FAQs ABOUT Sea Turtles

With their specialized biology and their unique behaviors, sea turtles tend to inspire a lot of questions. Spend an hour with someone who is watching a turtle nest for the first time, and inevitably the questions will come: How old do they get? Where will she go after she leaves the beach? Where did she mate? When will she come back? How long until the babies become adults? And so on.

When it comes to turtles, however, the answers to such seemingly simple questions can be surprisingly elusive. Those of us who work with turtles have therefore grown accustomed to answering with phrases such as "We don't really know, but …" or "Our best guess is that …" Although the lack of concise answers to basic questions about sea turtle biology can be frustrating, that lack is precisely what makes sea turtles so interesting to study. After decades of scientific study, sea turtles are still mysterious in many ways.

Increasingly, however, advances in technology and results of long-term studies are giving scientists the information they need to answer with increasing certainty some age-old questions about turtles. Some mysteries are being solved, yet others still are answerable only with our best guess. With such continuing mysteries in mind, last year we launched this new segment in *SWOT Report* by inviting experts to weigh in with current perspectives about some of the most frequently asked questions concerning sea turtles. This year we tackle two new questions. Read on to hear what the experts had to say.

IS THAT TURTLE A BOY OR A GIRL?

By Itzel Sifuentes-Romero and Jeanette Wyneken

How can we tell if a sea turtle is female or male? In adults, it's relatively easy—a male has a long tail that extends well beyond the carapace, with a cloacal opening near the tip. In comparison, a female has a short tail with a cloacal opening near the base. With hatchling and sub-adult turtles, it's not possible to determine their sex simply by looking at them; they are not sexually dimorphic, meaning that they do not have any external features to distinguish males from females. They lack such features because the hormones that are responsible for changing the anatomy are not present in high enough amounts to trigger those differences until they reach sexual maturity—and that can take decades!

Sexual identification of young sea turtles is further complicated by the fact that, unlike mammals, they don't have sex chromosomes (no X or Y); therefore they lack sex-specific genes that could be used to determine sex with a DNA sample. In mammals, for example, the *sry* gene is only on the Y chromosome, and its presence or absence can be used to determine sex. In contrast, sea turtles' sex is determined by the incubation temperature they experience as embryos—warmer incubation temperatures produce females, and cooler temperatures produce males. But, if not through sex chromosomes, how does that system work? We have found that temperature is able to trigger a gender-specific cascade of genes that directs the embryo to differentiate the reproductive tract and gonads (ovaries or testes) and instruct the formation of ducts that will carry eggs or sperm later in life.

Though small, these gender-specific differences in turtles' reproductive tracts can be seen by looking inside young, posthatchling turtles (120 grams, about 82–97 centimeter straight carapace length, depending on species) using a procedure called *laparoscopy*. In female posthatchling turtles, a laparoscope allows us to see a white ovary and a big, mobile, immature oviduct (called the Müllerian duct) with a very well-defined lumen. If the young turtle is a male, then we see cream-colored gonads, usually with a network of very small blood vessels. Male turtles also lack a complete Müllerian duct; it may be entirely absent or simply incomplete.

Unfortunately, hatchling turtles are too small for a laparoscope. So how can we tell if a hatchling is male or female? The answer relies on the sex-specific proteins that are induced by the incubation temperature. The majority of those proteins are produced in the gonads. We discovered that one protein, known as anti-Müllerian hormone, is released into the blood stream *only in males*. That hormone, therefore, makes it possible to identify the sex of hatchlings by analyzing a small blood sample. Currently, we know that this test works for loggerhead hatchlings, and we are beginning to test it on other sea turtle species as well. Our next goal is to develop this assay into a field kit, so that measuring the primary sex ratio of any species can be done in the field and not just in the lab. This next step would be a huge breakthrough for sea turtle conservation research, because sex ratio is a fundamental piece of demographic information that will allow us to help plan future management strategies in the face of climate change. •

HOW MANY SEA TURTLES ARE THERE?

By Bryan P. Wallace

Sea turtles swim in all of the ice-free areas of the world's oceans. Their generations span several decades, so populations comprise turtles of many sizes and ages. What's more, we humans catch only fleeting glances of them in the ocean, seeing mostly the females that come ashore to nest, so typically we can count just egg-laying adult females and their offspring. With all this in mind, making defensible estimates of the total number of sea turtles in the ocean requires math, modeling, assumptions, and a lot of creativity. But let's give it a try!

Others have tried estimating the number of turtles in the sea when trying to paint a picture of what marine resources looked like historically. For example, studies of historical harvesting and fishing records from 300 to 500 years ago estimated that between 33 million and 39 million, or even as many as 91 million, adult green turtles existed in the Caribbean before Columbus's fleet, and those that followed it, took their toll. The historical abundance of sea turtles is the stuff of legends: there were so many green turtles in the Caribbean that the sounds of turtles breathing and the bonking of their carapaces against the ships' wooden hulls were cues used by sailors to navigate around islands when visibility was poor.

For Europeans invading the Caribbean, sea turtles were free, they were relatively easy to catch, and they could be kept alive for weeks with minimal care, thus serving as a seemingly endless source of fresh meat and eggs. Europeans were unfamiliar with the region, and most islands did not readily provide agricultural resources to support new settlements, so it is no exaggeration to say that sea turtles fueled European invasion, exploitation, and colonization of the Americas. Think about that: one of the most consequential turning points in human history might not have happened if the sea wasn't full of turtles.

Historical depletion by European exploitation is now a well-documented theme in the Caribbean and elsewhere, so we know that today's populations of green turtles—and all other species—are far smaller than before Europeans got a taste for them. But how much have populations been depleted? And how many are there today? There is no robust estimate, and for the reasons raised above, generating an accurate number is probably impossible. However, a 2011 paper (Wallace et al. 2011) provided defensible estimates of nesting population abundance (in average annual ranges) for all sea turtle regional management units worldwide. If we sum up the minimum and maximum values of those estimated ranges, we can calculate rough estimates of the total number of nesting females. With assumptions about sex ratios, we can even estimate the number of adult males too. (I will leave estimates of juvenile turtles to braver folks than I.)

The totals from this exercise show that, as of 2011, a maximum of 7.5 million adult females of all sea turtle species existed globally. Assuming a 3:1 ratio of females to males, fewer than 10 million adult sea turtles remained. For green turtles alone, there were perhaps 1.5 million females worldwide, and only 300,000 in the Caribbean. That's quite a bit different than the historical estimates before European exploitation.

Despite the dramatic declines in turtle abundance since Europeans arrived, turtles have been hanging on. In some places, their numbers have increased in recent years. Over the past several centuries and even in recent decades, humans have done a great job of reducing sea turtle numbers through consumption and other activities. Now it's up to today's and tomorrow's humans to do a great job at reversing those trends. •

	TOTAL ADULTS (ASSUMING 3:1 FEMALE TO MALE RATIO)		
SPECIES	MIDPOINT	LOWER BOUND	UPPER BOUND
Loggerhead	314,000	91,000	536,000
Green	1,002,000	245,000	1,759,000
Leatherback	426,000	133,000	1,289,000
Hawksbill	57,000	30,000	83,000
Kemp's ridley	21,000	3,000	25,000
Olive ridley	4,618,000	558,000	5,600,000
Flatback	23,000	7,000	69,000
Global total	6,461,000	1,067,000	9,361,000

Female abundance estimates were derived from the midpoints and upper and lower bounds of ranges of average annual abundance in Wallace et al. (2011) Global conservation priorities for marine turtles, PLoS ONE 6(9): e24510. doi:10.1371/journal.pone.0024510. Average remigration intervals by species were used to estimate total numbers of adult females, and an assumed 3:1 sex ratio allowed for estimation of total numbers of adult males. These abundance estimates were generated for illustrative purposes only and should be interpreted accordingly. **AT LEFT:** One way to determine sex in adult sea turtles is to look at their tails. Males' are long and extend past their carapace, as visible on the lone turtle (left) in this photo, whereas females' are much shorter. © Nicolas J. Pilcher