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The hawksbill turtle, *Eretmochelys imbricata*, as photographed off the coast of New Ireland island, Bismarck Archipelago, in Papua, New Guinea. Photo © 2000 by Tom Doeppner. Source: Creative Commons; license CC-BY-SA-3.0.

featured species

Hawksbill Turtle, *Eretmochelys imbricata* (Linnaeus, 1766)

The Spongivore Sea Turtle

by M. A. Cohen

Critically endangered throughout its range, the hawksbill turtle (*Eretmochelys imbricata*) is one of seven marine turtle species belonging to the Cheloniidae family.

The genus name derives from two Greek root words: *eretmo-*, meaning an oar or a rower, referring to the species' powerful forelimbs that propel it through its ocean habitat, and *-chelys,* meaning a turtle or a tortoise. The species name derives from a Latin root word, *imbrica-*, meaning a roof tile or shingle, referring to the overlapping scutes on the hawksbill turtle's carapace.

The common name of the species, hawksbill, refers to its narrow head and distinctively bird-like beak, which enable the turtle to feed on sea sponges that dwell in crevices in the reefs the turtle inhabits.

What is a spongivore?

The biological term "spongivore" refers an organism that feeds on the aquatic animals commonly called sea sponges. Spongivory requires specific anatomical and physiological adaptations of the digestive system to ingest and process the tissues of sea sponges. Spicules, needle-like structures formed from calcite or silica, together with indigestible protein

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spongin fibers, comprise the skeleton of the sea sponge. Dr. Anne Meylan of the Florida Fish & Wildlife Conservation Commission aptly describes this dietary regimen in the title of her article: "Spongivory in Hawksbill Turtles: a Diet of Glass," published in the journal *Science* in 1988.

Aside from spicules, sea sponges also defend themselves against predation by producing various toxins, including "alkaloids, terpenes and brominated compounds, and some species produce neurotoxins" (Naish, 2007). Hawksbill turtles appear to be resistant or immune to these poisonous substances.

A variety of sea sponges photographed off the coast of the Cayman Islands in the Caribbean Sea, including the yellow tube sponge, *Aplysina fistularis*, the purple vase sponge, *Niphates digitalis*, the red encrusting sponge, *Spiratrella coccinea*, and the gray rope sponge, *Callyspongia* sp. Image by the National Oceanic and Atmospheric Administration. Public domain.

Fewer than a dozen vertebrates worldwide engage in spongivory; the hawksbill turtle is the largest of these vertebrates and the only known reptile that ingests sea sponges. Other vertebrate spongivores include species of several reef-dwelling fish. Moreover, certain species of the marine mollusks known as nudibranchs (sea slugs) also feed selectively on sea sponges.

Description of the hawksbill turtle

Known as a small to medium-sized marine turtle, *E. imbricata* reaches a maximum carapace length of 45 inches (1.14 meters); 30 to 36 inches (0.8 to 1 meter) is a more typical carapace length. Body weights of 100 to 200 pounds (45-90 kilograms) are common among hawksbills.

The carapace of the species is covered with scutes that are thicker than those of other hard-shelled marine turtles. The density of its scutes helps the turtle endure battering against sharp coral reefs and rocks during storm conditions.

The overlapping of the carapacial scutes is particularly pronounced in younger individuals and becomes less prominent as the turtle ages. Eventually, the scutes lie side-by-side on the mature hawksbill's carapace.

These carapacial scutes feature a background of amber, with marbled patterns of black, brown, gold, red, white, and yellow. This vibrant coloration is most pronounced in younger individuals, while older hawksbills generally have a more muted carapacial patterning.

Lacking a hinge, the hawksbill's plastron is yellow to cream-colored in juveniles. The scales covering the head are black to brown in the center and lighter toward the scales' rims. The turtle's chin and throat are typically yellow; its neck is dark-colored above and lighter on the underside (Ernst and Lovich, 2009).

In comparison with other marine turtles, the snout of *E. imbricata* is narrow and elongated, with a serrated upper jaw for cutting through its prey; there is no notch at the tip of the beak. The turtle's hooked snout bears some resemblance to a hawk's beak; hence, the species' common name "hawksbill." The formation of its jaws enables the hawksbill to reach into crevices in the rocks and reefs of its habitats to feed on the sea sponges and on other invertebrates it prefers (Ernst and Lovich, 2009).

Subspecies

In the herpetological literature, there are two accepted subspecies of hawksbill turtles: the Atlantic hawksbill, *Eretmochelys imbricata imbricata* (Linnaeus, 1766), and the Pacific hawksbill, *Eretmochelys imbricata bissa* (Rüppell, 1835).

However, several respected chelonian researchers question the validity of "these supposed races," citing geographic variations, changes in carapace shape and keeling, and the degree of melanism (darkening) as being of limited value in distinguishing between the two subspecies. They suggest the need for a "quantitative study" to "determine the true relationship between the Atlantic and Pacific populations" (Turtles of the World, n.d.).

Range

Considered the most tropical of all marine turtle species, the hawksbill turtle occurs in tropical oceans worldwide. Migratory in nature, the hawksbill nests in some 70 countries

throughout its range (Mortimer and Connelly, 2008).

The Atlantic population of hawksbills ranges through the warmer regions of the western Atlantic Ocean, from Massachusetts, USA southward through the Gulf of Mexico to southern Brazil. Furthermore, researchers have documented the presence of the Atlantic population in such distant locations as Morocco, Ireland, Scotland, and the island of St. Helena, a British Overseas Territory east of Brazil in the South Atlantic Ocean (Turtles of the World, n.d.).

Hawksbill turtle photographed off the coast of Venezuela in South America. Photo © 2000 by Petrosanch. Source: Creative Commons; license: CC-SA 3.0.

Ranging through the tropical portions of the Pacific and Indian Oceans, the Pacific hawksbill population occurs from the island of Madagascar on the east coast of Africa northward to the Red Sea, and eastward to Australia and Japan in the western Pacific. The Pacific population also appears in the Hawaiian Islands in the central Pacific, as well as from Peru northward to Baja California in the eastern Pacific (Turtles of the World, n.d.).

Habitat

Inhabiting tropical seas with coral reefs and hard-bottomed, rocky regions, *E. imbricata* also frequents shallow coastal waters, including mangrove swamps, coral reefs, estuaries, and lagoons.

While the hawksbill hatchlings' early years remain something of a mystery, researchers surmise that the hatchlings ride the ocean currents to *Sargassum*[1] mats on the surface of the open ocean because they cannot dive in the deeper ocean. The hatchlings spend their first few years in the *Sargassum* ecosystem feeding on the planktonic (free-floating) animals as well as the plants residing in the *Sargassum* drift community. When the hawksbills reach a carapace length of 8 to 12 inches (20 to 30 centimeters) between ages one and three years, they venture into coral reefs, bays, lagoons, and the deeper ocean (Spotila, 2004).

Foods and Feeding

Largely herbivorous as hatchlings, hawksbills feed on *Sargassum* during their early years and become more omnivorous as they mature (Ernst and Lovich, 2009).

Strictly speaking, the species is an "omnivorous opportunist" (Ernst and Lovich, 2009); however, the hawksbill appears to prefer invertebrates such as sea sponges to other types of prey. In the Caribbean Sea, some 95% of the diet of *E. imbricata* consists of sea sponges, but the turtles feed on only a few of the 300 species of sea sponges in the Caribbean, and generally avoiding the sea sponge species containing spongin fibers (Meylan and Whiting, n.d.).

In portions of their range other than the Caribbean, hawksbills ingest a greater variety of prey, depending on the availability of food sources in the particular localities in which they reside. However, sea sponges are the mainstay of the hawksbills' diet throughout their ranges.

Besides sea sponges, the adult hawksbill feeds on vertebrates such as fish, and invertebrates such as mollusks, aquatic or marine worms, aquatic crustaceans, echinoderms (starfish and sea urchins), and sea anemones. Plant foods consumed by the hawksbill include algae, macroalgae (seaweed), mangrove fruit, sea-grasses, wood and bark.

Hawksbill females of reproductive age greatly reduce their consumption of sponges and other foods, instead ingesting the calcium carbonate rubble found in coral reefs, and even feeding on the coral itself. Biologists surmise that this ingestion of calcium carbonate aids the female turtle in forming the shells of her eggs (Meylan and Whiting, n.d.).

Mating and Reproduction

Taking decades to reach reproductive maturity, hawksbill females begin breeding on average between 20 and 40 years of age. Females tend to return to their natal beaches, the beaches on which *they* hatched, to nest. Mating generally occurs in shallow coastal waters off the females' natal beaches.

Breeding generally takes place between July and October. Typically, hawksbill females nest every few years, laying up to six clutches of 100 to 140 eggs per clutch at intervals of up to 28 days between nesting events. Clutch size correlates positively with body size of the female; therefore, the larger the female hawksbill, the more eggs laid in her clutches. The gestation period of hawksbill eggs is approximately 60 days (Ernst and Lovich, 2009).

[1] *Sargassum*: a brown or dark-green macroalgae (seaweed) that grows in temperate and tropical oceans. Botanists have identified some 250 species of *Sargassum* worldwide.

E. imbricata has temperature-dependent sex determination. The pivotal temperature, the incubation temperature at which 50% males and 50% females are produced, is 84 to 85°F (29 to 30°C). Incubation temperatures warmer than the pivotal temperature produce predominantly or exclusively females, while lower temperatures yield males (Ernst and Lovich, 2009).

Hawksbill turtle swimming near a sea anemone and a clownfish off the Baa atoll in the Maldives, situated in the Arabian Sea (Indian Ocean) southwest of Sri Lanka. The clownfish is also known as the anemonefish because it forms a symbiotic relationship with the sea anemone, a predatory marine invertebrate. Photo © 2014 by Ahmed Abdul Rahman. Source: Creative Commons; license: CC-BY-SA-4.0.

Curiously, according to Ernst and Lovich, researchers report the existence of naturally occurring hybridizations between hawksbills and green turtles (*Chelonia mydas*), between hawksbills and loggerhead turtles (*Caretta caretta*), as well as between hawksbills and olive ridley turtles (*Lepidochelys olivacea*).

Hawksbills and Coral Reefs

Vital to the health of the coral reefs it inhabits, the hawksbill turtle keeps the local populations of sea sponges in check. By using its sharp beak to penetrate the rigid outer skeleton of the sea sponge, the hawksbill renders the soft inner tissues of the sea sponge available as a food source for all reef residents.

Sea sponges stake out territory in coral reefs, establishing a "foothold." Without the activity of the reef spongivores, sea sponges tend to out-compete the reef-building coral for resources such as vital trace minerals and other elements (Mortimer & Donnelly, 2008).

Sea sponges can readily overgrow the coral reef, choking out the biodiversity that is essential to a balanced reef ecosystem. Sea sponges form a symbiotic relationship with blue-green algae, the algae providing oxygen and possibly carbohydrates for the coral. Blocking out the sunlight on which the blue-green algae depends, the overgrowth of sea sponges directly threatens the health of the reef.

Furthermore, there are endolithic sea sponges that bore into and grow *within* the corals, killing the living corals from the inside out.

Weighing an average of 154 pounds (70 kilograms), the adult hawksbill consumes 1,200 pounds (544 kilograms) of sea sponges per year. Because of the decline in hawksbill populations worldwide, many of the world's coral reefs are currently being overrun by sea sponges (Spotila, 2004).

Threats

A variety of predators prey on the hawksbill at different stages in its life. Fire ants, raccoons, dogs, foxes, fungi, human poachers, and other predators, attack and destroy eggs, nests, and hatchlings. Ghost crabs, various birds, and rats prey on newly-emerged hatchlings as the turtles make their way from the nest to the sea. Once in the water, octopuses, squid, large fish, saltwater crocodiles, and fishermen prey on the hawksbill at (Ernst and Barbour, 2009).

The human penchant for the hawksbill's carapacial scutes, and, to a lesser extent, its plastral scutes, is the primary reason for the precipitous decline in hawksbill populations worldwide. Humans have relentlessly exploited the species for its "tortoiseshell," the multicolored scutes used for various ornamental and domestic objects, for thousands of years (Mortimer and Donnelly, 2008).

Besides exploitation for its "tortoiseshell," global threats to *E. imbricata* are varied, and include the continuing illegal trade in the "turtle's prized shell" as well as the market for eggs. The turtle's meat, despite sometimes poisoning humans, remains in demand in some parts of its range (Mortimer and Donnelly, 2008).

Destruction of nesting beaches and foraging habitats threaten hawksbill populations, as does entanglement in and ingestion of lost fishing-industry gear. Particularly in the Middle East, pollution from oil poses a significant threat to the sensitive hawksbill turtle (Mortimer and Donnelly, 2008).

Posing a significant threat to the future of the hawksbill turtle and many other species, climate change skews the ratio of the sexes in populations having temperature-dependent sex determination. According to biologists' studies, the sex ratio in marine turtles skews toward female hatchlings as the incubation temperature of the nest rises.

Conservation

Science has documented a "drastic decline" of approximately 80% in

hawksbill populations during the last century (Wildscreen Archive, n.d.). In this stark sentence, Ernst and Lovich state bluntly: "Survival of the hawksbill is questionable."

Worldwide, the hawksbill turtle is classified as "critically endangered" on the International Union for the Conservation of Nature (IUCN) Red List. Since 1977, the hawksbill's Convention on International Trade in Endangered Species (CITES) designation has been Appendix I, the highest degree of legal protection with regard to international trade. It is listed as Appendix I by the Convention on Migratory Species (CMS).

The increasing focus of many biologists and conservationists on marine turtle populations is benefiting hawksbills, as well as other species. Public awareness of the plight of endangered species and the interest in ecotourism are both promising developments. Efforts by many nations to protect the hawksbill's habitats include providing nesting and foraging sanctuaries, and enacting increased legal protection and enforcement activities.

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Texas Bans Unsustainable Commercial Wild Turtle Trapping

—List of States Curbing Commercial Turtle Harvest Grows

Austin, Texas—23 August 2018—In response to a petition filed by the Center for Biological Diversity and several Texas-based conservation organizations, the Texas Parks and Wildlife Commission today voted unanimously to ban commercial collection of the state's wild freshwater turtles, following a national trend of ending unsustainable turtle trapping.

"We're so grateful Texas has adopted these badly needed protections for the state's native turtles," said Jenny Loda, a Center attorney and biologist who works to protect vulnerable reptiles and amphibians. "This is a big victory for the health of the state's wildlife and waterways."

Texans showed overwhelming support for putting an end to commercial turtle trapping in the state — more than 98 percent of the comments received by the commission supported adoption of the proposed rule. It's the latest in a growing list of states — including Missouri, New York and Iowa — that have ended unlimited commercial collection of freshwater turtles. Neighboring Arkansas is currently considering restrictions on commercial collection.

Before today's vote, unlimited collection of four native, freshwater turtle species was allowed on private property in Texas: common snapping turtles, red-eared sliders, smooth softshells and spiny softshells.

Scientists have repeatedly documented that freshwater turtles cannot sustain any significant level of wild collection without leading to population declines. Populations cannot remain stable when high numbers of adults and older juveniles are steadily removed due to slow reproduction.

"This is great news for Texas' freshwater turtles as commercial trapping is devastating to turtle populations that are already suffering from multiple other threats, including habitat loss, water pollution and vehicular collisions," said Evelyn Merz, conservation chair for the Sierra Club's Lone Star Chapter. "It's great to see the Parks and Wildlife Commission following through with protecting these animals as a vital part of our state's ecosystems."

The petition that spurred today's action was submitted last year by the Center for Biological Diversity, Sierra Club's Lone Star Chapter, Texas Rivers Protection Association and Texas Snake Initiative.

Background

Millions of turtles classified as wild-caught are exported from the United States every year to supply food and medicinal markets in Asia, where native turtle populations have already been depleted by soaring consumption. Because turtles bioaccumulate toxins from prey and burrow in contaminated sediment, turtle meat is often laced with mercury, PCBs and pesticides, posing a health risk. Adult turtles are also taken from the wild to breed hatchlings for the international pet trade.

As part of a campaign to protect turtles in the United States, the Center for Biological Diversity has been petitioning states that allow unrestricted commercial turtle collection to improve their regulations. Earlier this month, in response to a Center petition, the Missouri Department of Conservation banned commercial collection of the state's wild freshwater turtles. In September of last year, Nevada created a statewide ban on the destructive commercial collection of all reptiles and New York halted all commercial terrapin turtle harvesting. Before that, in March 2017, Iowa adopted new regulations setting closed seasons and possession limits for commercial turtle trappers. In 2012 Georgia approved state rules regulating the commercial collection of turtles, and Alabama completely banned commercial collection. And in 2009 Florida responded by banning almost all commercial collection of freshwater turtles from public and private waters.

—Center for Biological Diversity press release

Reptilian Brumation by Stephen Rheis

Most readers are likely aware of the fact that all reptiles and amphibians are ectothermic (cold-blooded) animals, relying on their environment for thermoregulation. That said, these animals have evolved and adapted incredible survival strategies to ensure survival when environmental conditions become unsatisfactory. One such adaptation is brumation. Brumation is a term used for the hibernation-like state that cold-blooded animals utilize during very cold weather.

On the other end of the spectrum is a state known as aestivation, which like brumation, provides a way for reptiles to handle temperature extremes. However, aestivation occurs when environmental temperatures become too high for healthy physiological function to occur, and thus is beyond the scope of this article.

What is Brumation?

As previously mentioned, brumation can be loosely equated to hibernation among mammals. When a reptile brumates, it becomes lethargic, sometimes not moving at all for the duration of the cold season. In nature, these animals typically find hibernaculums within their environment in which they can be somewhat insulated. A hibernaculum is simply the place where the reptile spends these periods of inclement weather. Burrows, rock crevices, caves and leaf litter are a few examples of hibernaculums documented in nature. Some temperate species can even brumate under water!

The amount of time that a reptile brumates is dependent on a number of factors. Perhaps the biggest variable is in regards to whether the animal is in the wild or being maintained in captivity. In the case of the latter, environmental conditions can be easily manipulated by the keeper at any given time. Other considerations include the age of the animal, its gender, geographical origin, and varying natural conditions. Due to the wide range of species and habits, it is futile to make quantitative generalizations regarding how long a reptile will brumate. In the broadest of terms, reptiles will enter brumation in the late fall (when temperatures drop and the days get shorter) and come out of brumation in spring, triggered by increased temperatures, longer days, and changes in barometric pressure.

Why do Reptiles Brumate?

As ectothermic organisms, reptiles cannot raise their body temperature independently of environmental conditions, and as such must contend with the conditions that nature presents them with. The vast majority of our planet experiences seasonal temperature extremes, from the deserts to the plains to even the tropics. The amount of temperature variation does change from region to region. For example, sub-tropical animals, as well as those found near the equator, often do not undergo what herpetoculturists call a "true brumation." However, these animals are just as receptive to natures cues as those from more northern or southern climates. They may slow down, i.e. reduce food intake, eat less, etc, but not enter a true state of brumation.

Russian tortoise, *Agrionemys* (=*Testudo*) *horsfieldii*, photographed in Baikonur, Kazakhstan. Photo © 2010 by Yuriy75. Source: Creative Commons; license CC-BY-SA-3.0.

Conversely, many reptile species inhabit regions that do in fact get very cold in the winter, and accordingly must have behavioral adaptations in order to survive. In the most basic sense, brumation is a survival tactic—a tactic that has been hard wired into the brains of these animals for well over a million years.

Take for example, the Russian tortoise (*Testudo horsfieldi*). Over much of their range they experience summer highs well over 100 degrees Fahrenheit, and in the winter temperatures fall far below freezing. Without the option of brumation, these animals would perish. Instead, they construct burrows, sometimes as deep as six feet, and remain in them until conditions become favorable. During this time, the tortoises physiological functions grind to nearly a halt. Feeding obviously ceases, as does digestion and defecation. Heart and respiratory rates also drop.

Suspended animation is a phrase often used to describe this state among reptiles. In fact, there are theories suggesting that these long periods of inactivity may actually lengthen the lives of wild herps much the way your car would last you longer if you kept it garaged and purged of all fluids for 5 months of the year.

Reproductive Connotations

Aside from serving as a survival tactic during seasonal weather fluctuations, brumation (and winter slowing in general) does have an effect on reptile reproduction. Please keep in mind that there are exceptions, but in general, cooler temperatures trigger the production of sperm in males, and prepares females for ovulation in spring.

Despite this widely accepted theory, many breeders have found that only slight drops in temperature are needed to trigger this reproductive behavior, while others have found it to be completely unnecessary.

Renowned monitor breeder Frank Retes is well known for his successful captive breeding attempts with a number of Australian, Indonesian, and African monitor species. He is equally well known within the monitor-keeping circle for his unique methodology. His monitors are kept warm year round. His motto, "Heat them, feed them, breed them" has proven quite successful. In fact, in an interview in The *Vivarium* Magazine in the mid 90s he shared that his monitors also have light 24 hours a day.

This radical approach to breeding may seem outlandish, but experimental techniques such as those of Mr. Retes have allowed us to better understand reptiles in captivity. It remains clear that a short period of slight reduction in temperature and/or photoperiod can be vital in triggering reptiles to reproduce, but not always completely necessary.

In my experience, and in the experience of many of my colleagues and friends, true brumation does not seem to be a requirement in maintaining healthy, reproductively active reptiles. Generally a brief, slight change in conditions (as mentioned above) is all that is needed. Furthermore, in most American homes, this requires little work on the part of the keeper, as seasonal fluctuations and physiological cues will occur regardless of husbandry.

This is not to say that allowing temperate herps to brumate at cooler temperatures for longer periods of time is harmful if done properly. In some species, males that have been cooled are much more fertile than those which were not, and therefore more likely to produce viable clutches with a similarly cycled female.

Brumation in Nature

In the wild, reptiles are presented with both internal and external cues that it is time to brumate. Herpetologists have classified these cues into two main categories. The first are endogenous cues, which originate within the animal. Theories regarding endogenous cues suggest that some reptiles (but certainly not all) undergo hormonal changes as well as shifts in neurotransmitter levels and amino acid concentrations.

These factors are directly affected by circadian rhythms and the environment, making these biological cues little more than a secondary function of natural climatic changes. The question remains as to whether these internal changes occur spontaneously and trigger brumation, or if the animal begins to brumate and then these physiological changes occur.

It should be made clear that the role of endogenous cues in reptilian brumation is still poorly understood. Exogenous cues on the other hand are those with which we are already familiar and include factors such as photoperiod (day length), barometric pressure, humidity, and temperature. Exogenous cues seem to be of most importance to herps inhabiting temperate zones. Sub-tropical herps, because of the relatively constant conditions they experience, appear to rely more on internal (endogenous) cues.

Brumation is an extremely trying time for all reptile species. As we have discussed, it is a survival tactic at which many species are quite proficient. Nonetheless, many wild reptiles that enter brumation never emerge in the spring. Sometimes the choice of hibernaculum is a poor one, and when conditions become extremely harsh these areas simply do not provide adequate protection. Other times, reptiles may enter brumation with an injury or illness which would normally require supplemental warmth and nutrition to heal properly. In the brumative state these animals tend to succumb to their ailments.

As mentioned above, the length of time that a reptile brumates is extremely variable. A few generalizations can be made, although they are merely guidelines, and should not be considered definitive. Temperate and desert species tend to brumate much longer than sub-tropical and tropical species. In fact, some species originating from truly equatorial ranges do not brumate at all, but simply undergo a mild shift in activity and feeding patterns. Male reptiles typically emerge prior to females, allowing them ample time to establish breeding territories to further their chances of reproductive success.

Brumation in Captivity

Just as brumation can be risky to wild herps, the same holds for captive reptiles. Although they have the added advantage of being carefully monitored by attentive keepers, this does not rule out all associated risks. In general, brumating reptiles in captivity is the subject of much debate. On one end of the spectrum there are those saying that brumation is natural and will ultimately make your reptile live longer. On the other hand, does this unproven potential for longevity outweigh the risks previously discussed? This debate has been a longstanding one, and will continue to be further explored in the future.

I have adopted the following philosophy regarding brumating my reptiles, and have found it to be entirely successful thus far. Keep in mind that because your animals are in captivity, does not mean that they do not receive subtle cues from the outside world. With the exceptions of snakes being kept and bred in rack units (where all light and heat is regulated by the keeper) reptiles will begin showing signs of a winter slow-down and/or brumation regardless of what environmental conditions you provide.

Many temperate, desert, and sub-tropical herps will become less active and feed less in the winter, even when normal ambient and basking temps are provided. I do not adjust the husbandry of my bearded dragons from season to season. They are provided with the same photo-period and heating protocol year round. Yet year after year they begin losing interest in food in late fall, and remain in this psuedo-brumation until spring. During this time,

all of my animals will migrate away from all heat sources, and make themselves comfortable in the cooler regions of their enclosure.

The above anecdote should provide some credibility to the idea that reptiles are going to brumate or not regardless of what you do. With the vast majority of pet species, this type of maintenance is not a problem. When you begin dealing with species that undergo a true brumation in winter (and subsequently animals originating in climates with harsh winters) different actions must be taken.

Box turtles (*Terrapene* sp.) are a prime example, and one that has been more closely looked at than most other species. If a box turtle begins showing signs that true brumation is eminent (less activity, burrowing, lack of appetite) you are going to have to prepare a suitable hibernaculum. A hibernaculum is basically a well insulated box that will hold moisture and maintain a relatively constant temperature during brumation. Air holes should be provided to ensure air exchange. For turtles and tortoises (which coincidentally are most commonly brumated using this method), they are typically placed in a plastic bin with 10 to 12 inches of soft, fluffy, and barely moist earth. This can be sterile (no fertilizers, etc) potting soil, sandy soil, Eco Earth, or your own favorite blend. Finely shredded paper is another popular choice, although extended exposure to moisture may lead to disintegration.

This box will become the inner chamber, and will have to be closely monitored for temperature. I highly recommend the use of a quality digital thermometer with a probe that can be placed deep into the hibernaculum substrate. Many breeders actually tape the thermometers probe to the carapace of the turtle. This ensures that you know exactly what temperatures your animals are being subjected to. Remember, not cold enough and your pet will not be truly brumating. Too cold, and they may not wake up at all.

The inner chamber is then placed into another slightly larger box, leaving a 1 to 2 inch space between the walls of the inner and outer chambers. This space can be filled with packing peanuts, shredded paper, or any number of other insulating materials. The idea here is to ensure a constant temperature within the inner chamber, as significant environmental fluctuations during brumation can be problematic.

Although reptiles do not typically feed during brumation, the hydration of the animal must be considered. In the wild most reptiles dig deep into the ground to brumate, providing them with an adequate amount of environmental humidity to keep them from dehydrating. In captivity, it is recommended that your animals be offered water once or twice during brumation. While digging out your slumbering reptiles in the middle of winter may seem counterintuitive, it is very important, and the small amount of time that your animal spends awake will not affect the overall outcome of the brumative process.

Editors Note from Stephen Rheis

Before closing, I would like to re-emphasize that both in the wild and in captivity, brumation is risky business for reptiles. It puts a great strain on their bodies, but one that is nonetheless necessary to the survival of their species.

The guidelines above are just that; guidelines, and should not be construed or interpreted as a definitive source of information on this dynamic subject. If you are considering brumating your reptiles, I would expect you to consult with an experienced herpetoculturist or other expert prior to undergoing this task.

Similarly, if you have any doubt regarding your ability to properly brumate your animals, please get advice from a knowledgeable source. Although once mastered, brumation can be simple and streamlined, it remains one of the most complex and frustrating aspect of reptile husbandry. For this reason alone it should not be taken lightly.

As always, research the needs of your pet in depth prior to obtaining them. This way you can be best prepared to provide them with the best possible of care. ♧

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CTTC note: While it is a comprehensive overview of reptile brumation, this article is written regarding reptiles in general, and some information may not pertain to turtles or tortoises in particular.

Our nation has both an obligation and self-interest in facing head-on the serious environmental, economic and national security threat posed by global warming.

—John Sidney McCain III (1936—2018), American legislator and military officer

Erratum: On page 1 of the July/August 2018 [54(4)] issue of the Tortuga Gazette, the Featured Species subheading should read as follows: Morafka's Desert Tortoise, *Gopherus morafkai* (Murphy, Berry, Edwards, Leviton, Lathrop & Riedle, 2011).

My son and I spotted this little desert tortoise individual scurrying across a wash between thunderstorms in July 2018 in the Rainbow Basin Natural Area near Barstow, CA. Its shell was about the size of a man's clenched fist, and it seems to be one of the successful survivors. A good zoom lens let us carefully observe the tortoise from a distance. Be safely on your way, little one! May you grow big, strong and old.

—Marilyn Forsstrom
Long Beach Turtle and Tortoise Care Society

Mike's Turtle Net Picks by Michael J. Connor, Ph.D.

A varied selection of recent articles, stories and sites on the Web that some of you may find as interesting as I did. This list is also posted at **tortoise.org/turtlenetpicks**

New Very Early Turtle
Eorhynchochelys sinensis lived 228 million years ago, before turtles developed shells!

Agassiz's Desert Tortoise Conservation Genomics
Major new study opens new venues for conservation genomics in desert tortoises.

Aesop Was Right! Tortoise Does Beat Hare
Over a life-span, fast "sprinters" are among the slowest movers.

Myanmar Star Tortoise Conservation Success
Turtle Survival Alliance-Myanmar estimates that Myanmar star tortoise numbers now exceed 15,000 in forest reserves.

Palawan Forest Turtle Hatched
The first captive hatching of the critically endangered Palawan forest turtle, *Siebenrockiella leytensis*.

Videos

- **Manning River Turtle**
- **Three-toed Box Turtle**

Police Raid Europe's Biggest Turtle Farm
I don't know what the back story is to this bust, I assume there is one.

African Sea Turtle Newsletter
African Sea Turtle Newsletter issue 9 is now available.

Loggerhead Conservation Success Story
Cyprus conservation programs have increased the number of loggerhead sea turtles nests more than 3-fold since 1978.

Abandoned Fishing Net Kills 300 Olive Ridleys
Some 300 Olive Ridley sea turtles died after being trapped in an abandoned fishing net floating off Mexico's southern Pacific coast.

Red Tide Disaster in Florida
This year's massive red tide event along Florida's coast hasn't just killed sea turtles and manatees but has sent the state's tourist and fishing industry reeling.

Herpetologists' League Rescinds Award
The Herpetologists' League rescinded its Distinguished Herpetologists award to turtle biologist Richard Vogt for "sexually inappropriate behavior". Here is **one of the many news stories** and here is the **July 20, 2018 statement by Willem Roosenberg**, the Herpetologists' League's newly installed President.

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Temperature-dependent Sex Determination in Turtles and the Implications of Climate Change

by M. A. Cohen

Defined as sex determination by male or female chromosomes at the time of embryo fertilization, the well-studied mechanism of genotypic sex determination (GSD), also known as genetic or chromosomal sex determination, occurs in mammals, birds, and snakes.

Less well-understood is the mechanism of environmental sex determination (ESD), which relies on non-genetic factors such as humidity, nutrient availability, or incubation temperature following embryonic development for the determination of the sex of the offspring.

TSD in Reptiles

A type of ESD, temperature-dependent sex determination (TSD) occurs in many species of reptiles. In such species, incubation temperature at a critical point during incubation determines the ratio of male to female hatchlings well after the eggs are laid. Thus, the environment plays a crucial role in the proportion of males to females in populations subject to TSD (Bosch, 2015).

All crocodilians (alligators, caimans, crocodiles, and gharials) exhibit TSD. The ancient, lizard-like tuatara (*Sphenodon punctatus*) has TSD, as do some true lizard species.

TSD prevails in the overwhelming majority of turtle species (see Figure 1 for the exceptions). As of 2004, 93 percent (69 of 74) of turtle species tested were subject to TSD (Moeller, 2013).

TSD is a complicated mechanism, and there are species in which both GSD and TSD influence the ratio of males to females in a population. Such complexities are beyond the scope of this introductory article.

The remainder of this article will focus on the turtle species that exhibit TSD, and the implications of climate change on reproduction in these species.

The Pivotal Temperature

An important concept in TSD, the pivotal incubation temperature is defined as "the temperature in which the male and female determining factors are just balanced," yielding a 1:1 ratio of males to females. This ratio results in "evolutionarily stable... breeding populations" (Ewert, et al. 1994).

All marine turtles are subject to TSD Pattern I. Green turtle (*Chelonia mydas*) hatchling in Tortuguero National Park, Costa Rica. Photo © 2006 by Bernard DuPont. Source: Creative Commons; license CC-BY-2.0.

Far from being consistent worldwide, biologists researching TSD find that geographical variations exist for the pivotal incubation temperature in any given species. Variables include latitude (higher or lower), longitude (east or west) and climatic conditions (amounts of sun exposure and rainfall) [Ewert, et al., 2004].

Figure 1: Turtle species that do not exhibit TSD.

Exceptions to TSD in Turtles

- Austro-South American sideneck turtles (Chelidae family)
- Black marsh turtles (*Siebenrockiella* species, Geoemydidae family)
- Brown roofed turtle (*Pangshura smithii*, Geoemydidae family)
- Mexican musk turtles (*Staurotypus* species, Kinosternidae family)
- Softshell turtles (some species) (Trionychidae family)
- Wood turtle (*Glyptemys insculpta*, Emydidae family)

—Sabath et al., n.d.

Two Basic Patterns of Turtle TSD

While conducting research into chelonian TSD, biologists identified two general patterns, termed Pattern I and Pattern II. Additional research into and refinements of these patterns are ongoing, but, for purposes of this article, the basic characterizations in Figure 2 will suffice.

Pattern I consists of a "single transition zone of temperature below which incubation yields 100% (or nearly 100%) males and above which only females are produced." In contrast, Pattern II comprises "two transition zones, with males predominating at intermediate temperatures and females at both extremes." Generally, however, the coolest incubation temperatures produce the smaller sex (Turtles of the World, n.d.).

It is the incubation temperature of the turtle eggs at a particularly thermosensitive period, typically lasting seven to 14 days, during the middle trimester of incubation that determines the sex of the offspring, depending on the species (Bosch, 2015). The incubation temperature at this critical time prompts the release of enzymes that influence gonadal development, resulting in either male or female hatchlings (Turtles of the World, n.d.).

The enzyme aromatase plays a crucial role during this thermosensitive period: aromatase converts androgens (masculinizing hormones) to estrogens (feminizing hormones), depending on the ambient temperature in the turtles' nest. The function of aromatase at lower temperatures is inhibited, while at higher temperatures aromatase continues to function (Bosch, 2015).

The development of ovaries in females and testes in males following the middle trimester of incubation

moves forward, and the growth process is irreversible.

Turtle species are long-lived vertebrates that mature slowly. One or more decades may pass before an individual's anatomy displays its secondary sexual characteristics, making it challenging to assess the success of species recovery efforts in the cases of threatened or endangered species.

"Hot Chicks, Cool Dudes"

A mnemonic device used by the students of biology professor Jeanette Wyneken at Florida Atlantic University (FAU) in Boca Raton, Florida, the title of this section succinctly describes the effect of TSD Pattern I on marine turtles and many other chelonian species: higher nest temperatures yield female hatchlings, while lower incubation temperatures produce male hatchlings.

According to Prof. Wyneken, "sea turtles are an endangered species... and one of the things that needs to happen when you're trying to recover an endangered species is you need to know what impediments there are to making more turtles—are there enough eggs? Are they hatching? And if so, are there enough of both sexes?" (Balaraman, 2017).

In keeping with federal Endangered Species regulations, a team of colleagues at FAU that includes Prof. Wyneken has developed a means of determining the sexes of marine turtle hatchlings through a minimally-invasive laparoscopic biopsy technique involving a protein called CIRPB. Biopsy tissues are collected, preserved and analyzed in a laboratory setting.

Biopsy tissues were collected from the gonads of loggerhead (*Caretta caretta*) hatchlings. Federal law prohibits biopsies on living leatherback (*Dermochelys coriacea*) turtles; freshly deceased carcasses of leatherback hatchlings were retrieved from nests after the live hatchlings had emerged.

To the collected tissues researchers then applied the protein CIRPB "which responds to a protein on the cells of the female gonad—if it's a female, you get a lot of staining, whereas in males you don't," reports Prof. Wyneken (Balaraman, 2017). When compared to traditional techniques for estimating the sexes of hatchlings, including nest temperatures, beach temperatures, incubation duration, etc., the CIRPB proved to be remarkably accurate.

Within a week following collection of the tissue samples, all hatchlings were released offshore into the Gulf of Mexico. Many consider this new, highly reliable technique to be a breakthrough in marine turtle research.

Figure 2: Comparison of TSD Patterns I and II in various chelonian families.

TSD Pattern I (Male/Female) [Chelonian family–species]	TSD Pattern II (Female/Male/Female) [Chelonian family–species]
Carretochelyidae–Pig-nosed turtle Cheloniidae–Sea turtles (all species) Dermochelyidae–Leatherback turtle Emydidae–Pond or marsh turtles Geoemydidae–Species of tropical freshwater turtles Testudinidae–Tortoises	Chelydridae–Alligator snapping turtle Geoemydidae–a few species of tropical freshwater turtles Kinosternidae–Most mud and musk turtles Pelomedusidae–Sub-Saharan and Yemeni sideneck turtles
Pattern I occurs primarily in turtle species in which the adult female is larger than the adult male.	Pattern II occurs primarily in turtle species in which the adult male is larger than the adult female, or in species in which body size is not dimorphic (substantially different in males and females).

On Sanibel Island, FL, the first steps of a hatchling loggerhead turtle (*Caretta caretta*) running to the sea. Photo © 2016 by Jean-Lou Justine. Source: Creative Commons; license CC-BY-SA 4.0.

Changing Climatic Conditions

For decades climate scientists, known as climatologists, have been compiling documentation about the global changes in climatic conditions. The phenomenon that is commonly termed "climate change" is overwhelming accepted by the scientific community worldwide.

Because many turtle species exhibit TSD, some consider them to be important bioindicators, species that provide information about the quality of their environments and often serve as early warnings of future problems.

The environment plays an important role in the proportion of males to females in populations affected by TSD. Turtle species that are subject to the mechanism of TSD "are susceptible to alterations in temperature caused, for example, by climate change" (Bosch, 2015).

By raising the air temperature in and around turtles' nests, the incubation temperature of the eggs increases. For most turtles, increasing the incubation temperature of the eggs results in a skewed ratio of males to females. Because many turtles exhibit TSD Pattern I, skewing the sex ratio with an increase in incubation temperature means clutches will be female-biased.

In addition, biologists project two bleak scenarios based on an increase in nest temperatures. Eventually, there will be too few male turtles to maintain stable populations, and

A member of Testudinidae family, this hatchling tortoise, probably a marginated tortoise (*Testudo marginata*), is emerging from its egg. Photo © 2004 by Mayer Richard. Source: Creative Commons; license: CC-BY-SA-3.0.

extinction will follow. There is also the possibility of mass mortality if the nest temperatures rise to lethal levels, and turtle eggs die before hatching (Platt, 2017).

While much of the research into the effects of climate change on turtle species has focused on marine turtles, changing climatic conditions are also impacting many other turtle species in different environments, including pond and marsh turtles, North American and Asian box turtles, and all species of tortoises.

Considerable research about turtle species and the impact of climate change already exists, and there is documented scientific evidence of the deleterious effects of climate change.

With regard to marine turtles, scientists in Florida are documenting the temperatures on nesting beaches as being lethal to marine turtles in their nests—on some beaches, temperatures are so high that few, if any, embryos survive and develop into live hatchlings (McDermott, 2017).

Nesting beaches in Florida are not the only locations yielding evidence of negative climate change impacts. Marine turtle researchers in Costa Rica report that leatherback turtle and olive ridley (*Lepidochelys olivacea*) turtle species experience nest mortality when beach temperatures rise above 95°F (35°C) [McDermott, 2017].

In Australia the documentation is equally disturbing: scientists evaluating the hatching of green turtles (*Chelonia mydas*) recently recorded a ratio of 116 females to 1 male (Welch, 2018).

The painted turtle, *Chrysemys picta*, an extensively studied pond turtle species that is native to North America, exhibits not only TSD Pattern I but also nest location fidelity, described as "repeatable individual preferences for nest microenvironments" (Janzen and Phillips, 2006).

The rise in global temperatures coupled with temperature fluctuations from one year to the next will affect the male/female balance in species exhibiting TSD and the painted turtle is no exception. Biologists predict that "a rise of 4°C [ed. note: 39°F] in their habitat's temperature could cause the extinction of the species, because only females would be born." (Bosch, 2015).

A member of the Emydidae family, this hatchling painted turtle (*Chrysemys picta*) was photographed at Missisquoi National Wildlife Refuge, Lake Champlain, Vermont. Photo by Ken Sturm USFWS. Public domain.

Clearly, rising temperatures worldwide pose a significant threat to reptiles and other animals subject to temperature-dependent sex determination. ♧

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Inland Empire: 7 September; 5 October

Kern County: 10 September; 8 October

Low Desert: 1 October

Orange County: 14 September; 12 October

Ridgecrest: 10 September; 8 October

Santa Barbara-Ventura: Contact the chapter for meeting information.

Santa Clarita: 15 September

TOOSLO (San Luis Obispo): 12 September; 10 October

TTCS (Long Beach): 21 September; 19 October

Valley: 21 September; 19 October

Executive Board: 13 October. Meetings take place at the Los Angeles County Arboretum, Arcadia, CA 91007.

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Saving 1 million turtles worldwide

Launch of new global TUI Turtle Aid programme—TUI press release

- Integrated multifaceted initiative to protect sea turtles
- First partnerships with local NGOs in Greece, Turkey and Cape Verde
- Programme will further expand its global footprint and develop innovative ways to protect endangered animals

Berlin, Germany—20 June 2018—As one of the TUI Care Foundation's key environmental programmes, TUI Turtle Aid will protect the welfare of 1 million new-born turtles by 2020. To kick off the programme the foundation has now joined forces with local organisations on Cape Verde, Turkey and Greece. In the months to come the programme will be expanded to more regions all over the world. It will also entail innovative research and protection methods which will help to protect the endangered global sea turtle population.

The world recently celebrated the Sea Turtle Day on 16th June. This date aims to raise awareness for these ancient creatures reminding us of their importance for our ecosystem. Sea turtles are a globally protected species and conservation studies have been carried out for decades in many countries.

Sea turtles eat and live in the water but move to the land to lay their eggs. Consequently they are exposed to numerous threats. From suffocation due to ingesting plastic bags as they confuse them with jellyfishes—on which they regularly feed—to poachers who hunt them down or irresponsible beach use that may lead to the destruction of turtle nests and the killing of hatchlings. Furthermore, by-catch, coastal development, climate change, consumption and (illegal) trade are also critical factors. Despite intensive work, many of these key threats to sea turtle populations still remain.

As a matter of fact, six of the seven marine turtle species are today considered "critically endangered," "endangered" or "vulnerable" on the IUCN Red List. Moreover, according to experts, only 1 in 1000 baby turtles survives to adulthood under natural conditions.

To kick off the TUI Turtle Aid programme TUI Care Foundation has initiated partnerships with local organisations on the Cape Verdean islands of Sal and Boa Vista, in Greece as well as in Turkey to protect the environment of sea turtles —Project Biodiversity and BIOS.CV on the two islands of Cape Verde, Archelon in Greece and DEKAMER in Turkey.

Loggerhead turtle, *Caretta caretta*, one of the marine turtle species the TUI Turtle Aid program is helping to protect. Public domain photograph.

The beautiful coastlines of Cape Verde, Greece and Turkey are not only popular destinations to visit but also host large populations of sea turtles. These turtles fulfill vital functions in the various marine ecosystems, contributing to the health of the ocean environment. Such functions range from maintaining productive coral reef ecosystems and sea-grass beds, to transporting essential nutrients from the oceans to the beaches and coastal dunes.

The project regions are selected in order to maximize the impact of the programme on the global sea turtle population. For example, the Cape Verde archipelago supports the third largest Loggerhead nesting populations in the world, and the second most important in the Atlantic Ocean overall. Five of the seven existing marine turtle species can be found in the Cape Verdean waters. Various threats, such as poachers, by-catch, as well as climate change—that is causing severe egg mortality on the nesting beaches—have also made of Cape Verde the host to one of the eleven most threatened populations of sea turtles in the world.

In order to tackle these problems, TUI Care Foundation supports local projects which aim to protect turtle's nests on the beaches, increase hatchling survival rate and engage the community and local stakeholders in protecting Sal Island's marine turtle population. In addition, ongoing outreach and engagement programmes help to strengthen local capacity in terms of on turtle conservation competencies.

Activities undertaken include early morning and night patrols, as well as relocation of doomed nests into hatcheries, rehabilitation of sick or injured turtles, and environmental educational programmes in schools. Local tour guides are also taught about best practices on turtle watching excursions and stands are placed in partnering hotels where volunteers raise awareness of the importance of protecting turtles and give practical advice to visitors to help them enjoy their holidays in a responsible

manner. The involvement of hotel partners is crucial in order to foster responsible beach use, waste management and promote sustainable excursions.

With recently-approved legislation expanding the scope of national protection for sea turtles and their nesting areas, 2018 marks a pivotal moment for sea turtle conservation in Cape Verde. Support from the TUI Care Foundation will provide critical resources to ensure both organisations can continue to build on existing programmes and further broaden their impact.

The TUI Turtle Aid project in Greece not only engages in monitoring and research, but also in public awareness. Actions include assessment of impacts of climate change in Loggerhead sub-populations and info contributions to the photo identification database of sea turtles of the Mediterranean. Public awareness activities for schools and local communities will be offered to visitors to the Sea Turtle Rescue Centre in Glyfada and in other coastal urban centres close to nesting beaches, such as Kalamata, Kyllini and Heraklion. Most importantly however, conservationists will liaise with local enterprises and the tourism industry in Chania Bay and Rethymnon Bay on Crete and South Kyparissiakos Bay in the Peloponnese, for the implementation of management measures on the Loggerhead nesting beaches. It is expected that more than 60.000 loggerhead hatchlings per year will be successfully entering the Mediterranean from those beaches.

On the beaches of Dalyan, Dalaman-Sarıgerme and Fethiye in Turkey the project to protect and rehabilitate sea turtles lays a special emphasis on involving the various stakeholder groups in the turtle protection activities—from national and regional government to local businesses and visitors. As part of the project, injured turtles found along the Mediterranean coast of Turkey are also brought to a rescue centre to receive medical treatment and support rehabilitation. DEKAMER also develops many international research and conservation projects, including the satellite tracking of turtles, sex ratio estimation of turtles under global warming, genetic differences of sea turtles on various beaches and mitigation studies on fisheries by-catch issues, among others. ♧

Based in the Netherlands, TUI is the world's leading tourism group. The portfolio consists of airlines, cruise liners, hotels, tour operators, travel agencies, and affiliated entities. TUI expresses a commitment to best practices, public education, and sustainable tourism throughout its routes and destinations.

—Text adapted from information on the TUI Group website.

Loggerhead turtle, *Caretta caretta*, on a postage stamp issued by Azerbaijan. Public domain.

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