Crocodile Conservation and Breeding Management – Issues and Constraints: Experience of Myanmar

Myo Min Hlaing

Crocodiles play a vital ecological role as key predators in wetland environments where they thrive, and have always been part of human culture, even co-existing with people, and found in the form of leather as their skin is used to make boots, handbags, jackets, belts, and more. While some regions worship the crocodiles as holy creatures by honoring them to please the god or goddess associated with them (*e.g.* in some Egyptian towns), these reptiles are also being hunted elsewhere for their skin as well as meat for food, and other body parts for medical, religious or decorative purposes. Crocodiles belong to the Order Crocodylia or Crocodilia, comprising three families and nine genera. All 23 species of crocodilians are listed under the Appendix I or II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). While crocodilians were reported many years ago to be "slated for rapid extermination at the hands of man" because of overhunting and loss of habitat, currently the populations of many crocodilian species are known to have recovered or restored. Myanmar has been breeding crocodiles since the 70s, but issues and constraints relevant to the conservation and management of crocodile breeding had been encountered, as reported in this article.

Crocodilians are large reptiles with "robust skull, long snout and strongly toothed jaws, short neck, with robust cylindrical trunk extending without constriction into a thick laterally compressed tail, and short but strongly developed limbs" (Vitt and Caldwell, 2013). Crocodilians are known to be distributed in tropical areas but some species found their way in the temperate zones through rivers, but still some inhabit the coastal marshes and even in marine areas. Under the Order Crocodilia are the various species of crocodiles, alligators, caimans, and gharials (Fleming and Fontenot, 2015; Encyclopaedia Britannica, 2019). Alligators (Genus *Alligator*) are large animals with powerful tails used for defense and in swimming, and with eyes, ears, and nostrils found on top of their long head that project slightly above the water when the reptiles float. Gavial also called gharial (*Gavialis gangeticus*), is an exceptionally long and narrow-snouted crocodilian of the family Gavialidae. Inhabiting the rivers of northern India and Nepal, gharials also reproduce by means of hard-shelled eggs laid in nests built by the female, and are characterized by their long, very slender, and sharp-toothed jaws that can sweep sideways to catch fish, their main prey. Caimans also known as caymans, are species of Central and South American reptiles that are related to alligators, that are amphibious and carnivores, living along the edges of rivers and other bodies of water, and reproducing by means of hard-shelled eggs laid in nests built and guarded by the female.

Crocodiles are commonly found in tropical regions of Africa, Asia, the Americas, and Australia. The 13 species of crocodiles include the dwarf crocodile (the smallest crocodile) which grows to about 1.7 m in length and weighs 6.0 to 7.0 kg, and the saltwater crocodile (the largest crocodile) that could grow up to 6.0 m long or more and can weigh up to 900 kg or even more (**Figure 1**). Crocodiles are carnivores, eating fish, birds, frogs, and crustaceans in the wild, and in captivity, *e.g.* in zoos, eating small animals that have already been killed for them, such as rats, fish or mice (Bradford, 2014).

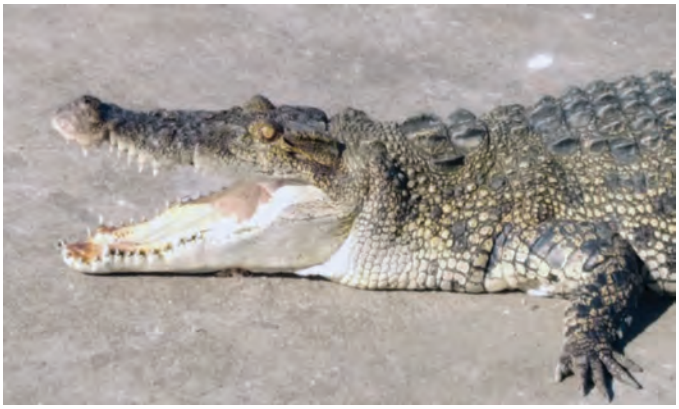

Figure 1. Saltwater crocodile commonly found in Asia

Alligators can be differentiated from crocodiles by the form of their jaw and teeth (Encyclopaedia Britannica, 2019). Alligators possess a broad, U-shaped snout and have an "overbite"— that is, all the teeth of the lower jaw fit within (lingual to) the teeth of the upper jaw, while crocodiles have a narrow, V-shaped snout and the large fourth tooth on each side of their lower jaw projects outside the snout when their mouth is closed (**Figure 2**). Like the crocodiles which are

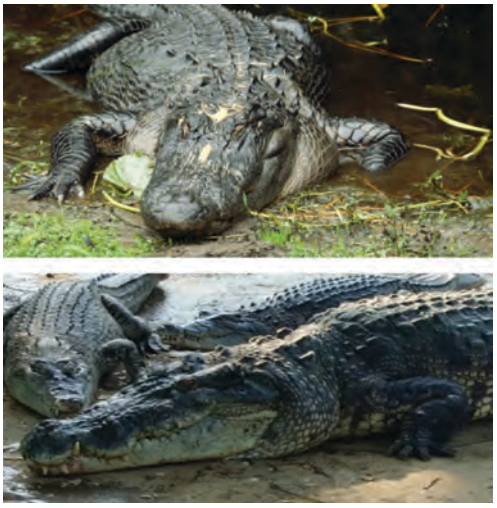

Figure 2. American alligator *(above)* *Source: Google;* and Asian crocodile *(below)*

carnivorous in nature, alligators also live along the edges of permanent bodies of water, *e.g.* lakes, swamps, and rivers.

Utilization of Crocodilian Skins

The Crocodile Specialist Group (2019) reported that the first records of commercial use of skins of crocodilians in the 1800s were found in North America, which indicated that right after the American Civil War (1861-65) the demand was high for footwear in particular, and also for belts, saddlebags, cases, and similar items. For such purpose, the American alligators (*Alligator mississippiensis*) were hunted for their skins to be processed into leather products. However, the demand had exceeded the wild alligator stocks, so the other species of crocodilians found in other parts of the country, *e.g.* Mexico and in Central America, were also utilized. The extensive and unregulated hunting of crocodilians had devastated the wild populations with most populations being greatly depleted (Martelli, 2019).

After the Second World War and during the subsequent economic revival in the Americas, crocodilian skins were again in demand, and to satisfy the North American markets, many stocks were again subjected to massive hunting not only the Nile crocodiles (*Crocodylus niloticus*) of Africa but also the crocodile stocks in South and Southeast Asian countries, as well as those in Australia and the Pacific island countries, resulting in the severe reduction of the wild populations of the saltwater crocodile (*C. porosus*) and other crocodile species.

Even the caimans in South America had been targeted for commercial hunting that began in the late 1950s, especially the black caiman (*Melanosuchus niger*), whose skin is regarded as the most valuable of all the caimans. When the wild black caiman populations dwindled and hunting was no longer profitable, other caiman species, *e.g. Caiman crocodilus* in the Amazon Basin, were utilized. Nevertheless, there were some species of caimans (*e.g.* dwarf caimans *Paleosuchus* spp.) that were not commercially-exploited due to their large bony deposits, and were not hunted for their skin. Nonetheless, their meat was harvested for the subsistence of local people. Such extensive worldwide exploitation during the 1950s, 1960s and 1970s resulted in the depleted populations of most crocodilian species, where in some extreme cases the stocks had been rooted out from parts of their range.

The relative value of the skin of different crocodilian species depends on a number of factors, including the degree of ossification (bone) in the belly, classifying the skins of crocodiles into two: the classic skins and the caiman skins (Crocodile Specialist Group, 2019). Considered the best in the world, the skin of the saltwater crocodile (*C. porosus*) has more commercial value because there is no bone in its belly scales, there is high number of belly scale rows in the belly, and the species grows very fast. Caldwell (2010) reported that from 2000 to 2008, the main producers of (*C. porosus*) skins are Australia (from crocodiles raised through captive breeding and ranching), Indonesia (captive breeding and ranching), Papua New Guinea (captive breeding and hunted from the wild), and Thailand, Singapore, Malaysia (captive breeding).

After the removal of the skin at culling, this is cured with salt to prevent from rotting and then converted to leather by soaking the skin in water to restore its original state. After the keratinous scales are removed, the skin is converted to leather through a series of chemical processes, then dyed and made ready for manufacture into various products (Fuchs, 2006). In general, the processes for converting skin into leather could also vary according to the species. There are many tanneries dealing with crocodile skins throughout the world, but according to the Crocodile Specialist Group (2019) considerable expertise producing the highest quality of crocodilian leather products could be found in Singapore, Japan and Europe (*e.g.* France, Germany, Italy).

International Trade of Crocodilian Skin

The trade records at CITES provided by the UNEP World Conservation Monitoring Centre (WCMC), indicated that the current international trade involves over 1.5 million crocodilian skins per year that are legally traded by about 30 countries (Caldwell, 2010; Caldwell, 2014; Caldwell, 2015). Specifically, between 2011 and 2013, the international trade averaged 1.57 million skins per year, comprising 47% classic skins and 53% caiman skins (**Table 1**). In spite of the reduced demand for crocodilian products, *e.g.* during the global financial crisis in 2009-2010, the market for the very highest quality crocodilian products has remained strong.

In 2013, caiman skins were more heavily traded at 1010.3 thousand skins than the classic skins at 878.3 thousand skins. The most traded was the skin of *Caiman crocodilus fuscus* from Colombia (856.6 thousand skins), followed by the skin of *Alligator mississippiensis* from USA (481.3 thousand skins), the skin of *Crocodylus nilotucus* from Africa (258.0 thousand skins), and the skin of *Caiman yacare* from Brazil, Argentina, and Bolivia (102.2 thousand skins). The other skins being traded internationally are from the *Crocodylus porosus* (Australia, Papua New Guinea, Indonesia, Malaysia, Singapore, Thailand), *C. siamensis* (Thailand, Vietnam, Cambodia), *C. novaeguineae* (Papua New Guinea, Indonesia), *C. acutus* (Colombia, Honduras), *C. moreletii* (Mexico), as well as from *Caiman crocodilus crocodilus* (Colombia, Bolivia) and *C. latirostris* (Argentina).

The Crocodile Specialist Group (2019) added that aside from their skins, crocodilians are also being exploited for their meat as the main by-product and also other parts of their body. Between 1990 and 2005 meat exports were relatively stable at around 400 metric tons (mt) per year (Caldwell,

Table 1. World trade (1000 of skins) in classic crocodilian and caiman skins, 2006-2013 (Caldwell, 2015)

Species	2006	2007	2008	2009	2010	2011	2012	2013
Alligator mississippiensis	422.9	262.1	230.5	297.2	369.7	312.5	326.5	481.3
Crocodylus acutus	0.1	0.4	1.4	1.5	0.2	1.4	1.6	1.9
Crocodylus moreletii	0.2	-	0.7	0.5	-	0.2	0.7	1.3
Crocodylus niloticus	156.2	148.3	161.7	149.1	167.8	212.8	204.3	258.0
Crocodylus novaeguineae	38.6	28.7	25.6	26.2	24.5	16.6	23.5	25.9
Crocodylus porosus	34.2	45.2	52.8	46.1	58.2	63.4	73.3	64.7
Crocodylus siamensis	48.0	54.3	63.5	34.4	33.1	38.2	35.5	45.1
Total: classic skins	**700.2**	**539.1**	**536.2**	**554.9**	**653.5**	**645.1**	**665.4**	**878.3**
Caiman c. crocodilus	34.2	45.2	52.8	46.1	58.2	63.4	73.3	64.7
Caiman c. fuscus	972.0	671.0	533.5	406.4	651.1	634.8	625.1	856.6
Caiman latirostris	1.7	1.1	0.8	0.4	1.9	3.0	4.6	6.0
Caiman yacare	50.5	65.5	51.3	48.8	29.7	58.4	81.5	102.2
Melanosuchus niger	-	-	-	-	-	-	0.3	-
Total: caiman skins	**1093.8**	**782.4**	**622.6**	**499.3**	**707.4**	**740.4**	**758.6**	**1010.3**
Total	**1794.0**	**1321.6**	**1158.8**	**1054.2**	**1360.9**	**1385.4**	**1424.0**	**1888.6**

2010), derived mainly from the American alligators, Nile crocodiles and Siamese crocodiles. China and Hong Kong are the main importers of crocodile meat. Other crocodilian parts are also being utilized, *e.g.* their blood for production of pharmaceutical products, the bones and fat for traditional medicines, while the teeth, heads, skulls are used to manufacture curios for the tourism industry. Minor trade in live crocodilians also occurs, *e.g.* for zoos and the pet trade. On a larger commercial scale, live crocodiles are also exported for farming (*e.g.* 268,000 hatchlings of the Nile crocodiles from Mozambique to Zimbabwe and South Africa over a 7-year period, the Siamese crocodile hatchlings from Cambodia to Viet Nam and Thailand), and also for food (*e.g.* 466,000 juvenile Siamese crocodiles from Cambodia, Viet Nam, and Thailand were exported to China between 1998 and 2008).

Crocodile Farming Industry

Considering the steep decline in the wild populations of crocodilians in the 1960s and 1970s, crocodile farming was perceived by many countries as an alternative industry, not only to reduce pressure on the wild populations but also as means through which the conservation of crocodilians could be sustained. Many countries then enacted legislations to protect the various species of wild crocodilians and promote crocodile farming and by the late 1970s and 1980s, captive breeding programs were being developed for such species as *C. niloticus* (Zimbabwe), *C. porosus* (Australia, Papua New Guinea, Indonesia), *A. mississippiensis* (USA), *Caiman crocodilus* (Venezuela), and *C. novaeguineae* (Papua New Guinea, Indonesia). Since one of the most depleted crocodilians was the saltwater crocodile *C. porosus*, where the wild populations had drastically declined in many countries due to over-exploitation because of the high commercial and economic value of its skin, meat and other body parts, several governments and agencies in the South and Southeast Asia were activated to initiate conservation measures. For the same reason, the International Union for Conservation of Nature and Natural Resources (IUCN) formed the Crocodile Specialist Group to be actively involved in the welfare of the world's crocodiles, especially the saltwater crocodile species (Jelden, 2004; MacGregor, 2002).

Meanwhile, the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) had listed all species of crocodilians on its Appendices, regulating their international trade. Countries that are signatories to CITES and utilize the wild crocodilian resources, must demonstrate that such utilization does not threaten the survival of the species by establishing the non-detriment findings, through regular monitoring of the wild population to assess the impacts of the exploitation, and regulating the trade of their products. As a result, crocodilian skins involved in the international trade are uniquely numbered with non-reusable tags attached to confirm the legality of the skins being traded (Webb, 2004).

Countries signatory to the CITES had been encouraged to protect these reptiles from overhunting and to conserve their habitats as the crocodilian species are almost in the verge of extinction, more specifically, the *Crocodylus porosus* which is listed on Appendix I of CITES throughout its Indo-Pacific range with the exception of Papua New Guinea (Appendix II), Indonesia [provisional Appendix II with a quota] and Australia [Appendix II (ranching)]. The transfer of the Australian population of *C. porosus* from Appendix II (ranching) to Appendix II (unqualified) will not have any impact on the international trade-protective status of the species. Although the international trade for the CITES Appendix I listed species is prohibited, crocodilian species in the CITES Appendices could still be traded provided it is established that these come from closed-cycle captive breeding without detriment to the

wild populations. To be able to trade the cultured reptiles internationally, their breeding facilities must be registered as "CITES-registered captive breeding operations." To date, captive breeding facilities had already been established in many countries for a number of crocodilian species, including *A. sinensis, C. moreletii, C. acutus, C. porosus,* and *C. siamensis*, leading to the emergence of the concepts of "crocodile farming" and "crocodile ranching."

"Crocodile farming" is the activity of breeding and/or growing crocodilians for commercial purposes, while a "crocodile ranching" involves then collection of wild crocodile eggs, hatchlings and/or juveniles and growing them in captivity. From the CITES perspective, three production systems apply to crocodilians: ranching, captive breeding, and wild harvest. Crocodile production through captive breeding is a form of intensive animal husbandry, where the culture requirements are similar for all crocodilian species, although some aspects vary and are species-specific. For example, the Siamese crocodile (*C. siamensis*) is considered a good "farm" species relative to the saltwater crocodile (*C. porosus*) as the latter is much more territorial and aggressive. A general guide to the farming of crocodilians was compiled by Hutton and Webb (2002; 2003). Unlike the conventional domesticated animals, that are raised for their meat and leather is a by-product, the main product from crocodilians is the skin, and their meat is a by-product. For this reason, care is taken during the rearing to minimize damages to the belly skin, either from the substrate surface or from social interactions with other crocodiles. The density at which crocodiles are maintained is reduced as they grow larger, to reduce interactions (including fighting) between individual reptiles and to promote good growth of the reptiles.

Crocodile Breeding in Myanmar

Aung Moe (1993) reported that some crocodilian species, *e.g. Crocodylus porosus, C. siamensis, C. palustris* and *Gavialis gengeticus* had existed in Myanmar based on the historical record of the occurrence of crocodilians. However, Thorbjarnarson *et al*. (1999) confirmed that only one species of crocodile, *Crocodylus porosus* (Schneider, 1801) now definitely exist, mainly in the Delta Region of Myanmar. *C. porosus* prefers to inhabit the tidal mangrove forests, brackishwater estuarine environments, and small creeks and streams, which are present in Myanmar and where the tidal water reaches in its Delta Regions. In the Meinmahla Kyun, Bogalay Township, Ayeyarwady Delta Region, about 136 km^2 has been designated as a wildlife sanctuary since 1944, and in 1999, about 100 crocodiles were spotted and recorded (Thorbjarnarson *et al*., 1999). Meinmahla Kyun was then established as protected area also for the wild life population of the crocodilian species *C. porosus*. However, the effect of urbanization, industrialization and agriculture led to the destruction of the habitats and nesting grounds of the crocodiles, *e.g.* the loss of mangrove forests. Therefore, strict conservation measures for crocodilian species and their habitats could be the most appropriate way to save the crocodiles from extinction (Ohn, 2003). With these factors taken into consideration, a Crocodile Breeding Farm was set up by the Government of Myanmar at Thaketa Township in Yangon Region in 1978, and placed under the supervision of the Ministry of Livestock and Fisheries.

The Crocodile Breeding Farm at Thaketa Township is mainly involved in the R&D on crocodile conservation, sustainable utilization of crocodile skins, development of public recreation and tourist attraction, enhanced public awareness of conservation of wild life and endangered species, and dissemination of knowledge and experiences to students and the youth, with the university students being enjoined to cooperate in the R&D activities. At present, the Farm is reported to have approximately 280 adult crocodiles with another 120 sub-adults and 136 juveniles. The experiences from the Thaketa Crocodile Breeding Farm with respect to conservation, management and breeding of *C. porosus* taking into consideration their characteristics and behavior are compiled below, in order that such information could also be shared with the other countries in the Southeast Asian region.

General morphometric characteristics of *C. porosus*

The head of *C. porosus* is broad and triangular in shape with long beak-like snout, sharply demarcated from the head. The 4th lower tooth is visible from outside when the mouth is closed. Dorsally, the color of the body is yellow with dark blotches in young crocodiles and yellowish dark color in adult. Ventrally, the color of the body is white in both young and adult (**Figure 3**). Males and females could be distinguished based on the nature of their snouts (broader in male than in female) and body size (males are larger than females).

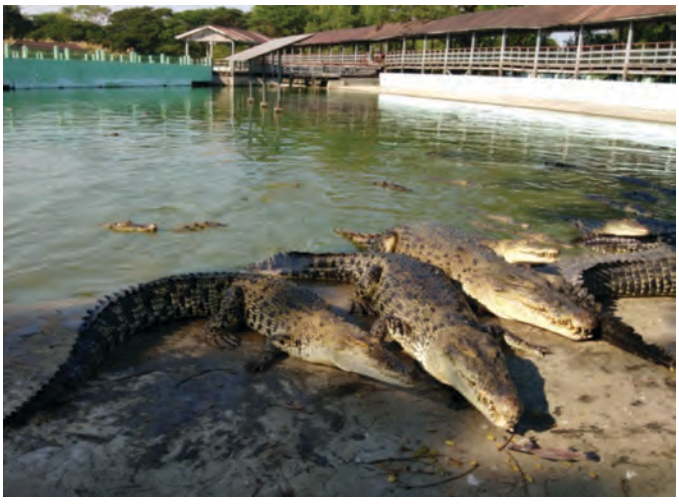

Figure 3. Adult crocodiles at Thaketa Crocodile Breeding Farm, Myanmar

Breeding behavior of *C. porosus*

Lang (1975) had worked on the reproductive ecology of *C. porosus*, especially on their pre-copulatory and copulatory

behaviors, the males defending their territories during the breeding season, as well as courtship and mating. Lang (1979) observed that during the pre-copulatory activity, males and females are engaged in a variety of species-specific behaviors, *e.g.* snout contact, snout lifting, head and body rubbing and riding, where the conspicuous male displays vocalizations and exhalations, produces narial and guttural bubbling sounds, and undergoes circling actions including periodic submergence and re-emergence. Mating occurs when the male mounts the female by moving on to her dorsum, position its tail and vent underneath the female's tail, and inserts the anteriorly curved penis into the female's cloaca. Copulation is however difficult to observe because it occurs underwater but successful copulation appears to take several minutes that could last 10-15 minutes or longer. The crocodiles mate during the day time, while nest construction and egg-laying take place at night. The crocodile breeding season starts from February and lasts until September.

Courtship and mating behavior of *C. porosus*

Lang (1979) also noted that courtship and mating in *C. porosus* usually occur from February to May. As a sign of courtship, a male crocodile searching for its mate produces a loud vocal sound through head or jaw slapping performed at the surface of the water. During the head or jaw slapping, its widely opened mouth is lifted above the surface and only the lower jaw is visible. The loud sound is produced when the raised upper jaw is lowered in a biting motion, making a loud popping sound as the jaws closed, followed immediately by a resounding splash at the water surface. If a female accepts the courtship, the female whose body remains submerged below water lifts its head and produces croaking sounds louder than the sound produced by the head slapping of the male. If the courtship is not accepted, the female rapidly swims away from the chasing male. The male that had been accepted by the female is most aggressive when another male approaches its mate, driving away the intruder by knocking it away with its head and rapidly protecting its mate. The accepted male then approaches its mate with its fore limbs over the back of the female, and swims around to climb on to the back of the female. If not successful at the first attempt, the male swims around the female two to four times before it climbs on to the back of the female.

The male on the back of the female turns the female ventrally to be in contact with its ventral side. The female is submerged under water except the head and twisted part of its tail with the male once the mating is secured. Fertilization is internal and the mating process could last for more than 10 minutes.

Nest construction and egg-laying behavior

The nesting season of *C. porosus* starts from May until July. During this time, a female crocodile with eggs that can be distinctly recognized by the expanded abdominal part of its body comes up to a forested area approximately a week before egg-laying to select its nesting area. Usually, an area that cannot be flooded when the water level rises and where there is penetration of light is selected by the female. The nest is constructed by the female by making mounds of leaves, twigs and soil.

Once the area has been selected, the female starts to collect the plant materials from shrubs, climbers and grass around the chosen area aided by its strong teeth. The plant materials as well as the fallen twigs and debris are drawn forward with its fore and hind limbs and piled up in the selected area and pressed down with its belly. This manner is repeated for three to four days. One day before egg-laying, the female crocodile makes a hollow in the nest by pushing out the nest materials with its hind limbs. The following day, the female crocodile lays eggs into the hollow and when the egg-laying process is completed the hollow is covered by pulling the pushed away plant materials using its fore and hind limbs, and pressing down with the abdominal part of its body. The eggs could be collected for incubation in the nursery units (**Figure 4**).

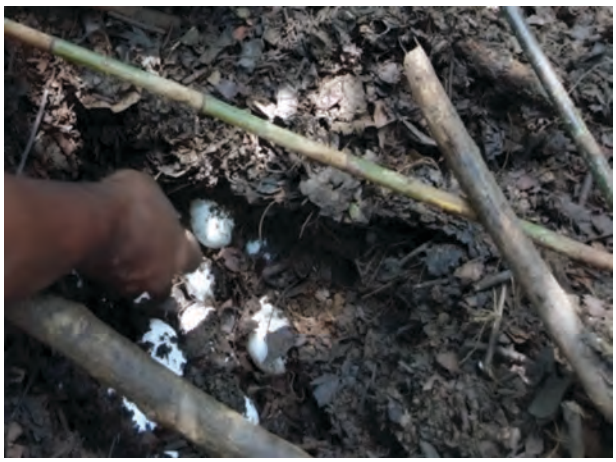

Figure 4. Collection of crocodile eggs from a crocodile nest inside the compound of the Thateka Crocodile Breeding Farm

Nest defense behavior

The behavior of crocodiles defending their eggs could vary between species and within one species over the different geographic areas. In saltwater crocodiles, intruders are chased immediately upon approaching the nest areas and will bite at anything within their reach. The female crocodiles tend to stay at or near the nest throughout the incubation period. The features of the terrestrial habitat of the nesting females and recently hatched young crocodiles are important information that could be used to define the habitat requirements, and identify the nesting areas as well as the type of habitat into which the young crocodiles are born. Such information is crucial for the management of the crocodile farms.

Thaketa Crocodile Breeding Farm

The Thaketa Crocodile Breeding Farm is located on the bank of Nga Moe Yeik also called Pazundaung Creek comprising

the total area of 16 ha at Mya Khwar Nyo Road, Industrial Quarter, Thaketa Township, Yangon (**Figure 5**). The Farm was established in May 1978 by the Peoples Pearls and Fisheries Corporation (PPFC) under the Myanmar Fisheries Enterprise. At the beginning, wild crocodiles were bought from Bogalay Township, Ayeyarwady Delta Region and reared at the Thaketa Farm. Since 1982, the Farm has been promoting crocodile egg-laying and hatching. Records showed that from 1983 to 1989, the Farm exported 1,830 live crocodiles to Thailand and Singapore on FOB price of US$ 162,689. In 1992, a total of 1,076 eggs were collected from 26 nests, and in 1994, there were nearly 830 crocodiles of all sizes reared at the Farm.

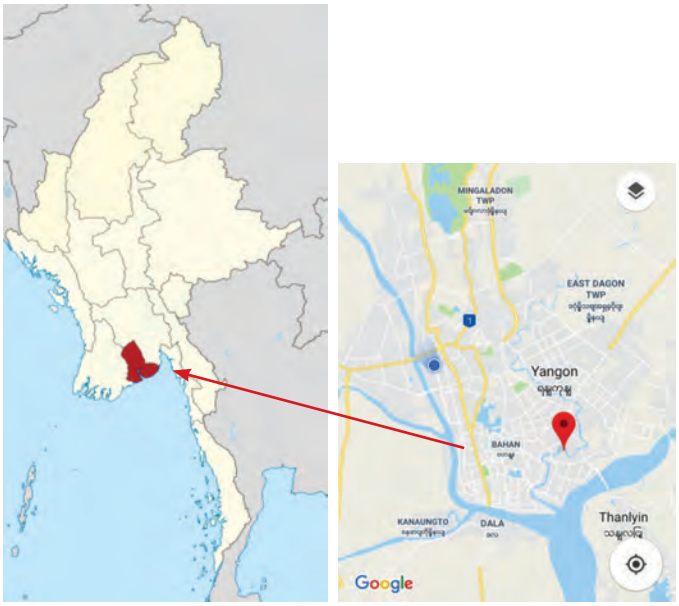

Figure 5. Map of Myanmar *(left)* and Yangon Region *(right)* showing Thaketa Township (site of the Thaketa Crocodile Breeding Farm)

In 1995, management of the Farm was transferred from the Peoples Pearls and Fisheries Corporation under Myanmar Fisheries Enterprise to the Department of Fisheries under Ministry of Livestock and Fisheries. The Farm has several types of facilities for crocodile breeding and rearing, *i.e.* concrete tanks as nursery and shelters for juveniles and sub-adults, comprising Unit No. 1 measuring 100 x 30 x 8 feet for nursing crocodile hatchlings 7-10 months to 2 years old with lengths of up to 1-3 feet, Unit No. 2 measuring 250 x 110 x 9 feet where 3 to 5 years old with lengths of up to 3-5 feet juvenile crocodiles are nursed, and Unit No. 3 measuring 100 x 50 x 8 feet where 6-7 years old with lengths of up to 6-7 feet sub-adults are kept. Newly-hatched crocodiles are nursed in intensive care nursery unit and cared up to 7-10 months. Approximately 280 adult crocodiles 8-30 years old with lengths of up to 8-15 feet are reared in 450 x 350 x 10 feet concrete and natural earthen ponds. These adults are nesting from May to August in a 2.5-ha mangrove forest within the area of the Thaketa Crocodile Breeding Farm.

Duties and responsibilities of Farm staff

The Farm is run by a number of staff members who continuously and carefully watch the animals to ensure their safety as well as that of local people and foreigners visiting the Farm every day. Some staff take charge of demonstrating and coordinating the daily crocodile performance show for visitors; maintaining the cleanliness and hygiene in the crocodile nursery units and shelters; feeding shrimps with vitamins every day for the 1-3 feet crocodile hatchlings at nursery Unit No. 1; feeding marine fishes 2 times per week to the 3-5 feet crocodiles in nursery Units No. 2 and No. 3; and feeding marine fishes 2 times per week for the 6-10 feet crocodiles in concrete and natural ponds. The total quantity of feeds given could reach to 400 kg of marine fishes fed twice per week for adult crocodiles in the Farm. The staff regularly clean the Farm compound, offices and public rest rooms; check and observe the crocodile nests at a nearby mangrove forest during the mating season; collect the eggs from crocodiles' nests; monitor and control the temperature and moisture for the eggs during the incubation period at the incubation boxes and in hatching rooms; provide nursing and intensive care to the crocodile hatchlings in intensive nursery care units; measure the length and weight of crocodiles every three months; monitor and evaluate the number of eggs, hatching rate, survival rate, mortality, growth rate, and so on.

Eggs of crocodiles

Eggs are translucent white and vary in sizes of up to 40-140 g, but all have hard calcified shell attached to a fibrous eggshell membrane (**Figure 6**). Inside the eggshell membrane is albumen and yolk, where the yolk is itself enclosed within a very thin membrane (the vitelline membrane). The calcified portion of the shell can appear smooth or rough, but always contains a network of fine pores passing through it, which might not be obvious to the naked eye. The pores are vital for oxygen (into the embryo) and carbon dioxide (out from embryo).

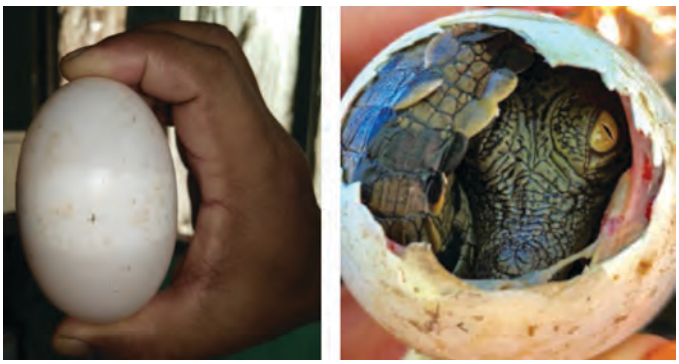

Figure 6. Egg of *C. porosus (left)* and developed embryo *(right)* at Thaketa Crocodile Breeding Farm, Myanmar

Table 2. Size and Number of crocodiles in 2019 at Crocodile Breeding Farm Thaketa

Nursery/Culture Unit	Size (feet)											Total
	1	2	3	4	5	6	7	8	9	10	> 10	
Nursery Unit 1	78	32	4									114
Nursery Unit 2					9	6	1					16
Nursery Unit 3				48	60							108
Concrete/Natural Ponds						62	103	80	21	15	17	298
Total	**78**	**32**	**4**	**48**	**69**	**68**	**104**	**80**	**21**	**15**	**17**	**536**

If an egg is placed under water, gas exchange ceases and the embryo dies. Inside the egg, a yolk sac membrane is developed to transport the nutrients to the embryo that measures about 5 x 1 mm. In 2019, there were 536 crocodiles in varying sizes, nursed and reared in the Farm (**Table 2**).

Incubation of crocodile's eggs

The incubation environment for the crocodile's eggs is extremely important as it influences the rate of embryonic development and growth, hatching time, embryonic mortality rate, and sex. After hatching, the incubation conditions affect the growth and survival rates of the crocodiles. The three major variables of the incubation environment are temperature, humidity and gas exchange. All crocodilians have temperature dependent sex determination. Typically high and low temperature females (< 31 °C and >33 °C), with a band of males in the middle close to 32 °C. In this crocodile breeding farm artificial incubation technique was applied by using styrofoam boxes (60 x 40 x 30) cm, crocodile eggs were collected shortly after laying by opening the mound surface once the female was driven out of the nesting place for safety. Eggs are handled very gently to avoid from being damaged as even a slight shake could damage the eggs.

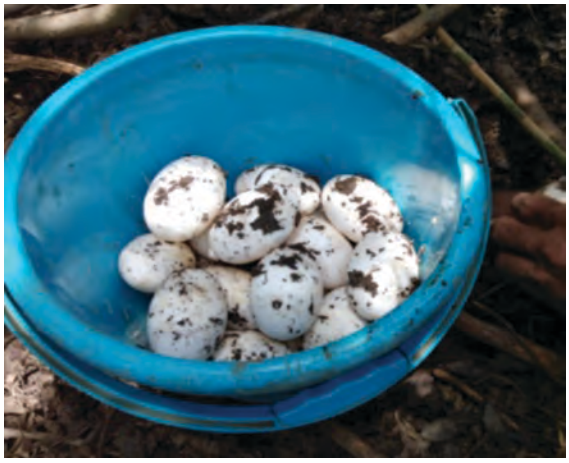

Figure 7. Crocodile eggs for incubation in the intensive care nursery unit

The collected crocodile eggs (**Figure 7**) are placed in a basket and covered with straw to prevent the effect of direct sunlight while transporting them to the incubation unit. The eggs are transferred into styrofoam boxes for artificial incubation and where the temperature is maintained at around 30 °C using wood sawdust. The relative humidity should be adjusted to 90% and the mound is frequently sprinkled with water to maintain the required humidity. The hatching performance of the eggs of *Crocodylus porosus* at the Thaketa Crocodile Breeding Farm is shown in **Table 3**.

Nursing of the crocodile hatchlings

Hatching of eggs occur after 90 days of incubation period and the entire egg has become opaque. Eggs are examined by patting the nest mound to listen to the call of hatchlings. When the call is heard, the mound is removed and the hatching eggs are extracted from the stock. The egg shell should be gently opened so that the hatchlings could emerge easily (**Figure 8**). A healthy hatchling will have a scar-line on the belly where the body wall is almost closed over the mass of yolk. A newly hatched hatchling consists of a yolk sac (3.9 x 1.8) cm protruding through the slit in its abdomen (**Figure 9**) with the protruding yolk sac covered with a fine membrane. The hatchlings with yolk sac are then reared in intensive care nursery units. Hatchlings should be kept out of water for at least 24 hours after hatching so that the membranes can dry, shrivel and break away. No attempt should be made to wash the hatchlings or pick them clean by hand. Premature hatchlings should be kept out of water until the yolk has been absorbed and the abdomen has closed. Drinking water should be provided for the hatchlings in a small container. Hatchlings are nursed for about 90 days and kept dry to lessen the risk of the yolk becoming infected. Mesh-covered incubation boxes are suitable containers to keep the premature hatchlings (inside the incubation room) for the first few days, while keeping away flies, ants and other insects. Temperature should be maintained at 34 °C to speed up absorption of the yolk and strengthen the hatchlings as quickly as possible.

Table 3. Hatchability of *Crocodylus porosus* at Thaketa Crocodile Breeding Farm

Place	No. eggs per clutch		No. of Hatchlings		Hatchability (%)	
	Range	Mean	Range	Mean	Range	Mean
Thaketa Crocodile Breeding Farm	30-60	43.2±10.4	2-38	20.1±10.2	7.5-90.0	44.7±10.5

Figure 8. Hatching of crocodile eggs

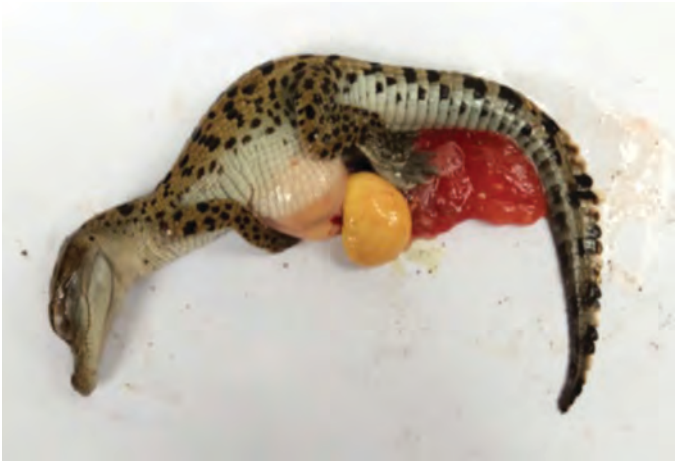

Figure 9. Hatchling of crocodile with a yolk sac protruding through a slit in the abdomen, for rearing in the intensive care hatchery unit

Since the young crocodiles do not require food for a few days after hatching because of their remaining yolk supply, their immediate need is for warmth and behaviorally for seclusion. The saltwater crocodile hatchlings at the Thaketa Crocodile Breeding Farm usually measure 28-30 cm and are kept at the nursery intensive care unit for 7-10 months they reach about 45 cm in length.

Issues and Constraints

The successful breeding and rearing of crocodiles in a crocodile farm is necessary to comply with the requirements specified under Appendix II of CITES allowing for international trade of live crocodiles and their products only from captive-bred crocodiles. This has been the mission of the Thaketa Crocodile Breeding Farm, to adopt good management and culture practices for the captive-bred crocodiles. It should be noted however that there is a possibility of cross-breeding of crocodiles in the Farm considering that in 1978, the Farm initially reared *C. porosus* collected from the wild in Meinmahla Kyun, Bogalay Township, Ayeyarwady Delta Region but during the same year, three *C. siamensis* were received as present during a State Visit in Cambodia and stocked in the Farm. This might have resulted in the hybridization of the crocodiles in the Farm. Therefore, it is necessary to undertake a genetic study of the crocodiles at the Thaketa Crocodile Breeding Farm to determine their population structure. However, this would mean necessitating the services of experts to undertake such genetic analysis.

There are other issues that confront the breeding of the crocodile *C. porosus* in Myanmar, which should be addressed for the breeding activities to be successful, and inputs from the other Southeast Asian countries would be much welcome to improve the situation at the Thaketa Crocodile Breeding Farm in Myanmar. The issues include: inadequate knowledge and technology not only for the commercial breeding of crocodiles based on international standards but also for the processing of crocodile products, *e.g.* crocodile meat, skin for leather products, and other parts for various accessories. For the survival of the Farm, stunt shows are arranged for visitors and tourists, however, the Farm has insufficient knowledge and experiences in the area of crocodile shows and farm-based tourism. The Farm is also saddled with constraints with respect to its budget which is limited for the crocodile's feeds and infrastructure maintenance of the Farm. The supply of fresh feeds becomes limited at times, considering that the small fishes are delivered by communal and private fishing vessels that do not necessarily consider such deliveries as urgent. Generally, the financial support for public awareness and research services is not adequate.

The Farm could also experience annual flooding by high tide from Ngamoyeik or Pazutaung Creek during the monsoon season, and is not very accessible by public transportation so that special transportation is needed to bring the public and tourists to the Farm, while the entrance fee is only 500 kyats (12 Thai Baht or 0.40 US$) for locals and 1000 kyats (25 Thai Baht or 0.80 US$) for foreigners. There is also a need to develop the Farm to enhance public attraction for recreation and promotion through advertisements and in the media. At this juncture, the collaboration of relevant international organizations should be tapped to support the breeding activities at the Farm and enhance the capability of the staff assigned at the Farm, making sure that the operations of the Farm adhere to the relevant international standards for crocodile breeding and rearing in captivity.

References

Aung Moe, B. K (1993). Conservation, Management and Farming of Crocodiles in the Union of Myanmar. ***In***: Crocodiles. Proceedings of the 2nd Regional (Eastern Asia, Oceania, Australasia) Meeting of the Crocodile Specialist Group. Darwin, Northern Territories, Australia. IUCN - The World Conservation Union, Gland, Switzerland; pp 9–11

Bradford, A. (2014). Crocodiles: Facts & Pictures. Live Science. Accessed June 25, 2014

Caldwell, J. (2010). World trade in crocodilian skins 2006-2008. UNEP-World Conservation Monitoring Centre (WCMC), Cambridge, UK

Caldwell, J. (2014). World Trade in Crocodilian Skins, 2010-2012. UNEP-World Conservation Monitoring Centre (WCMC), Cambridge, UK

Caldwell, J. (2015). World Trade in Crocodilian Skins, 2011-2013. UNEP-World Conservation Monitoring Centre WCMC, Cambridge, UK

Crocodile Specialist Group (1996). *Crocodylus porosus*. The IUCN Red List of Threatened Species 1996: e.T5668A11503588. *http://dx.doi.org/10.2305/IUCN.UK.1996.RLTS.T5668A11503588.en*. Downloaded on 22 May 2019

Crocodile Specialist Group (2019). Farming and the Crocodile Industry: *http://www.iucncsg.org/pages/Farming-and-the-Crocodile-Industry.html*. Accessed on 22 May 2019

Encyclopaedia Britannica (2019). Last Updated: April 24, 2019

Fleming, G.J. and Fontenot, D.K. (2015). Crocodilians (Crocodiles, Alligators, Caiman, Gharial). ***In***: Fowler, M.E. and Miller, R.E. (eds). Zoo and Wild Animal Medicine Current Therapy, Volume 8 (2015); Elsevier Saunders, Montana, USA; pp 38-49

Fuchs, K. (2006). The Crocodile Skin: Important Characteristics for Identifying Crocodilian Species. Edition Chimaera: Frankfurt, Germany

Hutton, J. and Webb, G. (2002). Legal trade snaps back. ***In***: Crocodiles. Proceedings of the 16th Working Meeting of the IUCN-SSC Crocodile Specialist Group. International Union for Conservation of Nature and Natural Resources (IUCN), Gland, Switzerland; pp 1-10

Hutton, J. and Webb, G.J.W. (2003). Crocodiles: legal trade snaps back. ***In***: Oldfield, S. (ed). The Trade in Wildlife: Regulation for Conservation. Earthscan Publications, London; pp 108-120

Jelden, D. (2004). Crocodilians and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). ***In***: Crocodiles. Proceedings of the 17th Working Meeting of the IUCN-SSC Crocodile Specialist Group. International Union for Conservation of Nature and Natural Resources (IUCN), Gland, Switzerland; pp 66-68

Lang, J. W. (1975). American Crocodile Courtship. Am. Zool. 16:197

Lang, J. W. (1979). A Study of Social Behavior of *Crocodylus novaeguineae* and *C. porosus* at Moitaka. Unpublished Report to Wildlife Division

MacGregor, J. (2002). International trade in crocodilian skins: Review and analysis of the trade and industry dynamics for market-based conservation. ***In***: Crocodiles. Proceedings of the 16th Working Meeting of the IUCN-SSC Crocodile Specialist Group. International Union for Conservation of Nature and Natural Resources (IUCN), Gland, Switzerland; pp 12-18

Martelli, P.R. (2019). Medical evaluation of crocodilians. ***In***: Miller, R.E., Lamberski, N. and Calle, P.P. (eds). Zoo and Wild Animal Medicine Current Therapy, Volume 9 (2019). Science Direct, Elsevier; pp 412-420

Ohn, M.O. (2003). Ecology and Breeding of the Estuarine Crocodile (*Crocodylus porosus*, Schneider 1801). Ph.D. Dissertation. Department of Zoology, University of Yangon, Myanmar; 92 p

Thorbjarnarson, J., Platt, S.G. and Khaing, S.T. (2000). A population survey of the estuarine crocodile in the Ayeyarwady Delta, Myanmar. Oryx 34: 317- 324

Thorbjarnarson, J.B., Platt, S. G. and Khaing, S.T. (1999). Ecological Reconnaissance of Meinmahla Kyun Wildife Sanctuary and Vicinity, Southern Ayeyarwady Delta, Myanmar. Wild Life Conservation Society, Yangon; 53 p

Thorbjarnarson, J.B., Platt, S.G. and Khaing, S.T. (1999). Ecological Reconnaissance of Meinmahla Kyun Wildlife Sanctuary and Vicinity, Southern Ayeyarwady Delta, Myanmar. Working Paper No. 12. Wildlife Conservation Society, Bronx, New York

Thorbjarnarson, J.B., Platt, S.G., Win, K.K., Khin, M.M., Khaing, L.L., Kalyar, and Holmstrom, B. (2006). Crocodiles in Myanmar: Species diversity, historic accounts, and current population status and conservation. Herpetological Natural History 10: 77-89

Vitt, L.J. and Caldwell, J. P. (2013). Herpetology (Fourth Edition): An Introductory Biology of Amphibians and Reptiles. Academic Press, Elsevier, Cambridge, Massachusetts, USA; 776 p

Webb, G.J.W. (2004). Article IV of CITES and the concept of non-detriment. ***In***: Crocodiles. Proceedings of the 17th Working Meeting of the IUCN-SSC Crocodile Specialist Group. International Union for Conservation of Nature and Natural Resources (IUCN), Gland, Switzerland; pp 72-77

About the Author

Dr. Myo Min Hlaing is Deputy Director of the Department of Fisheries, Ministry of Agriculture, Livestock and Irrigation of the Republic of the Union of Myanmar. He was the Regional Fisheries Policy Network Member for Myanmar assigned to the SEAFDEC Secretariat in Bangkok, Thailand in 2014.