need to address lighting as a form of pollution in many parts of the world.

The study of light itself is a very complex topic. Light is described by wavelengths and lumens (brightness) and is a challenge to measure in a standardised way on a nesting beach, but quantifying the magnitude of light is important because we need some way to measure change. There is little point simply looking at a light and having a wild guess as to whether it is bright or very bright, we need to know how bright it is in some measurable quantity. There have been a number of different approaches to measuring artificial light at night, including the use of low-cost and easy-to-use Sky Quality Meters (SQM). While the SQM can be used to measure overhead light, it cannot be used to measure light on the horizon, which is what turtles see and through which they are impacted. Turtles don't look upward, they look forward, and therefore see lights that are on the horizon. The SQM cannot be turned on its side to measure light on the horizontal plane, because it is designed to make observations of a roughly homogeneous field of light without bright glare sources. The horizon does not match this description, as it demarcates the transition in brightness between the land or sea and the sky. Also, when aimed at the horizon, the field of view includes the area below the horizon, resulting in average radiance much less than the brightness of the sky in the region. Professional assessments of light therefore require sophisticated equipment and analysis of images to generate something called isophote (light level) contour maps and calculate a sky brightness value (in something called Vmag/arcsec2). If nothing else this explanation should convey the fact that measuring and quantifying in a precise way how light changes over time light is an immense challenge.

Next comes the need to assess the impacts to the turtles and the hatchlings themselves. To measure impacts to adults, one could establish the differences in emergence rates and nesting success of turtles at a bright beach and compare these with similar counts on dark beaches (the control site) to establish the impacts of lighting – provided all other factors remained the same.

For hatchlings there are two key ways in which impacts of light are studied: One involves the use of arena trials and the second uses measurements of the. In arena trials, a circular area on the beach is cleared of any debris, and the centre and the edges are carefully marked. After this, magnetic bearing north is established and a marker is placed at the edge of the arena, and other markers are placed at (usually) 10-degree intervals. Under dark conditions when hatchlings would usually emerge from the nests, a sample of hatchlings that have been kept in the dark and unexposed to any light is released into the centre of the arena, and these are allowed to crawl undisturbed until they exit through the outer edge of the circle. At this point lights can be turned on and all of the angular measures from the centre to the points where hatchings exited the arena can be calculated and recorded. Angular directions to major light sources are also recorded at this time. When you have a sufficiently large sample size, circular statistics can be used to demonstrate impacts (or the lack thereof) from artificial lighting.

The second approach is to measure the spread of the dispersal of tracks as turtle hatchlings make their way to the sea, and any deviation the mean of the dispersal tracks has to a direct path to the ocean. When hatchlings emerge, they head down from the nest to the ocean, and by default spread out into a bit of a V-shaped fan, with some heading slightly to one side of a straight path to the ocean, and some heading to the other side, and most finding their way somewhere in the middle. The wider this dispersal V-shaped fan, the greater the disorientation in hatchling orientation. If we average the bearings between the two spread extremes, we come up with a rough average bearing to the ocean for the clutch, and the more this orientation differs substantially from a direct path to the ocean (how much it is offset), the more the hatchlings were misoriented. It is important to measure spread and offset (disorientation and misorientation) in a robust sample of nests that are under similar light influences and generally in the same area, to arrive at an average impact of artificial lighting. While this particular study does not link the orientation of hatchlings to specific light sources, inferences can be made as to the role of these lights on hatching orientation, particularly if control studies exist for dark areas where hatchlings are not exposed to man-made light.

Process #23	Pros	Cons	Frequency	Tool(s)	Refs
(23) Wide Area Threat Studies	Rapid; Low cost; Useful in identifying key threats; Can identify previously-unknown threats; Provides an opportunity for a subjective classification of threat magnitude	Not all predators might be seen during the surveys (e.g. day-time surveys may not detect foxes, or the potential magnitude - if any - of avian predation); Assessment of magnitude of threats is subjective; Requires in-depth understanding of ecological processes as they relate to sea turtle biology in order to correctly identify threats	Once, follow-ups as needed	Foot patrols, Vehicles; Notepad; Camera; GPS	10, 28, 49, 50, 51, 53
Description					

As the name implies, these surveys generally extend over large areas, assessing potential threats and the potential magnitude of these threats on nesting sea turtles. They are used when little is known of specific threats or places where threats exist, and are used as a first step to narrow down geographical threats areas, so that more detailed studies can be implemented, and threats mitigated. These surveys require an understanding of sea turtle biology and ecology to identify real and perceived threats, and their potential magnitude. Threats in this category might include poaching, and links to other activities that negatively impact turtles (e.g. in some places drug runners use the same beaches where sea turtles nest for their activities, presenting risks to teams who are studying sea turtles). Other threats might include predation and climate impacts, much as have been described above, but that are of unknown magnitude and spatial extent.

What is needed from these wide area surveys is to narrow down what threatens sea turtles and their nests, and where these threats exist, so that management and remediation actions can be prioritised. The use of aerial surveys (see Process #15) or drone-based surveys (see Process #19) is a good way to start, as these cover large areas and minimise risks of running into the wrong people or dangerous species (e.g. crocodiles) along the way. Follow up surveys on foot can confirm data collected by these remote platforms.

During these wide area surveys the observers would be looking for stranded turtles – maybe a source of bycatch; butchered turtles and / or disturbed nests – maybe from poaching; discarded fishing gears – that could impact emerging hatchlings; runoff areas – that could indicate where pollutants might be entering the sea; and a range of other variables. They may record the location of nests in relation to the high tide or vegetation lines, to assess the adequacy of nest site selection. They may record presence or absence of vegetation that could provide shade for developing embryos. They could record cases of erosion and beach loss. They may identify the location of inhabited areas where turtles might be at higher risk, or locate large assemblages of birds that might predate on hatchlings.

Most importantly, these wide area surveys are used to narrow down the potential threats, which are then ground-truthed and evaluated for actual impacts, in order for management and mitigation strategies to be effective and targeted. While they are somewhat less standardised that rigorous threat assessments, they are extremely useful in identifying hotspot areas and prioritising further studies and management action.

Photo: Stuart Chape

Process #24	Pros	Cons	Frequency	Tool(s)	Refs
(24) Bycatch Questionnaire Surveys	Relatively low cost to implement; Provides a rapid, low-cost solution to acquiring preliminary marine species and fishery data incorporating local and traditional knowledge that may be assimilated into conservation and management efforts; Can be deployed by volunteers or graduate students; provides a good way to use traditional knowledge	Due to the nature of the questions and the variability in responses, potential bias and respondent misinformation, and the questionnaire does not always provide absolute numbers, exact population abundance estimates or precise locations of fishing and turtle areas; It is indicative rather than prescriptive; Respondents may not be completely truthful and a significant sample size of respondents is required to alleviate this challenge	Once, follow-ups as needed	Access to local community members; Transport; Voice recorder; Notebook	55, 56, 57, 58, 59

Description

Bycatch questionnaire surveys are qualitative in-depth interviews with a large subset of fishers from the community. The purpose is to collect spatial and numerical information on historical sightings of sea turtles, or strandings, and a depiction of fishing areas and important habitats for sea turtles. Depending on the survey design a substantial amount of local information can be gained from simple structured surveys, and questionnaires are a powerful tool for studying distribution and relative abundance for marine species and fishery pressures, and determining potential conservation hotspot areas.

Interview surveys are considered to be one of the most inexpensive and practical techniques in developing countries. These surveys are most useful when there is little or no information available to establish population status before more intensive assessments are conducted, and provide considerable information about the characteristics of artisanal fisheries / turtle interactions over broad geographic areas. They can also be implemented for a fraction of the cost of other more qualitative survey methods over short periods of time. The surveys can also provide quantitative information about sea turtle bycatch in both artisanal and commercial fisheries when observer data are limited or not feasible, as well as qualitative information such as sea turtle occurrences and thus distribution patterns, threats and potential management strategies. The resultant data can be used to highlight priority sites where conservation efforts should be concentrated and to inform future quantitative surveys.

There are many questionnaire tools available, and you can create your own depending on your information needs. But one worth highlighting is a questionnaire that was developed for dugongs by the United Nations Environment Programme's Convention on Migratory Species (UNEP-CMS) Dugong MoU Secretariat, in partnership with the Marine Research Foundation (MRF) and a team of global experts. The survey was designed to collect data on dugongs originally, but also marine turtles and cetaceans, and can be adapted to various other species. Indeed, the survey has been adapted to focus on river dolphins, sea turtles, and manatees – it just depends on what you want to study.

The questionnaire is a powerful tool for studying distribution and relative abundance for marine species and fishery pressures, and determining potential conservation hotspot areas. A standardised Excel spreadsheet is also provided, with locked fields controlled via filters and validation to minimise data entry errors. Locked formula cells process the data in real time and construct multiple graphic and numerical chart outputs in a standardised format, so that data may be similarly interpreted from location to location. There is also a User Manual, that guides the survey design, implementation and analysis of results. The questionnaire and supporting documents are available for open-access use by the scientific and conservation communities at https://doi.org/10.1371/journal. pone.0190021.

Photo: SPREP/Carlo Iacovino

Process #25	Pros	Cons	Frequency	Tool(s)	Refs
(25) Water Sampling Surveys	Can provide relatively rapid results that might indicate causes of pollution, eutrophication, and even turtle diseases such as fibropillomas; Sampling is relatively straightforward, and requires minimal equipment - that is readily available (e.g. Niskin bottles; plankton nets, dip nets, current meters)	Analysis of water samples can be costly; Some tests require specialised collection bottles and storage at specific temperatures; small sampling scopes may not be sufficient to determine underlying threats to sea turtles	Once, follow-ups as needed	Variable and subject dependent and thus vary widely; For instance, water may be sampled for organic or inorganic pollutants, or for solid waste such as plastics	117, 118, 119, 120
Description					

Impacts to turtles and to nearshore sea turtle habitats such as coral reefs and seagrass beds can often be caused by pollution. A recent study found that excess nitrogen in the runoff accumulates in algae that sea turtles eat and may cause the disease Fibropapillomatosis which is a known cause of death in endangered green sea turtles. Runoff from farms introduces chemicals into the water that can damage or kill seagrass. Fertiliser runoff typically contains lots of nitrogen, which promotes rapid blooms of algae - these blooms deplete oxygen in the water and block sunlight, killing the seagrass. When sediment and other pollutants enter the sea, they can smother coral reefs, speed the growth of damaging algae, and lower water quality. Pollution can also make corals more susceptible to disease, impede coral growth and reproduction, and cause changes in food structures on the reef.

Oil pollution is another major threat to sea turtles, and assessments of impacts of oil spills are lacking in many parts of the world. Sea turtles can be impacted by direct exposure to hydrocarbon contaminants (petroleum, fuel oil, sludge), and also from measures used to control the oil spills such as in-situ burning and application of dispersant. Threats to sea turtles also differ depending on whether they are found in the terrestrial or marine environment. Turtles that are lightly oiled or those who are successfully captured, rehabilitated, and released have better chances of survival. Turtles that have been heavily oiled are unlikely to survive in the wild.

Analysis for contaminants typically involves sampling water or sediment and getting the sample tested in an accredited laboratory. The main types of samples are biological, geological, and water samples, and usually measure temperature, salinity, pH, oxygen, carbon, hydrocarbon pollutants and nutrient levels. Solid debris such as plastics and micro plastics can be filtered out with different size mesh nets and also be quantified.

Samples are typically obtained from devices deployed from a boat, but coastal samples may be collected from drains or along nearshore areas. Water samples can be collected in Niskin bottles, which can be lowered to specific depths before a trigger is released to seal the bottle – ensuring the water sample comes from that depth. Routine water monitoring typically would sample just of the bottom, in midwater, and just under the surface, but actually the options for sampling variation are virtually endless. The 'bottle' is a actually tube, usually plastic to minimize contamination of the sample, and open to the water at both ends. Each end is equipped with a cap which is either spring-loaded or tensioned by an elastic rope. The messenger weight trips both caps shut and seals the tube. A modern variation of the Niskin bottle uses actuated valves that may be either pre-set to trip at a specific depth detected by a pressure switch, or remotely controlled to do so via an electrical signal sent from the surface. This arrangement conveniently allows for a large number of Niskin bottles to be mounted together in a circular frame called a rosette.

These samples can be split into multiple containers, each to be analysed for different things. You might keep one for measuring dissolved oxygen, and another for microplastics, another for hydrocarbons, and yet another for trace heavy metals. The specific analysis will be linked to the actual research goal, and based on local knowledge of effluents and pollutant sources. More expensive equipment might include automated electronic data-logging samplers, which are lowered through the water column and which collect a range of data on different (user-selected) water chemistry parameters. An example of this is the YSI multiparameter sonde (www.ysi.com).

Sediment samples are collected for a variety of reasons including chemical, physical, toxicological and biological analysis. Your choice of the most appropriate sampling device and technique depends on (1) the purpose of the sampling; (2) the location of the sediment; and (3) the characteristics of the sediment. Once the sampling site and collection techniques have been selected, the specific methodologies for the actual collection of the samples should be closely followed to make sure there is no contamination of samples, and that samples can be traced from the point of collection to analysis and reporting (also called a chain-of-custody process).

Chemical and physical analysis of sediments can be used as a tool for the monitoring of pollutant discharges to marine ecosystems. Sediments can also be used to help locate nonpoint, historical, or intermittent discharges that may not be readily apparent using samples collected from the water column. The following are some of the more common sediment sampling tools used in field studies:

Cores

These are vertical discrete grab samples and are most appropriate for historical contamination information or dredging decisions at heavily contaminated areas.

Scoops and Dredges

These are used to sample surface (top two to four cm) sediment samples. They are most appropriate for benthic, sediment oxygen demand (in-situ), recent ambient conditions and recent contaminant investigation.

Surface Sediment Grab Samplers

These clam-shaped self-closing devices are relatively inexpensive, are widely used and available, and are standard for many sampling purposes (benthos), often don't need expensive equipment to operate and come in a wide variety of sizes.

Sediment bioassay samples are used to determine if there is toxicity to representative aquatic organisms from contaminated sediments. These samples are usually collected within the top 10 cm of the sediment surface with equipment that causes the least disturbance to the sediment surface during collection. Macroinvertebrates are often collected for biological surveys from soft, fine-grained sediments with a hand scoop or with clamshell-like devices that can be deployed from boats. Microplastics sampling techniques including various coring devices or grab samplers that are available to sample sediments such as clay, silt, sand and gravel with various grain size distributions. Even simple tools such as shovels or spoons work well for collecting samples for microplastics analysis.

As important as the selection of the research tool and analysis procedures are the care in sampling design, sample preservation and handling, and objective analysis of the results. As in most standardised sampling, the use of control areas can help in determining if there are sea turtle-specific impacts, either by linking sea turtle abundance and behaviour to the sampling results, or by comparisons between impact and non-impact sites.

CHAPTER 5: CONTRIBUTION TO GLOBAL AND REGIONAL DATA SUMMARIES, AND DATA ARCHIVING

By now you have figured out what you want to know, assessed your resources and expertise and available funding and all kinds of other factors that might lead to the selection of a research tool and study method, and you and your teams have gone out and collected a load of information. That information is yours, to use as you see fit in conserving sea turtles and habitats at home. But there is also value in sharing that information among a wider audience, so that it has a global impact. And that is what I'd like to discuss in this Chapter.

I know, you are probably worried about complicated things like data sharing agreements, confidentiality issues, how exactly to share your data, worried about data quality, and there may even be thoughts along the lines of "why should I share my data that I spent so much money collecting?" But let me assure you, there is great value in doing so, for you and for others, and especially for the sea turtles we all work so hard to protect. I would not have been able to write this booklet without people sharing much of their information with me over the years.

The purpose of this chapter is to highlight the immense values of collective data sets, and the importance of sharing the data that are collected by individual projects 'up the ladder' so that regional and global assessments can be made, and so that the sum of all the parts is worth more than the value of those individual parts. Sometimes small data sets don't mean very much when they are on their own, but when they are combined with others they can often, surprisingly, tell us a lot more than we thought we might learn.

Let me give you a quick example: Back in 1999, over in the Arabian Gulf, far away in the Middle East, a research team deployed two satellite transmitters on Hawksbill turtles. One went north and kind of looped around the Gulf, while the second wandered off in a somewhat straighter line. And that was that. Case closed. As far as everyone was concerned, this was done and dusted. Except that years later, in 2014, a second team that I was involved with undertook a much larger project and deployed 75 transmitters in the same general area. And you know what we found? We found that 65% of all turtles deployed in the Gulf did the same loopy things that the one turtle had done back in 1999.

All of a sudden that one single track from which little was learnt joined forces with 50 other tags and a novel discovery was made: Hawksbill turtles apparently know when the water is too hot and make these summer migrations into cooler weather – a likely response to climate change. Imagine that! On its own that single data set was just a single data set with little meaning, but when combined with others, it contributed to a better understanding of turtle ecology. Your data can do the same thing, when it is assimilated into other global data sets.

Closer to home in the Pacific region, back in 2015 a single satellite transmitter and a handful of flipper tags from the Solomon Islands indicated some Hawksbill turtles moved over to the Coral Sea and northern Australia. When that work was expanded to include additional tags in 2017 and 2018, all of a sudden it became clear that the linkage was far more than just the occasional turtle. Indeed, when this information was added to flipper tag recoveries from Hawksbill turtles deployed in Australia, the linkage between Australia and the Solomon Islands was cemented in stone. The two graphics shown side by side in Figure 13 give you an idea of how strong the linkage is between the two countries, and a good example of *habitat connectivity* as we discussed earlier in Chapter 3.

A last note on data complementarity lies in the fact that individual sea turtles, from place to place, are very similar. Sure, there are differences among species, but within a species, we find that things do not change that much. Sizes of Green turtles in the Pacific region are largely similar. The same thing goes for Hawksbill turtles. And because clutch size is often related to the size of a turtle and the eggs it deposits, it makes sense that clutch sizes would likely not differ very much either, and that is exactly what we find. Hawksbill clutch sizes in the Pacific region have been reported as 121.1, 121.7. 151.0. 132.4 and 167.8 – I hope you agree there's some variation among these values, but not extreme differences. Green turtle clutch sizes have been recorded as 104.0, 92.4, 93.5, 102.0, 107.3. Again, not much difference among these either.

So if we did not know clutch size for a particular location there are valid biological reasons to assume it could be similar to a value reported for the same species at a nearby location – *if* that value were reported! There's a very high chance that clutch frequency for Green turtles in Tonga is similar to that over on Fiji, and we could use one as a proxy for the other. It is likely that clutch size in Hawksbill turtles in is similar to that of Hawksbill turtles in the Commonwealth of the Northern Mariana Islands (CNMI). We don't know this for sure just yet, but we do know that two different studies, one in Australia and one in the Solomon Islands, both reported a clutch frequency of 3.0 for Hawksbills. So it is not that farfetched…

Of course, there's no substitute for knowing these things first-hand for your location. But turtle research and monitoring work can be expensive and resource demanding, and we can learn a lot from what is reported in neighbouring areas. When data are shared widely, we can learn from them and invest our limited research and monitoring funds more wisely.

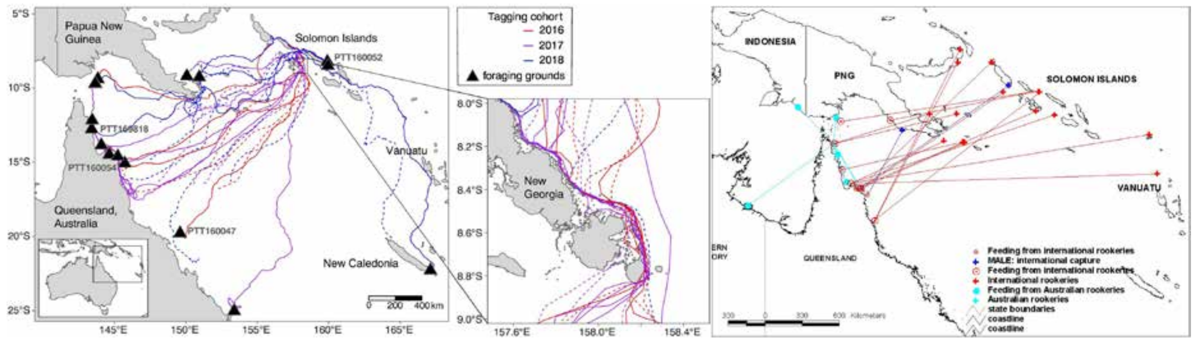
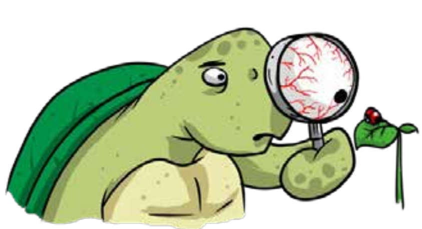


Figure 13. The value of amalgamated data sets to highlight turtle habitat connectivity. On the left the satellite tracks reported by Hamilton et al. (2021) and on the right the flipper tag recapture records described by Limpus (2009).

In the coming sections I want to introduce you to different ways in which sea turtle research and monitoring data can be shared, the different types of data that can be shared, the formats in which those data are often shared, and some of the ways in which shared data sets are used for the benefit of science and turtles.

But just before we get started, I also want to point out the some of the downsides to *not* making data public, or not sha ring data and collaborating on larger assessments and studies. Some are a bit obvious, like the backup role. When we share our data there is another copy stored somewhere else just in case something happens to ours. How many of you can relate to computer failures, hard drive losses, lost paper records, or storms and cyclones that wiped out years of work?



But what of the replacement cost of data loss? Or simply the cost of redoing work that nobody knew was already done? Imagine this: someone goes somewhere and spends two seasons working on a beach to figure out clutch frequency in Green turtles. The work requires multiple people, comes at great cost, and is utterly exhausting.

Then the team leave, do not publish the information and do not share it, and then eventually it is lost to science. To get that information back guess what we need to do: we need to go and repeat that resource heavy and expensive and utterly exhausting study. If research is conducted and the data are not made public, there is a chance that data will get lost – forgotten even – and need collecting once more, one day in the future. That is certainly a waste of our limited resources which we could better invest in conserving sea turtles… Depending on source of funds or other support, there might also be a legal or ethical obligation to publish or otherwise make public the data, especially when funds are from taxpayers.

There are also other downsides to keeping small data sets isolated. A single satellite track of one turtle's movements might tell us little from a scientific perspective. It tells us that one turtle went from one place to another place. It does not tell us how representative that movement is. And it does not tell us if this happened just because of the particular time of year the transmitter was deployed.

But when we start compiling lots of small data sets together into a comprehensive picture, we can really understand what movement patterns for sea turtles look like. Our understanding of Leatherback turtle movements in the Pacific was made possible by just this sort of data amalgamation, as shown in Figure 14. In this figure the brown tracks were from transmitters deployed in West Papua, Indonesia. The blue ones were deployed in Papua New Guinea and the Solomon Islands. And the green ones were deployed off the coast of California, USA. And from the different colours we can actually start to see some patterns: blue turtles like to head south; brown ones like to go over to the USA or to say close to Borneo. And the reverse tracks in green show that these linkages exist in both directions.

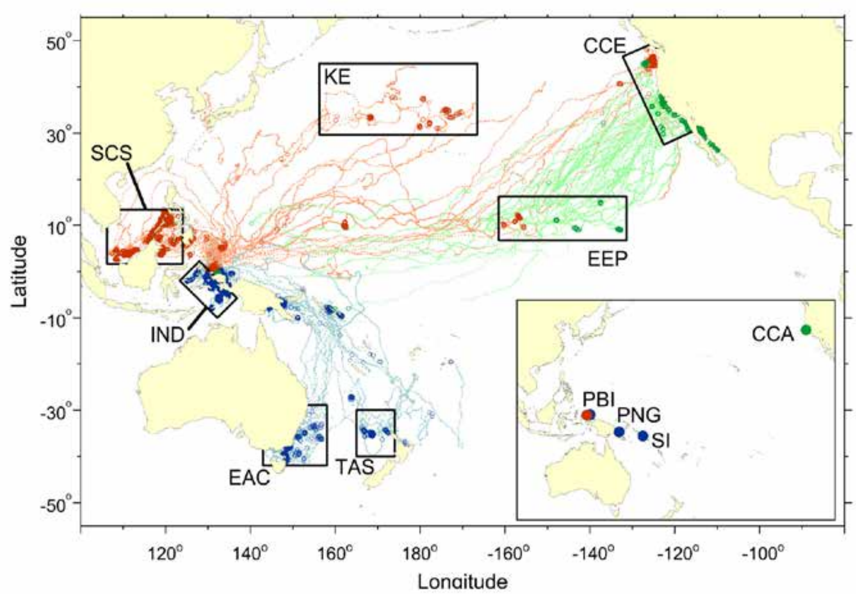


Figure 14. Large scale movements of leatherback sea turtles in the Pacific from satellite telemetry. Graphic provided by Benson et al. 2011.

This section has introduced some advantages of integrating your work into larger assessments, and the drawbacks of not doing so. In the next sections we will look at some of those global assessment processes that benefit from wide data sharing as they relate to sea turtles.

STATE OF THE WORLD'S SEA TURTLES

The State of the World's Sea Turtles (SWOT) programme is led by the Oceanic Society, a US non-profit organisation, in collaboration with a massive international network of institutions and individuals. This powerful group - the SWOT Team - compiles and publishes global sea turtle data that support conservation and management efforts at the international, national, and local scales. The data they collate resides within the SWOT database, which is maintained and managed in partnership with Duke University's OBIS-SEAMAP (see a bit further down).

This publicly-available database is regularly updated and is widely used by researchers, conservationists, students and teachers, funding agencies, and government officials. One such use is the annual publication of the State of the World's Sea Turtles report, an award-winning magazine designed to channel the SWOT Team's collective power by highlighting its success stories, innovations, and new findings. These reports are provided for free to anyone who asks, and are available for download as PDF files from the SWOT website. You can find out all about SWOT and access the reports here: https://www.seaturtlestatus.org.

Incredibly, SWOT relies on a network of people who pool and synthesise their collective resources. This is how you can help – and I imagine many of you already do. By contributing to the SWOT database, you are contributing to many global conservation processes. Have you heard of RMUs? Regional Management Units for sea turtles (RMUs) are defined assemblages of marine turtles from the same species that share areas critical to life history requirements such as breeding, foraging, and juvenile development – and they were born from SWOT and other global data sets. How about global priorities for sea turtles? Back in 2010 the process of identifying priorities at the RMU level was ground-breaking and led to prioritised funding for critically endangered turtle *regional management units* – not species. And guess what: these priorities were developed by interrogating SWOT and other global data sets.

Figure 15. Worldwide green turtle nesting sites as known in 2012. Graphic courtesy of SWOT Report, vol. VI.

Everything that SWOT produces, from the database and maps to the conservation tools and reports, is built upon individual data inputs by SWOT Team members – people like you. The maps that are produced for each report are only possible because of the contributions of (literally) thousands of people. The information displayed in Figure 15 is a good example. Imagine how many data sets went into creating just this one map. Yours could be there too!

In the process of developing the first few reports, the SWOT Team figured out that data came in all shapes and sizes, and that there were numerous people across the globe who would benefit from guidance on what sort of data contribute best to these sorts of global assessments and data compilations. Different projects collected different types of data (e.g. nests vs. females vs. crawls vs. activities, etc.) and used different methods and levels of effort to collect the data (e.g. night patrols vs. morning crawl counts vs. partial season coverage, etc.), which made results largely incompatible from beach to beach or project to project.

To address this, the SWOT Scientific Advisory Board designed a set of Minimum Data Standards (MDS) for nesting data provided to the database with a view to: a) identify datasets that could be included in future analyses of abundance and long-term trends, and b) provide SWOT data providers with guidelines for improving their existing monitoring schemes to enhance effectiveness of documenting local temporal sea turtle nesting abundance patterns.

SWOT MINIMUM DATA STANDARDS

In previous chapters we have addressed defining what it is you want to know, and then how to go out and acquire that information. But that still leaves us with a bit of a thought process on what should be the very least information that a project collects. How can you be sure that the data you collect meets the right standards for inclusion, and even answers your original question? Hopefully this section and the SWOT Minimum Data Standards, which can be accessed here https://www.seaturtlestatus.org/minimum-data-standards, will help.

As acknowledged by the SWOT Advisory Board, presenting global-scale data sets in maps, comparing among sites, and detecting trends are challenging tasks because different projects use different techniques and varying levels of effort to collect nesting data. This means, for example, that one location might appear to have fewer nesting turtles than another simply because the data provider uses a lower level of monitoring effort to collect the data.

Also, new projects start every year and are often in need of effective monitoring protocols that fulfil their own needs but also are adequate to contribute to global analyses and assessments. Enter the SWOT Minimum Data Standards, which have three key purposes: (1) to establish a minimum threshold for data quality that provides guidance for improved survey methods among the projects that contribute data to SWOT, (2) to facilitate site-to-site comparisons in nesting abundance and (3) to enhance the SWOT database's role as a global clearinghouse for sea turtle data.

This section does not presume to summarise everything that is provided in the SWOT Minimum Data Standards Technical Report, which is available for download from the SWOT website. Instead, the idea is to draw your attention to the key decision-making matrix (Figure 16), so that you can get an idea of the levels of data collection, and enable you to best position your work moving forwards. The following graphic is reproduced here courtesy of the SWOT and it provides you with some idea of the decision-making process. Full details of each protocol are clearly outlined in the MDS Technical Report available at https://www.seaturtlestatus.org/minimum-data-standards.

You should immediately notice that the MDS follows a very simple decision-key matrix. Do you know this? Yes. Ok, go to this next question. No. Then go down this route. Some questions ask about how much you know in advance (species, season duration, etc.), others about the effort you already do or could invest, and others ask about the type of monitoring you do (or want to do).

We addressed these decisions in Chapter 4. What is really useful in the MDS flowchart is how the user gets to look at scenarios for data collection (and find out whether their data will meet SWOT standards (Level 1 and Level 2 projects).

Level 1 - These data meet SWOT Minimum Data Standards, and are of the highest quality in the SWOT database. The data include total abundance counts, total abundance estimates with sampling error of less than or equal to 20% (CV ≤0.2), or a reliable index of seasonal abundance.

Level 2 - These data do not meet SWOT minimum quality standards but will be included in the SWOT database. The data will produce annual abundance estimates with sampling error of greater than 20% (CV >0.2).

Take a quick look at the MDS decision key and you will see that different data needs require differing amounts of effort and resources, and result in differing monitoring Protocols. These are briefly presented below, but important details for each of these are provided in the MDS manual.

Protocol A: Basic survey to identify species and nesting season

Protocol B: Monitoring three times (or more) per week throughout the nesting season. This monitoring protocol applies to typical, bell-shaped nesting distributions, as well as year-round nesting.

Protocol C: Monitoring one out of every 15 days outside of the known nesting season; three times per week during the first and last month of the nesting season; one time per week during the peak of the nesting season. Applies to bell-shaped nesting seasons.

Protocol D: When numerous sites are used by the same nesting population you can:

- **a) Monitor an index beach or beaches within each population or management unit.**
- **b) Monitor diffusely across multiple sites, followed by aggregate analysis of abundance and trends.**

Protocol E: Mid-season counts for remote nesting sites where access and prolonged monitoring events are not possible because of logistical challenges. These consist of complete counts of nesting females during a roughly two-week period (or longer if possible) within the period of highest density nesting.

Protocol F: Used for mass nesting sites and not applicable to Pacific islands nesting.

DECISION KEY: Find the right protocol for you, or assess your current protocol

To help you identify an appropriate monitoring protocol for your circumstances and to assess whether your current protocol meets SWOT's minimum data standards, we have developed a Decision Key that poses several questions about your monitoring project and that steers you toward suggestions about which monitoring protocol might be best for your project. Through the chain of questions you will be asked about various monitoring protocols which are possible for your situation. Any of the protocols about which you are asked are possible for your site, and will allow you to meet SWOT's standards. The end of the chain of questions will indicate whether your current protocol meets SWOT's minimum data standards and will send you to further explanations of the classification scheme that SWOT is using based on these standards.

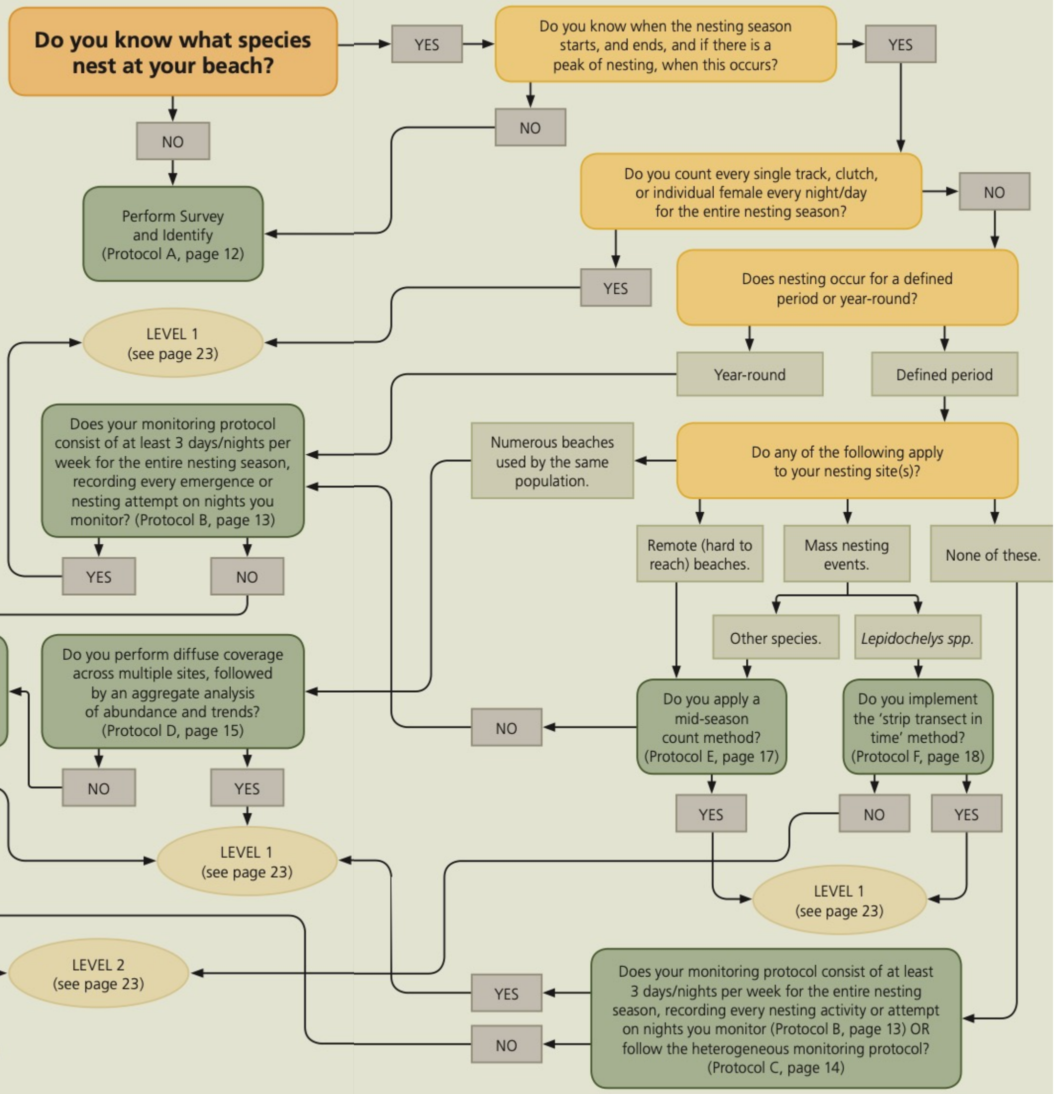


Figure 16. SWOT Minimum Data Standards decision key. Graphic courtesy of SWOT.

IUCN MTSG REGIONAL REPORTS

These regional reports are annual MTSG publications that aim to summarise all known published data and pertinent unpublished data (at the authors' discretion) for every country and region in which sea turtles occur. The key to this phrase is the word *known*. These reports take a long time to produce, and can be massive. The Oceania report published in 2020 was so big it took up two volumes, spanned 642 pages, had 23 authors, several of whom wrote several chapters, and took 3 years to produce. It was a massive effort. And let me tell you, a load of that effort went into tracking down the information that people had, spread far and wide, hidden on old computer hard drives, and scanned from old reports for which original files had been lost. If information was shared and disseminated in a timely manner – or at least the knowledge that the information existed were made public – along with the names and contacts of the data owners, this would have saved loads of time. Today's digital world should make this much easier from now onward.

In many ways the regional reports are a way to synthesise the data needed for Red List assessments ahead of time, to make it easier for the assessors. But they are also a major resource and repository of data. People will be looking back at the two Oceania volumes for decades to come because for now they are among the most authoritative sources of the largest amount of data about Oceania's sea turtles all compiled in one place.

As future editions are produced, contributing data to the process will do several things: (1) it will make sure your data are part of a global dataset, and help paint the most robust picture about the biology and conservation status of sea turtles in the Pacific region; (2) it will elevate the local profile of your work and put your project and the valuable data it collects 'on the map', so to speak; and (3) it will open up communication with other sea turtle biologists around the region, and even across the world, and further strengthen the work you do.

To contribute data to the IUCN MTSG Regional Reports, you can contact the Chairs of the IUCN Marine Turtle Specialist Group via the MTSG website at https://www.iucn-mtsg.org.

RED LIST ASSESSMENTS

The Marine Turtle Specialist Group (MTSG) of IUCN is responsible for providing information on the seven species of marine turtles and for developing marine turtle global and regional assessments. MTSG members provide scientific advice to conservation organisations, government agencies and other IUCN members, but the most important role of the MTSG is to provide scientifically robust species assessments for the Red List of Threatened Species.

Surely you have heard of the IUCN Red List? It is SSC members that compile the Red List Assessments that you have seen and used for turtles and other species. The IUCN Red List can be accessed at https://www.iucnredlist.org. I would imagine that several of you reading this are members of the IUCN MTSG or other specialist groups, and that you have contributed data and resources to Red List Assessments. A great thing about the Red List is that it provides credible risks of imminent extinction at a global level for species that are comparable across different plants, animals, and insects even. That is, the Yanita tree in Fiji (*Pterocymbium oceanicum*) – which is Critically Endangered – is considered just as Critically Endangered as the Hawksbill turtle.

Assembling the data to undertake a Red List assessment is a mammoth task. To give you an idea, the last global Hawksbill assessment was completed in 2008, and comprised over 100 pages of data and tables and figures and analyses and justifications. To compile an assessment properly, assessors need to look at the trend in numbers, the amount of available nesting and feeding habitat, whether the population is fragmented, whether the population is genetically distinct, and a number of other factors. And they need to align these exactly with some very specific IUCN Red List guidelines.

Among these guidelines are the thresholds used to determine risk of extinction that are related to the decline of a species. These criteria can be rather complex and there are far better places to learn about Red List processes (IUCN has some great instructional videos on YouTube, for instance), but I'll outline one set of these briefly here to give you an idea:

- If a species declines by more than 90% over 10 years or three generations, whichever is longer, then it gets classified as Critically Endangered.
- If it declines by 70% then it is Endangered.
- A decline of 50% leads to Vulnerable.

The tricky bit for sea turtle assessments is the part that reads *10 years or three generations, whichever is longer*. As we discussed earlier, the most common criterion on which to determine risk extinction assessments for sea turtles is the trend in numbers of nesting turtles over time. But to meet the IUCN guidelines we would really need three generations of data or about 100 years or so. Which we don't have…

A second challenge, as I am sure you are aware of, is that sea turtle numbers on a nesting beach fluctuate naturally. One year there can be many, and the following year there could be fewer, and this would be completely normal. It is only after we collect, say, 20 or 25 years of data that we are in a position to detect *trends* in numbers of nesters. In Figure 14 I provide a very typical nester abundance fluctuation, for Green turtles in Hawaii. If you look at the left panel (a), you will see that in some years nesting is down, and others it is up. But if you look at the general trend of those ups and downs, the long-term trend is that the population is increasing. This is confirmed by the right panel (b), which modelled the data and smoothed out the growth trajectory.

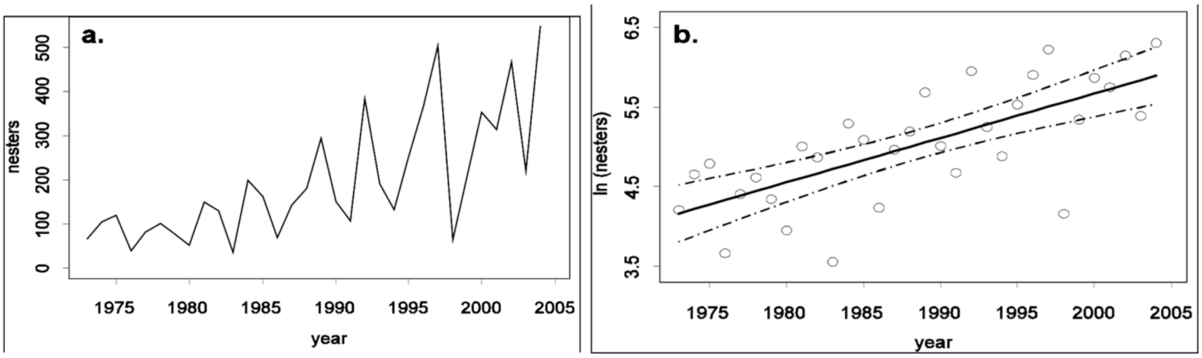


Figure 17. Long term nester abundance at French Frigate Shoals, in the Northwest Hawaiian islands. Graphic courtesy of Balazs & Chaloupka, 2006.

So now we are challenged by not having 100 years of nesting data, and we are also challenged because short data sets, or *time series* of data, do not really get a clear picture if the population is on the rise or declining. The absolute minimum the MTSG will consider is 10 years of data, and even then this is not an ideal situation. There are a number of mathematical and procedural ways around this, but what is important is that the longer the data series for our nesting beach, and the more publicly-available we can make these data so that assessments can rely on them to understand what is happening with turtle stocks, the more accurate the MTSG can make each Red List assessment.

Ultimately the goal of a Red List assessment is to determine if the population trajectory is upward, stable, or downward. To detect this the assessors need access to data sets that can demonstrate this trend, either in the form of number of tracks, number of nests, or number of female turtles. As we learnt earlier, these can be interchangeable with a few calculations:

 # nests = track counts × % nesting success

 # females = # nests / clutch frequency

Also, as we discussed earlier, we can assume that clutch frequency for Green turtles in Tonga is similar to that of Green turtles in Fiji, and can use these values when data for one or the other location are not available.

If you can provide any of these figures to an assessment you will be making a massive contribution to the Red List process. Data sets need to identify the location, and then the number of tracks (or nests or females) per year over as many years as possible, with some indication of effort.

To contribute data to the IUCN MTSG Red List Assessments, you should keep a look out for the public announcements made on global list servers such as CTURTLE and the MTSG mailing list, and you can also contact the Chairs of the IUCN Marine Turtle Specialist Group via the MTSG website at https://www.iucn-mtsg.org. Importantly, the more people who know of you and your work, and the more you participate in collaborative processes, the easier it will be for assessors to find you when the time comes to review a species status.

OBIS-SEAMAP

OBIS-SEAMAP, which stands for the Ocean Biodiversity Information System - Spatial Ecological Analysis of Megavertebrate Populations, is a global data centre for marine mammal, seabird, sea turtle and elasmobranch spatial information. The OBIS-SEAMAP service is made possible by data sharing from contributors all over the world, including people like you. The observation data are registered into the OBIS-SEAMAP database and presented on the website only with data contributors' permission – and the ownership of the data always belongs to the contributors. It is an incredible global resource, and the service is now a project under IOC-UNESCO's International Oceanographic Data and Information Exchange.

It contains a massive data set, which you will hopefully appreciate from Figure 17. For sea turtles alone there are 1.1 million records, contained in 576 data sets, that detail sea turtle migrations, nesting beaches, sea turtle photo ID data - you name it. A lot of my own turtle data is on OBIS-SEAMAP.

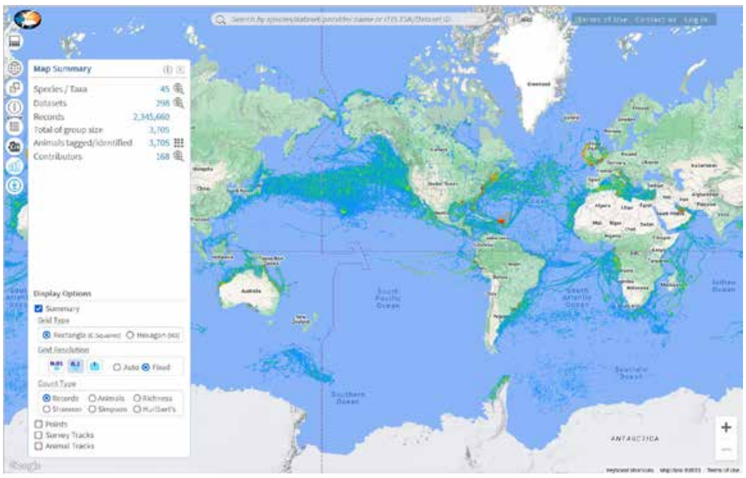


Figure 18. Screenshot of the global summary of the unfiltered telemetry data for all species at OBIS-SEAMAP. Graphic courtesy of OBIS-SEAMAP.

For information on OBIS-SEAMAP and submitting your data to the collection, please visit https://seamap.env.duke.edu/content/provider_faq/ This page has an email link to the Data Manager, with whom you can then communicate to finalise data sharing. Virtually any data format is acceptable but they do have some minimum data requirements so that these can (1) be assimilated into the geographical information system and (2) be compatible with other data sets that are submitted. In their most basic form, data needs to provide the "what", "where" and "when" of an observation:

1. What = SPECIES IDENTIFICATION: A scientific name (*Genus species*) for your sea turtles is preferred, however data at higher taxonomic levels, such as genus.
2. Where = LOCATION: The latitude/longitude coordinates of the observation. The coordinates can be in various formats.
3. When = DATE/TIME: The date and time of the observation. Almost any format is acceptable.

REGIONAL TAG DATABASES

Have you ever found a tagged turtle (or heard of one) and tried to track down the team that originally tagged it? When turtles are 'recaptured' because someone found a flipper tag, it is extremely useful to science to know these *habitat connectivity* linkages, and it is always interesting for members of the public to find out the sort of amazing migrations sea turtles can make. On the global CTURTLE list server there are numerous requests every year by people who have found a turtle with a tag, and were trying to track down its 'owner'. I personally have had multiple requests for this sort of information. A great example was when someone found a turtle in Malaysia that had been tagged in the Federated States of Micronesia. A journey of some 3,500 km! And the story behind it was even more intriguing… the person said that he had found the tag in a grouper's stomach, but over on FSM the tag was apparently affixed to an adult Green turtle... That would have to be one giant grouper! Or a tall tale by the person who found the tag…

Regardless, we now know that some turtles from FSM can go as far as Southeast Asia, and I am sure you can see the value of being able to track down the data owner. In this case, it turned out that the tag was recorded in the TREDS database (Chapter 6), and a quick email to SPREP solved the puzzle of where and when the tag was deployed.

To help with this challenge as and how it emerges, there are a few turtle tag databases where you can share information about the tags you are deploying, and these are the first places someone else would look when trying to track down a tag owner. Normally you have to key in things like the number range, prefix or suffix details, and provide a contact address and details. Then if someone finds a tag, they can search for that tag series on the database and if they find it, they would know who to contact.

It would be a great idea – if you were tagging turtles – to upload at least your tag metadata to one of these online repositories so that people can track them down with ease. Also, in case this is a concern you might be having, at this stage you are not sharing any actual data, you are just telling people that you and your team have used or deployed these particular tags. There is a final advantage to lodging your tag series to collective data sets, and that is that nobody else will use the same series. Imagine this: if you used tag series R35001 to R40000 without consulting one of these lists, you would have used at least one of the tags already deployed over in FSM that was found inside a grouper!

- The Pacific Islands region has its own data register for tags – the Turtle Research and Monitoring Database System, or TREDS, which we will discuss in a bit more detail in Chapter 6. The database is maintained by SPREP and can be accessed at https://www.sprep.org/thetreds.
- The Archie Carr Center for Sea Turtle Research (ACCSTR) in Florida maintains one of these turtle tag inventories, and it can be accessed at https://accstr.ufl.edu/resources/tag-inventory/ or by searching online for these key words: Archie Carr / tag / database.
- Another online database is the one maintained by the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA MOU), which can be accessed at https://www.cms.int/iosea-turtles/en/page/flipper-tag-series, or also by searching online for these key words: IOSEA / tag / database.
- Given the number of sea turtles that have been tagged in Australia, another good place to check is with the Department of Environment and Science in Queensland. They don't have an online database, but their website is https://www.des.qld.gov.au and links from there should be able to put you in touch with the right people, and you could email them with an inquiry.
- Today, tag manufacturers themselves maintain a good database of the tags they sell and they might sometimes be able to tell you who they sold a particular tag to. Two of the more common tag companies are Stockbrands in Australia (https://www.stockbrands.com.au) and National Band & Tag Company (https://www.nationalband.com) in the USA.

I do hope these opportunities to share your work and complement that of many other researchers has been of use, and that the combination of the methods we reviewed in Chapter 4 and the Minimum Data Standards we looked at above, are of use in your project design. I'd like to finish this particular section on data sharing by talking a little about the Pacific's very own turtle database TREDS in the coming chapter.

CHAPTER 6: THE TREDS DATABASE

In this last section we will take a slightly more in-depth look at the Turtle Research and Monitoring Database System (TREDS) that is maintained by SPREP. TREDS provides information about sea turtles for PICTs to manage their turtle data resources, and can be used to collate data from strandings, tagging, nesting, emergence, and beach surveys as well as other biological data on marine turtles.

The original database structures and data collection philosophies behind TREDS are based on a database system designed by Dr. Col Limpus and his team at the Queensland Parks and Wildlife Service (now Department of Environment and Science). Subsequent development of TREDS was a collaborative effort by SPREP, the Western Pacific Regional Fishery Management Council, the Secretariat of the Pacific Community (SPC), the United States National Oceanic and Atmospheric Administration (NOAA) Fisheries, the Queensland Government Environmental Protection Agency, the South-East Asia Fisheries Development Centre and the Marine Research Foundation - that's me! It ran on a Microsoft Access platform and had a series of predesigned data entry and reporting protocols.

Over time the database had become less useful with users encountering a number of errors and glitches with the system, and so in recent years the database has been upgraded from the old interface to a web-based system (https://treds.sprep.org/user/login?destination=/projects) which has provided a number of benefits such as access across multiple operator platforms (Mac, Windows), giving you quick and easy access to your data from anywhere in the world, and the ability to upload and access data from multiple user platforms. The new system has an awesome User Manual that goes with it, that it is all driven by screenshots of what to do and why to do it and how to do it. A second difference between the two databases is that there is an offline data entry Application that is built into the database. You can download this App onto your laptop or mobile devices (phones/tablets) and input data out in the field where there is no internet connectivity. When you return to the office, you can upload the data directly from the App to the database. These are certainly some massive improvements!

The purpose of the database is to act as a repository for sea turtle data in the Pacific region, and when TREDS was first created a driving force was that SPREP would distribute tags to PICTs to apply on sea turtles, and that the data from the tags would be entered into TREDS so we could learn all about turtle movements. That is still the case, but the functionality of the system has improved to where many other benefits can be derived from using the system. If you want to use SPREP tags you will need both a project that has a clear and objective monitoring or research proposal and had training in the use of TREDS before tags can be provided.

In the early days, as tags were deployed, the data for each turtle were supposed to be uploaded to the TREDS system via an annual report to the TREDS database manager. When the database migrated to the Microsoft Access system users had the opportunity to enter their data into a remote Access file that could be shared with SPREP and amalgamated into the regional database at any point in time. This process of reporting has worked better in some areas than others, but despite this, there are over 23,000 turtle records in TREDS that help paint the picture of who does what, when, and where. For example, some generalised movements of sea turtles across the Pacific, as determined from tag recoveries in the TREDS database, are shown in Figure 18.

The TREDS system is accompanied by a user manual to guide data entry and interrogation that addresses the following topics: Introduction; Initial download and installation of TREDS; Registering and creating a TREDS database; Considerations before data entry: Projects, fieldwork and tag inventory; the Tag register; Administration; Reference tables; Data entry and editing; and Reporting.

STRUCTURE

For you technology-oriented readers, the following brief description describes how the database (actually a series of *relational databases*) works. A *relational database* is a database structure whereby one field in one database can be used to link to another database in which that same field is used. For example, a turtle might come up and nest and be tagged with tag TV3245. The entry record might have details of the *tag*, location, date, time, success, turtle size and any additional fields that are keyed into that database. But if she lays eggs, we could create a record in a *Nest* database that also contained the *Tag* field – in this case tag TV3245 would send us to any records of this particular turtle's nesting events, where we might also find details such as number of eggs, nest depth, nest location, nest number, etc. The *Tag* field becomes the relational field that links everything together like glue.

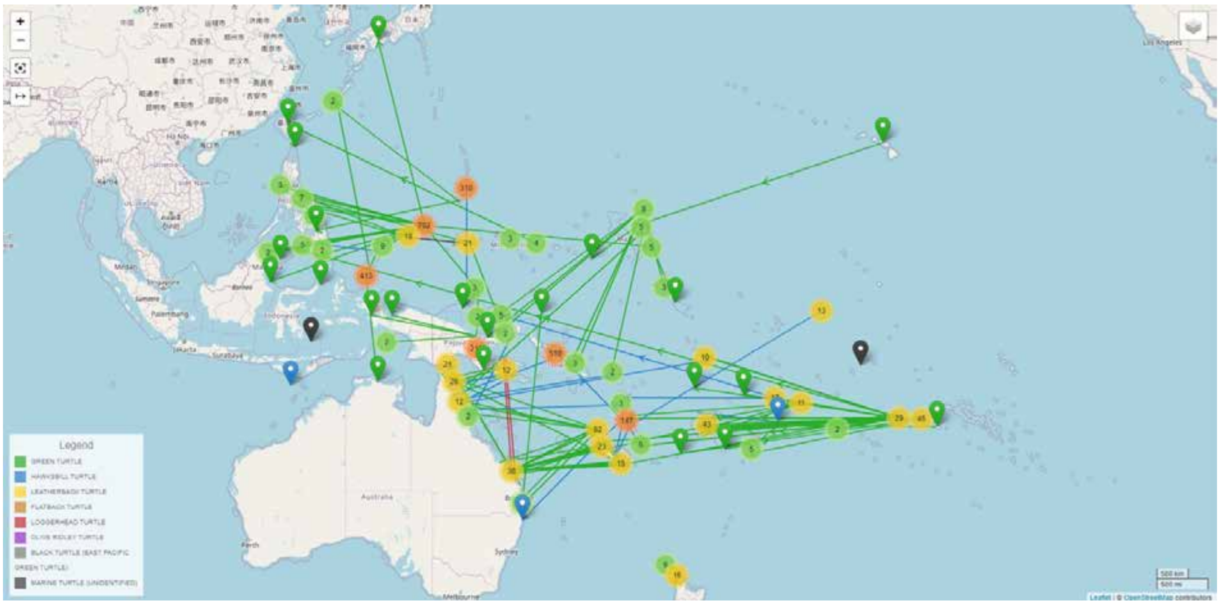


Figure 19. Turtle movements across the Pacific Ocean as described by recoveries of tags deployed in one country and recovered in another and that were maintained in the TREDS database. Colours denote different species and numbers denote number of records to and from those locations. Graphic courtesy of SPREP.

Once you register your organisation (which gives you and your team access), your create your *Project*, which is best described as an independent operation. For example, SPREP might provide tags (and applicators) to an independent association in New Caledonia to conduct their own tagging, which would be seen as an independent 'project' distinct to a National project (and yet connected through the provision of tags and the subsequent receipt of data collected).

Within each *Project*, there may be one or many tag inventory records. A *TagInventory* database is used to manage the inventory of tags. Information is recorded in this table when a series of tags are received from the manufacturer, a series of tags are issued to a project or a series of tags are used, or returned from fieldwork within this project. Basically any movement of tags in or out of the project is recorded here.

Within each Project, there also may be one or many fieldwork activities. A "*Fieldwork*" unit is a discrete period of time during which data are collected from one study site during a specific project. This provides a means of distinguishing discrete fieldwork activities over different areas/ time periods within a project – in our case these are normally called nesting seasons.

For each *Fieldwork*, there may be one or many instances where tags have been applied to turtles.

So let's say you have a *Project* in New Caledonia, and it wants to have a *Fieldwork* monitoring season in 2023. Any tags deployed that season get recorded in the *Encounter* page, and the system then knows when and where the tags were deployed. The *Encounter* page is used to store information on tags applied to turtles or tags that are lost, damaged or missing for one reason or another. Associated with this tag number of course is all the turtle information (like age class, sex, species, etc). Additional information related to the turtle is stored in other database tables that are part of the main structure – a bit like branch offices – and this information is linked to the *Encounter* by the first or *Primary* tag that has been applied to that turtle.

There are also areas where one can key in data on clutch sizes, and egg sizes and weights, and hatchling sizes and weights, and on migrations and on genetics and pretty much anything else you can think of related to turtle monitoring. And all of these are linked via relational fields to that everything can be tracked by project or by turtle or by location. It is, without a doubt, a pretty awesome tool, and is available for pretty much anyone to use for free.

USES & CHALLENGES

The TREDS tag inventory can be used to record different types of tags (e.g. passive integrated transponder (PIT) tags, flipper tags, and satellite tags) and data loggers, and handle a wide range of biological information (e.g. clutch sizes, emergence success, incubation period). Well used, TREDS is a formidable tool and data storage option, and can serve multiple purposes:

1. Data can be interrogated to determine *habitat connectivity* between where the turtles were tagged and where they were subsequently found;
2. Data can identify possible migration routes for sea turtles in the Pacific;
3. The system could provide summaries of nesting and foraging activity by sea turtles at a national level which could be amalgamated to a regional level as needed;
4. At the country level projects could collate and perform simple analysis on data collected from turtle surveys and generate reports to assist in informed decision-making for turtle conservation and management.
5. At the regional level, TREDS could be used to collate data, provide backup services to SPREP members and identify trends in turtle populations and migration patterns in the Pacific region.
6. The system could also act as a central repository of data on sea turtles (sizes, nesting locations, numbers) across the Pacific.

The downside is making sure that all of the appropriate data are entered into the database and people are utilising the full functionality of the system. Some limitations to TREDS use are provided below, not because TREDS is not a good system – it is a *great* system – but because it is important to understand what TREDS analyses can tell us and what they can't.

Challenge 1: Getting all of a project's data into TREDS. Of the 65,090 flipper tags distributed by the secretariat to SPREP member PICTs, only 14,741 (23%) have been recorded in TREDS. This does not mean the balance are out there swimming around on turtle flippers and not in TREDS. It could mean that some have not yet been deployed. It could mean that some got put in a box and that the box was lost during an office move, or the person responsible moved to a new position and the incoming staff didn't know they even had tags in a box… But it is this lack of knowing what is the status of those tags that provides a great degree of uncertainty;

Challenge 2: Getting multiple people familiar with the use and functionality of the TREDS system and maintaining that capacity as people move from one job to another;

Challenge 3: Interrogating the system with a clear understanding of the data limitations. For example, if Fiji were to enter no data into TREDS, it would not mean there were no turtles in Fiji, it would just mean that the turtles from Fiji were not yet in TREDS;

Challenge 4: Interpretation of the data already in TREDS. For example, we could request TREDS to produce a table of the number of nesters by country. We could then build a graph or assemble a table of the results, but these data would not necessarily paint an accurate picture of nesting across the region. If someone monitored nesting in Tonga but did not enter all the data into TREDS, the values for that country would be incorrect. Or if 215 turtles were recorded in TREDS for Fiji and 342 were recorded for Vanuatu, would this mean that Vanuatu had more turtles? No. It just would mean that Vanuatu teams entered more data records. Now, by all means, Vanuatu might have had more turtles than Fiji, but this cannot be determined through TREDS data alone. The understanding of the limitations of what TREDS tells us is as important as the data itself.

Personally, I think it would be useful to know what tags SPREP gave to who, and when. By the way, the TREDS team know this – I mention it because other countries need to know how many tags are where, when they assess the value of the data. I also think it would be good to know from each recipient country office what tags were knowingly deployed, and which ones remain, and which have been lost along the way. Keep in mind the person in charge of the turtle data today might be the replacement of the replacement of the replacement of the person who was in charge when the tags were received. If you think you might be able to help, please do contact the TREDS team.

At the end of the day, TREDS can only be only as good as the data that goes into it and the astute use of it by scientists and managers. If we do not populate it with consistent, accurate data that also describe the level of effort that was invested, TREDS will be unable to detect trends or provide accurate regional summaries. On the other hand, if we conscientiously add data and by so doing improve the robustness of TREDS, the Pacific Islands region will have a wonderful and useful regional database that can store and also help analyse data – and point the way towards conservation goals. As more people use TREDS as a regional repository of data, greater functionality will come of the amalgamated data set.

THE END

ACKNOWLEDGEMENTS

In the preparation of this Manual I have had some amazing sounding boards – people with whom I could share things unashamed, and who willingly criticised and commented and provided constructive feedback (and probably laughed at me behind my back…). My wife Carmen stood by while all this writing was ongoing and I am grateful to her for her patience and the occasional word here and there that provided illumination on ways forward.

I am also grateful to some amazing sea turtle scientists and conservation practitioners who responded with feedback, input, guidance and who corrected my errors. In alphabetical order I am grateful to Alexander Gaos, Bryan Wallace, Christina Shaw, Christine Madden Hof, Col Limpus, George Balazs, Grahame Webb, Irene Kelly, Michael White, Robert Baldwin and Shritika Prakash, some who commented on the original structure and ideas, and some of whom have seen all or parts of this Manual before you, and provided constructive and valuable feedback. Rob Baldwin and I discussed many aspects of what has now become this manual while sitting on a turtle beach in Saudi Arabia. Bryan Wallace has provided sound science advice over multiple conversations in various parts of the world. Both of them gave up substantial time to review the content of this manual and deal with numerous queries, and I am particularly grateful for their support.

I am also grateful to colleagues among the wider turtle community with whom I have had discussions at one point or another over the years, and who have provided sound reasoning for some of the discussion points I have presented. For this I especially would like to single out Col Limpus, who has entertained my wild thoughts, shared immense amounts of sea turtle wisdom, and provided sound guidance for many years. I owe a lot of my understanding of long-term sea turtle ecological process to Col's campfire and catch-boat chats. He also let me catch a Flatback. I would also like to thank Karen Baird and Unity Roebeck at SPREP for input on TREDS and on the overall SPREP Pacific turtle programme.

For the artwork, I take my hat off to Sheng Haw Lim – an amazingly talented artist who understood my vision for bringing some of the pages and discussions to life, and worked his magic in truly amazing form.

Finally, I want to acknowledge the vast contributions from thousands of turtle biologists and researchers as well as community members, fishers, government representatives and others who contributed data to the studies I have used as examples and baseline knowledge, and the wealth of information from their own original publications – some of which I referred to in this document, and many of which helped shape my ideas.

I acknowledge that all ownership and intellectual property of the information I refer to or draw upon resides entirely with all the original data owners and providers. I have used a couple of graphics in here, and hope that the rightful owners are happy to see them put to yet another good use. I am also grateful to the numerous research teams, NGOs and government agencies who have funded all the work I have just described.

My thanks also go to you, for reading through this Manual and being part of the global movement promoting wise sea turtle use, management and conservation, backed of course, by robust science.

SUGGESTED READING LIST

Over the years I have managed to read and accumulate some books in my library that I decided were 'keepers'. Some have guided my thoughts as a conservation practitioner, others have been authoritative and reliable sources of information on sea turtle conservation methods, yet others a compendium of everything you ever wanted to know about a particular sea turtle species.

The MTSG manual on this list can be downloaded from the IUCN MTSG website, and provides a wonderful summary of many of the things we discussed in this manual. I am particularly attracted to the simple basic structure and messages the manual provides. Similarly, the Minimum Data Standards booklet can be downloaded from the SWOT website and provides guidance on selecting 'levels' of projects that provide more and more data in a robust manner. The rest are books you would need to purchase, but I assure you they would be well worth the investment. Most are available from the original publishers online, and all can be found at a range of online retailers.

The trilogy of 'The Biology of Sea Turtles' books, and for me particularly the first volume, are some of the best compilations of widely scattered information on sea turtle biology. I have come to rely on these books when I need to know facts and figures, and when I needed to be pointed in the right direction or towards the right person to contact regarding a particular aspect of turtle biology. The 'scene-setting' books by Archie Carr and others are wonderful reading material if you want to go back in time and see what the world looked like as sea turtle conservation became a 'thing'.

Then, towards the end, are some books that I am convinced have made me better at what I do – saving sea turtles. In The Tipping Point I learnt all about what makes something finally happen – how do we bring governments or communities on board with turtle conservation, or how do we get a certain type of fishing gear accepted by fishers. In Blink, the author showed me how I could use limited information to reach a conclusion – something that I find relatable in those times when I need to make a conservation decision with fewer facts than I have at hand. And in David & Goliath the author showed me how running a small nimble conservation agency I could make significant things happen. These last ones are personal preferences. I don't claim that these books will transform your lives or thinking, but I assure you they played a role in how I have approached sea turtle conservation. I often found myself saying 'hey, that's me" as I read through the books, and found I could relate to the messages within. And as a last note, I am in no way affiliated with the author, and don't benefit by pointing you in this direction in anything other than I think you will be better turtle conservation practitioners and researchers, which is good for turtles!

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Blink: The Power of Thinking Without Thinking by Malcolm Gladwell; 2006

ANNEX I: KEY THREATS TO SEA TURTLES IN THE PACIFIC REGION

HABITAT LOSS

As human populations expand, and towns and industries expand alongside them, nesting beach habitat can be taken away from turtles and overrun by hotels, industrial complexes, and beach-front homes. As dredging takes place to create new coastal properties, valuable seagrass or coral habitats are destroyed – and along with them the primary food source for Green and Hawksbill turtles.

ACCIDENTAL CAPTURE IN FISHERIES

More and more, fisheries are having a massive impact on turtle mortality, and this is no less the case in the Pacific region. As fishers set their nets and leave them in the water overnight, turtles get caught accidentally and drown. Sometimes they swim into fish traps set on the seafloor, looking for food, and sometimes they get entangled in the float lines fishers use to recover the traps. Turtles also get caught in gill nets and drown, as they cannot come to the surface to breathe. On the high seas, turtles get entangled in long-line gears, or go after the bait and get hooked just like the target fish. They also are taken in commercial purse and trawl fisheries.

COLLECTION OF EGGS

By far one of the biggest problems is collection of eggs on beaches. Turtle eggs are literally defenceless and particularly vulnerable to poaching. People collect the eggs as food, to sell at market, and as also as aphrodisiacs (although there is absolutely no 'secret' chemical in turtle eggs and they are pretty much the same in content as a chicken egg).

HARVESTS OF TURTLES

While in some parts of the Pacific the traditional harvest of sea turtles is permissible, the challenge lies in knowing just how many turtles can be taken before the population starts to feel the impact. And let me tell you, this is an elusive number that defies even some of the best scientists. As you will find out a bit later in this manual, in many parts of the Pacific, sea turtle populations are not massive, and likely cannot withstand a sustained harvest for long. Finding that balance – the level of *sustainable take* – is going to be a challenge for a very long time, and the reasons are quite simple: Sea turtles take a long time to reach maturity, and therefore a certain level of removal is going to take a while to be noticed. And then if the turtle numbers appear to be declining, we would need to adjust that level, and wait again. In the meantime, we are probably better off being a bit precautionary and making sure sea turtle populations are increasing and doing well before we start experimenting with this. Or at least being precautionary and setting low harvest numbers until turtle populations recover.

POLLUTION

Pollution comes in many forms. It can be in the form of chemicals that are spilt or leach into the ocean, and which damage coral reef and seagrass habitats. It can also be in the form of plastics - turtles can mistake a floating bag for a jellyfish; juvenile and adult turtles also ingest plastics as they feed on floating materials, and they can also get entangled in plastics which litter the seas.

LIGHTING

Manmade light is also considered a form of pollution. Turtle hatchlings are attracted to bright horizons, and lights deter adult turtles. As coastal development expands, and villages and developments are co-located with turtles, hatchling misorientation and decreased nesting is inevitable. When hotels, industries and homes have bright lights behind the beach, hatchlings get attracted inland instead, and are frequently lost to predators and dehydration. Adult turtles also avoid bright beach sectors when selecting a nesting spot. Luckily there are many remote beaches and islands spread across the Pacific where this is not yet the case – but knowing lighting can be troublesome for turtles works in our favour: forewarned is forearmed, as they say, and we can put ourselves in positions to guide future developments so that lighting is not a concern to sea turtles.

GHOST FISHING

Nets and other fishing gears discarded at sea by fishers or lost at sea in storms, or simply by accident, continue fishing long after they leave the boat. Hundreds upon hundreds of turtles die each year drowning in gear which are no longer of any use to people.

CLIMATE CHANGE

Warming global temperatures could lead to feminisation of stocks (because sea turtles have temperature-dependent sex determination and warmer nest incubation temperatures produce females]), embryonic mortality (due to incubation at extreme, lethal temperatures), and loss of nesting beach habitat, as we talked about earlier. Less obvious, as sea levels rises beaches become narrower and shallower. A narrower beach offers less nesting area. A shallower beach means turtles may not be able to deposit their eggs as deep as they would like, or abandon the site altogether.

GENETICS

To round out this section, we should touch briefly on turtle genetics. While genetic disposition is not a threat *per se*, it is a natural turtle trait that doesn't always work in their favour. Turtles are grouped into distinct genetic stocks, and there is little interaction among these stocks, restricting gene flow. This restricted gene flow can be a problem for sea turtles, and it goes something like this: a key portion of genetic material – the *mitochondrial* DNA, or mDNA – gets passed down only by the mothers. Because sea turtles return to nest in the general vicinity of where they were born, the mDNA is maintained in somewhat of a closed loop, with very little immigration of turtles from other areas. This means turtle populations that have been decimated will not rebound through immigration from outside populations – at least not for a very, very long time because those other turtles would be going back to 'their' nesting sites. For practical purposes on human time frames, when a turtle population is gone, we can consider it locally extinct.

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