The Saltwater Crocodile – *Crocodylus porosus* (Schneider, 1801)

**Taxonomy**

Kingdom – Animalia  
Phylum - Chordata  
Class - Sauropsida  
Order - Crocodilia  
Family – Crocodylidae  
Subfamily - Crocodylinae  
Genus - Crocodylus  
Species – porosus

Crocodiles are thought to have remained largely unchanged since the time of the dinosaurs, making them representatives of one of the oldest constant animal lineages on the planet with the modern crocodile originating more than 100 million years ago. The continuity of the species is in no small part due to their formidable array of predatory adaptations. Despite their prehistoric look, they are in fact biologically complex creatures. They have a four chambered heart, a diaphragm and cerebral cortex, more in line with the mammals than other reptiles.

Externally, these animals are extremely well adapted to their aquatic lifestyle. Their body is streamlined, allowing speed in the water, and they are able to tuck their feet closely to their sides while swimming to cut down drag. Their feet are webbed, and though they serve to initiate swimming, the primary function of the webbing is to act as a rudder for the reptile, allowing the animal to make sudden and fast turns in the water. Webbed feet are also an advantage when the animal is in shallower water, giving it a firm and steady purchase on the substrate where crocodiles may walk rather than swim.

Crocodiles are able to move quickly both in and out of water. Over short distances, a crocodile moving on land can travel at speeds up to 10km/h. The crocodile is able to move its entire body length in half a second, giving it success in ambush predation. Their jaws are the strongest of any other animals, with a bit force of 5000 pounds per square inch (psi). To put this into context, a Rottweiler can offer a force of 335psi, a great white shark 690psi. All of the muscle space within the skull of the crocodile is taken up with muscles producing this immensely strong bite, the pterygoid muscles. Because of this, if a crocodile’s jaws are held together it cannot force them open; it has developed no muscles for this purpose. Therefore, zoologists are able to capture and study crocodiles and avoid the threat of the bite by holding their jaws closed with ropes or large rubber bands.

There are 23 species of crocodile, the largest of which is *Crocodylus porosus*, the saltwater or estuarine crocodile. On average, this species reaches five to six metres in length and obtains a weight of 450kgs. Sexual dimorphism is present in this species, and it is the males that reach the largest size; currently the largest living specimen is 7.1 metres and weighs over 1000kgs, its location is Orissa in India. The largest confirmed *Crocodylus porosus* on record measured 8.6 metres in length. Females of the species are much smaller than the males, reaching on average 210 – 270 cm in length. *C. porosus* lives to over 70 years of age. In the past, these reptiles were assumed to be alligators due to their size. Indeed, the
Alligator Rivers in Northern Australia are so named due to misidentification of the crocodiles inhabiting these areas; they show a closer resemblance to the alligators than the freshwater crocodile species also found in this area.

Saltwater crocodiles have rows of bony scales on their neck and back, though the skin lacks osteoderms (bony plates), which makes it an ideal material for the leather industry. Juvenile crocodiles are yellow in colour with black stripes and spots. This colouration holds for many years, though eventually through maturity the colour becomes paler and the stripes indistinct; adults of the species are dark in colour with dark bands on the lower flanks and a yellowish belly. Colouration will vary depending on the region the crocodile is from.

The heads of these reptiles are very large, with a pair of ridges running from the eyes along the centre of the snout. The eyes, ears and nostrils are located on the same plane along the top of the head, allowing all sensory function even when the majority of the crocodile is totally submerged in the water. Both the ears and the eyes have extra protecting membranes that cover the organs when underwater. They have three eyelids; two which are leathery and serve a protective function and one which is translucent, giving protected underwater vision. One distinguishing feature of *C. porosus* is the teeth; the top and bottom jaws are perfectly aligned with one another, though the fourth tooth on each side of the bottom jaw is larger than the other teeth and visible, even when the jaws are closed.

This animal is distributed throughout South East Asia and in the Northern Territories of Australia, showing the largest distribution range of all crocodilians. However, sightings in Thailand, Cambodia, Laos and Vietnam have become increasingly rare, to the extent that it is suspected the species is extinct in one or more of these areas. It is thought that *Crocodylus porosus* used to prevail as far west as the east coast of Africa along the coast. These animals were falsely identified as Nile crocodiles, later to be recognised as *C. porosus*. There is a sporadic population in Indonesia and peninsular Malaysia, though the Malaysian states on Borneo harbour a large number of these reptiles.

*Crocodylus porosus* is, in the majority, an aquatic animal, rarely spending time on land. It is found in coastal brackish water habitats in many of the countries it inhabits, and the tidal sections of rivers, which is where it gets its name of the saltwater crocodile. It is able to cope with high salinity in part due to the presence of salt glands in its tongue. The functionality of these glands has been questioned, and experimentation on captive *Crocodylus porosus* in the past showed that these glands failed to secrete in response to salt load. However, Taylor et al (1995) successfully demonstrated that while resting, the glands in the crocodiles secreted spontaneously with production increasing rapidly when the animal was loaded with salt. Also important in this animal’s ability to withstand high salinity are its relatively impermeable skin and its small surface area : mass ratio, certainly in the larger specimens.

The saltwater crocodile is also commonly found within freshwater sections of rivers and also frequents inland lakes, swamps and marshes. Location of the crocodile shows seasonal differences. It is during the wet season that time is spent within the freshwater swamps, marshes and rivers, and during the dry season the crocodiles will move downstream to the estuaries. Chosen territory of the animal will also depend on its social status; the dominant males will occupy the most eligible stretches of freshwater creeks and streams. It is the juveniles and weaker males that will be forced into more marginal river systems with higher salinity. On occasion a crocodile will be forced out to
Male saltwater crocodiles reach maturity at around 3.3 metres, which puts them on average at 16 years old. Females are almost fully grown when they become sexually mature at around 12 – 14 years of age. Within captivity, sexual maturity is reached at an earlier age, and it is thought to be the sporadic feeding and therefore lower food intake that delays development in the wild. They are solitary animals, coming together to breed in September and October, then separating, with the male maintaining his breeding territory. Reproduction is maximised by attaining a large size before maturity in suitable habitats.

The breeding behaviour of wild males has not been studied, though in captivity it is the larger males that are the successful breeders. The females takes sole responsibility for the eggs laid and the hatchlings. She will construct a mound nest in which to lay her eggs out of grasses, mud and other vegetation, and nesting occurs throughout the wet season, from November through to March. The structure of the mound is important in maximising the survival potential of the eggs; they are protected from temperature extremes (temperatures higher than 34˚C cause 100% mortality to the eggs), they are largely hidden from predators, moisture is retained to prevent dehydration and the raised status of the nest means the risk of flooding is slightly diminished. Despite the females efforts, in some areas up to 70% of eggs are lost each year, the main threat to *Crocodylus porosus* eggs being flooding.

Location of the nest is also carefully selected and shows continuity in features throughout the species. They will always be close to a water source; this is in part so the female is able to stay close to her eggs at all times and defend them from any predators. The importance of the proximity of the nest to freshwater has been questioned. Although nesting takes place in the wet season, and therefore when rivers are flush with fresh water, it has been observed that the location of nests is almost always close to a source of fresh or mildly brackish water that withstands the dry season. It has been suggested that these locations are chosen because of the hatchlings’ dependence on a fresh water source for survival. Grigg et al (1980) studied hatchlings in the wild to determine their dependence on fresh water. Hatchlings were observed over a period of four months, the water salinities in their location exceeding the osmoticity of crocodile body fluids at all stages during the tidal cycle. The hatchlings appeared to show no signs of stress and the majority put on weight and grew in length during the observed time period. Distances involved in travelling to a fresh water source could not feasibly be covered by such a small crocodile, therefore it seems that access to fresh water is not necessary for survival. It is suggested that the best nesting materials are found at sites that are within close proximity to a dry season fresh water source, and it is this reason that leads to the situation of nests.

The female will lay between 40 and 60 eggs, the exact number is dependent on factors such as the size and age of the female. Laying takes an hour, and within several hours the embryo will attach to the egg shell, visible as a small white spot on the surface. As the weeks pass and the embryo grows, this spot expands to eventually cover the whole shell. The eggs will hatch after an incubation period

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sea to search for a new river system in which to make its territory. It is thought to be this behaviour that has led to the large distribution of these animals. The territorial behaviour of the male is very subtle, relying on cues such as slight changes in body posture or low frequency vocalisations. Violent encounters are rare as they are costly in terms of energy involved and carry the risk of serious injury or death.
of around 80 – 90 days, dependent on the temperature of the nest as this effects the rate of embryonic development. When the young crocodiles hatch, they emit a ‘chirping’ sound, which stimulates the mother to begin digging the nest site to aid the emergence of the hatchlings. She both excavates the nest and assists the hatchlings in their journey to the water, carrying them gently in her jaws. She will break open any unhatched eggs within the nest. After hatching, the juveniles stay close to the mother for many months, emitting acoustic calls so they are all aware of each other’s location.

The embryos do not have sex chromosomes, therefore sex is not genetically determined. This is instead dependent on the temperature of the nest. The sex will be determined during the first third of the incubation period as temperature influences both development rate and release of hormones during development. At a temperature between 31˚C and 33˚C males will be produced, with female embryos developing at a few degrees above or below this. However, a complete female clutch, in theory obtainable with a high nest temperature, has not been documented for *C. porosus*, which is thought to be because of the high percentage of death and abnormality of hatchlings developing in temperatures above 34˚C. Sex ratios vary between populations and also from season to season within any given population.

*Crocodylus porosus*, as is true of the vast majority of other reptiles, is ectothermic. The majority of its time is spent regulating its body temperature, the most common methods of accomplishing this being basking, moving in and out of the water, changing position whilst in water so that varying proportions of surface area are exposed to the sun, and mouth gaping. The act of mouth gaping increases the surface area for evaporative cooling and also reduces the direct impact of heat on the brain when the crocodile is directly facing the sun in order to gain heat. The preferred body temperature of any crocodile is influenced by many factors, including age, size, feeding activity, climate and incubation temperature of the embryo.

The body temperature of *Crocodylus porosus* is subject to both daily and seasonal cycles, and Seebacher *et al* (1999) studied the temperature fluctuations in the species. The average body temperature of a crocodile weighing 1010kgs was 3.7˚C higher than that of an individual weighing just 42kgs. Measurements taken in winter months showed the larger specimen to be on average 1.9˚C warmer. *C. porosus* becomes warmer with increasing mass, and the larger the individual, the more stability is shown in body temperature, to the point where individuals weighing greater than 500kgs are essentially thermostable. This species shows marked changes in its behaviour in different seasons. In the cooler months it is observed
to spend the majority of its day basking, retreating to the water only at night. However in the warmer months the day is spent in the water with the animal relocating to the land only at night. This marked seasonal change in behaviour is an important tool for maintaining thermoregulation, and it allows *C. porosus* to minimise annual fluctuations in body temperature. In the study above, the body temperature of the largest specimen, 1010kgs, fluctuated by less that 2°C where the temperature in its environment varied by 20°C. Competition for basking sites may prevent animals of a lesser status achieving their preferred body temperature, which seemingly must have significant implications for the success of individuals within a population.

Though many efforts are made to maintain the optimum body temperature for any individual, most crocodiles will conduct most of their lives at a temperature away from their preferred range. This is not too much of a burden, as crocodiles are well able to hunt and continue to be active at a wide range of body temperatures. The effects that this may have on long term reproductive success is not yet known.

The cardiovascular system of the reptile plays an important role in the transfer of heat between the body core and the environment. When the animal is basking, and therefore warming up, the heart rate increases and conversely decreases when the animals cools down. This is known as heart rate hysteresis, and it allows the animal to spend longer portions of the day within its preferred thermal range. Franklin and Seebacher (2003) investigated the effect of temperature changes on the heart rate of *Crocodylus porosus*. They discovered that during the initial period after a heat source was applied or removed, heart rate of the animal changed dramatically, though body temperature remained stable. This indicates that heart rate is controlled independently of body temperature at these times.

The time spent basking, or cooling in the water aids the crocodile in its feeding. *Crocodylus porosus* is an opportunist ambush predator, remaining still and waiting for its prey to come within reach and striking from the water. The crocodile will always strike head on, as it is unable to move its head from side to side. *Crocodylus porosus* are born with very sharp teeth and will begin feeding on small prey almost immediately after hatching. The eggs, however, contain a very good yolk supply, which can provide nourishment for days, even weeks. The juveniles of the species are restricted to small prey items, such as insects, amphibians, small reptiles, crustaceans and fish. When in areas of high salinity, prey consumed will also have a high constituent of salt, which led Grigg et al (1980) to conclude that juveniles of the species have a well developed salt gland.

As an adult, *Crocodylus porosus* is an ambush predator. It will lie in wait in the water for its prey to come close to the water’s edge and then strike. Larger crocodiles are able to persue their prey to a certain extent, but the ambush is the most reliable method of hunting. The immense strength of the animal allows it to drag prey as large as a fully grown water buffalo into the water. Should the bite of the animal not be enough to kill, it will drown the prey, sometimes utilising the ‘death roll’. This roll also subdues prey through disorientation. The teeth and jaws of the crocodile have evolved for biting rather than cutting, indeed the jaws are powerful enough to crush a full grown bovid’s skull, so the death roll is also used as a method for tearing prey apart into edible chunks for consumption if the prey is large enough to hold steady under its own weight. Otherwise the crocodile is able to tear it apart with a violent flick of the head. Crocodiles are most successful when hunting animals already swimming in the water, as the prey has no way of gaining purchase on the substrate and therefore resisting the predator.

The teeth of the animal are generally undifferentiated, therefore food is not processed within the mouth, simply teared into a size which the animal can swallow. Large crocodiles will eat almost anything, including dingos, wallabies, birds, domestic animals, other crocodiles and large reptiles, and will also prey on man. They are able to jump out of the water to a distance of half their body length
should hunting necessitate it. Prey is swallowed at the surface of the water to prevent water flooding the lungs. A fleshy ‘palatal’ valve is present at the back of the throat to prevent this happening when the head is submerged. Stones and pebbles will also be ingested to aid digestion, creating a grinding action within the gizzard. It has also been suggested that these stones also act as ballast, important for aiding buoyancy.

Their success as ambush predators is in part due to the shape of their body. They are able to hide the vast bulk of their body completely under water, leaving just a small part of their head exposed. Their well developed sense organs are able to continually monitor the surrounding environment. Daytime vision is good, with their night vision being more enhanced by a layer of guanine cells in the retina, which reflect light entering the eye back over the visual sensory cells a second time. The hearing sensitivity of the crocodile is similar to most mammals, being the most developed of all the reptiles. There are also sense organs in the skin around the jaws that detect very subtle pressure changes in the water, aiding their detection of prey when hunting.

Larger specimens of *C. porosus* (upwards of four metres) are able to remain underwater for up to 2-3 hours at a time during a dive. This is achieved by a marked reduction in their heart rate, coming down as low as one to two beats per minute. They have a four chambered heart which serves to divert oxygenated blood away from peripheral and unessential organs during diving and maximises blood flow to the brain and other vital organs. Haemoglobin within crocodile blood has twelve binding sites, contrasting to the four binding sites present in human haemoglobin. This allows greater quantities of oxygen to be released from the molecule at any given oxygen tension, allowing in turn an increased submergence time for the animal.

*Crocodylus porosus* is one of the few animals that views man as a potential food item, and it is for this reason that man has feared them through the ages. Man is, and has been, subject to attack by many animals, but does not face the threat of being eaten by many. Caldicott et al suggest reasons as to why crocodiles attack man without provocation:

- Defense of territory: these crocodiles will actively defend their territory against any intruder, be it another crocodile, animal or man
- Defense of a nest or young
- Hunting
- Mistaken identity
- Self defense when people attempt to capture crocodiles

Because of this fear, and the incidence of attacks, conservation efforts can be challenging as *Crocodylus porosus* is not widely loved.

Estuarine crocodiles were extensively hunted from the mid 1940s to the early 1970s, to such levels that the species was brought to the brink of extinction. Since 1971, *C. porosus* has been a protected species and the population has shown a great recovery. However, public feeling towards the animal
is still generally negative, which can pose a challenge to conservation efforts. Conservation is also problematic due to the large distribution of the species; its range includes thousands of islands where status and trade are difficult to monitor and control. The hide of *C. porosus* is also the most commercially valuable of any animal, leaving it susceptible to hunting and trade. As with many other species, habitat loss also poses a threat.

Presently, *C. porosus* is given a conservation status of ‘least concern’. It is listed on Appendix II of CITES in Australia, Papua New Guinea and Indonesia; Appendix I for all other countries. Papua New Guinea employ a number of measures to retain their population of *C. porosus*; they harvest wild-caught eggs and hatchlings, with controls on the frequency that this takes place. They also maintain crocodile ranches, enabling both captive breeding of the species and also a means of developing skins and meat for commercial use, which does not draw on and therefore deplete the wild population. Crocodile farms for this purpose are becoming common place in many countries, reducing the need for trade in products obtained illegally through hunting of protected wild populations. In Australia now it is thought that the population of the estuarine crocodile, including both numbers of the animals and age ranges present, is approaching pre-exploitation figures. As well as the ranching of wild-collected eggs, the country also places great importance on education programs for the public and removal of any problem crocodiles, not exterminated but placed within farms, the intent being to both reduce conflict and ill feeling.

It now seems unlikely that this species will again become threatened with extinction, due in large part to extensive suitable habitat and effective management and protection in just a few countries; Australia, Papua New Guinea and perhaps Indonesia. Unfortunately, should present trends continue, it seems that the species will cease to inhabit many of the areas of its current range, or at the least become increasingly rare. It is informative and ironic that it is the countries that encourage sustainable use of the species that have been most successful, not only in stabilising, but also greatly increasing wild population sizes. However, we also consistently find that where conservation efforts for large animals are successful, population increases are not long followed by needs to cull. It seems we cannot quite make up our minds if we want to share the world with some animals or not; indeed, we should question whether it is the human species’ perogative to make such decisions in the first place.
References


