



Master's degree in Management and Conservation of the Species in Trade: the
International Framework

11th edition

International University of Andalusia

Baeza, Spain

2015

**Sustainable Management and conservation of the Mugger
Crocodile (*Crocodylus palustris*) in Iran**

By: Asghar Mobaraki

Supervisors:

Dr. Marcos Regis Silva

Elham Abtin (Msc.)

Acknowledgments:

I would like to express my great thanks to CITES secretary for supporting my attendance in the course, without which it was impossible for me to participate in such a great work.

I would like to express my sincere to Dr. Margarita Celemnate for her so perfect management of the course and kind helps and advices. My great thanks also go to all the lecturers who gave me chance to use and learn from their knowledge.

Without the kind and perfect helps and supports of University of Andalucía, and the Antonio Machado Campus in Baeza, it was impossible to conduct such a course and the sweet memories staying there would be pleasant. Great thanks to all staff in the campus.

A main part of the sweet memories come from my great classmates, I would remember them all time, my special thanks to all of them.

Preparing the thesis was as the one of the most important part of the course which its completion was impossible for me without the perfect and knowledgeable helps of my supervisor, Dr. Marcos Regis Silva, I would like to express my sincere gratitude to him for such a great favor and helps. My great and special thanks to my other supervisor, Elham Abtin (Msc), another member of IUCN Crocodile Specialist Group in Iran for her so kind and useful advices and helps. I would like to remember and express my great thanks to Dr. Mercedes Nunez, Carlos Ibero, Antonio Galilea and all the lecturers again.

By this way I would like to express my great thanks to IUCN Crocodile Specialist Group for their kind helps and supports to my works, to Dr. Grahame Web, Charlie Manolis and Tom Dacey for their encouraging helps and advices.

The final acknowledgments and gratitude is for my sweet family that supported me and helped to be in the course and managed to live without me, always encouraged me and without their kind assistance it was very difficult to stay long days far from the home.

Finally I would like to thank everybody who contributed to the course and expressing my apology that I couldn't mention personally each one by one.

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Abstract: Small populations of Mugger crocodiles, with an estimate of more than 500 individuals, are distributed in the southeastern part of Iran, namely, the Sistan and Baluchestan province. The area is known as the western most global range of the species. The main characteristic of the population is that it has been divided into several sub-populations which are scattered. As a management option, the main areas of crocodile habitats have been designated as "protected areas" and "International wetland sites". The local name for the species in Iran is ‘Gandou’. The crocodiles occupy vast ranges of natural and artificial water bodies as their habitats. Crocodiles use any available resources as food like fish, birds, dogs and villager's livestock. However, they are mainly dependent on fish. The nesting season for the crocodiles in Iran has been reported to be in May and, consequently, the eggs hatch in July. Hatchlings have mean total length and weight of 30.47 cm and 84.29 g respectively. One of the most specific and important behaviors of the Mugger is burrowing which is mostly used as refuge, even by the hatchlings. Evidence indicating of nesting in the burrows is not found in the literature. Migration or movement between habitats is another considerable behavior of Muggers, which provides potential threat for the crocodiles that have to cross roads resulting in death by automobiles. Fortunately, as a unique situation in the world, there is no hunting of crocodiles in Iran and local people based on their cultural beliefs respect crocodiles and refrain from harming the species, although they have very close contact with crocodiles. Drought and flooding remain as the main natural threats for the crocodiles. Mugger crocodiles are listed in Appendix I of CITES, which prohibits commercial trade in that species.

Introduction

Crocodylians are one of the largest living reptiles, and are also part of one of the remaining of ancient group of reptilians, widespread and dependent on aquatic habitats of tropical and semi-tropical regions. In addition to their ecological importance and identification as the "Key Stone" species, Crocodylians also play a very important economic role. Most of the populations of the different species have been depleted in their ranges due to over harvesting for different uses, particularly with regard for their highly valued skins. Consequently, out of 23 living species, almost half of these species are listed in different categories of IUCN Redlist and "threatened species" and facing to problems for their survival.

Other important threatening factors like habitat loss and degradation and global warming are additional pressures that threaten their survival in the wild. However, because harvesting and trade for skin and products of the different Crocodylians species have been the main reason driving their depletion all the species are listed in the CITES appendices to control their international trade and harvest. In fact, all Crocodylia spp. are listed in Appendix II of CITES except for a number of species listed in Appendix I¹.

Due to the importance of the different crocodylian species to local communities and their livelihoods, their sustainable utilization and use have been the main objectives of programs that aim to conserve the species. The listing of the species mostly under Appendix II of CITES is also to ensure that its utilization is legal, sustainable and traceable. IUCN's *World Conservation Strategy* defines three specific objectives for the conservation of living resources: (1) to maintain essential ecological processes and life support systems, (2) to preserve genetic diversity, and (3) to ensure that the utilization of species and ecosystems is only done on a sustainable basis (IUCN1980). Development of national sustainable yield utilization

¹ <http://cites.org/eng/app/appendices.php>

strategies in compliance with national laws and regulations have been emphasized in Crocodilian conservation plans (Thorbjarnarsen, 1992).

1- Order Crocodylia: The characteristics of Crocodilians

1-1 Evolution and systematics

The 23 remaining species of crocodiles, alligators, caimans, and gharials, form the order Crocodylia, often described as “living fossils,” unchanged in millions of years. Their body has changed very little over the past 20 million years. Crocodilian's body is a mixture of reptile, bird and mammal, given their brain, heart, diaphragm and efficient breathing system as well as the stomach and digestion system. The position of their eyes, ears and nostril openings, which are found high up on the skull, helps them to hide their body underwater while breathing, seeing and hearing, allowing them to approach their prey without being identified. The order has been divided into 3 families including Alligatoridae (alligators and caimans; eight species), Crocodylidae (crocodiles; 14 species), and Gavialidae (gharial; one species). They have considerable positive effects on their habitats which helps in the maintenance and function of the ecosystem. This is the reason a why, from an ecological point of view, they are considered "Key Stone Species" in their habitats. These species effects include selective predation on fish species, recycling nutrients, and maintenance of wet refuges in time of droughts.

1-2 Physical characteristics

All crocodilian species resemble an enlarged lizard with three main distinctive parts comprising of the: head, body and tail. The smallest species of the family is the dwarf caiman (*Paleosuchus palpebrosus*); while the massive estuarine crocodile (*Crocodylus porosus*) is considered the largest of the living crocodilians, with reported lengths of up to 6-7 meters (Webb and et al 2010). However, crocodiles over 6 meters are exceptionally rare. Furthermore, in all species females are always of the smaller sex. Crocodilians undergo a dramatic increase in size from hatchling to adult. Over the lifetime, a crocodile may grow from about 30 cm and 80 g hatchling to a

more than 6 meters and 1,200 kg adult. The Mugger crocodile is reported to have a considerable growth rate compared to other species, reaching from 25 cm at hatching to 1 meter in length at the end of their first year (Holiday and Adler, 1989).

The body of the Crocodilians is covered with a thick, leathery skin which has various sizes and shapes of scales in particular areas. The dorsal part is covered with large and rectangular scales, called as "Scute", in different and parallel rows from shoulders to pelvis and continuing onto the tail. Osteoderm ("skin bone") is another specific feature of crocodilians which is a layer of small bones under the scutes, especially in the dorsal part just below the skin. This layer of bones provides more protection to the body from injuries and bites of predators, especially to spinal cord. Osteoderms also function as solar panels, transporting heat from the surface to the body core during basking. The scutes on the flanks and limbs are usually smaller, rounder, and softer so as to provide for bending. The scales of the belly are even, rectangular, and smooth to reduce friction when sliding over the ground. In some species, especially species belonging to genus *Crocodylus*, there are no Osteoderms on the belly, and are referred to as classic species, making their skin more valuable. Thick, rectangular scales on the tail, with sharp, upward-pointing scutes, provide extra surface area, especially when the tail sweeps through water. Most species exhibit distinctive color patterns, which enhance camouflage. Dorsal color is mostly tanned yellow to dark brown, dark green or olive, with dark bands, spots, or speckles. These patterns change throughout the life stages and in different species it is possible to see different colorations too.

There are two pairs of openings on either side of the cranium, which provide for the classification of the skull of the crocodilians as diapsid. There is considerable variation in skull and jaw morphology across all 23 species. Such variation has ecological significance as the broad jaws provide for more bite forces when crushing prey. Slender jaws move faster with little resistance through water to catch slippery prey like fish. This characteristic difference in the skull reflects some variation in the diet of the species. In the Gharial or *Tomistoma* crocodiles, the extremely

elongated snout is associated with a fish eating diet while the broad snout of the Muggers is associated with diets of large mammals with hard skeletons (Holiday and Adler, 1989). All the important and major sense organs are located in the head and provide for navigation, communication, and hunting. Senses are concentrated on the dorsal surface and upper part of the head, so a crocodilian species can hide its entire body below the water and be able to see, smell and hear. The palatal valve is a fleshy extension of the tongue which completely separates the esophagus from the trachea. Crocodilians, therefore, breathe easily even if the mouth is flooded with water and are able to feed underwater. The limbs are used to crawl, walk, and gallop and a high walk is quite usual in all crocodilians. Their limbs are strong enough to tolerate their weight in the walk, but the tolerance of the weight between the species is different.

1-3 Distribution

Crocodilians are a widespread species found generally in tropical and subtropical regions sufficiently warm for successful reproduction. American and Chinese alligators, found in the highest latitudes of any species, and have the ability to tolerate cold and freezing weather in their region (Holiday and Adler, 1989). Alligatoridae are restricted to North, Central, and South America, except for the Chinese alligator (*A. sinensis*), which occurs in eastern China. The main distribution area of the Crocodylidae is Africa, India, and Asia, although some species is found in the Americas. A single member of Gavialidae is found in India and adjacent countries like Pakistan and Nepal. Estuarine crocodiles have the widest distribution (India to Vanuatu), although the Nile crocodiles cover the greatest area (most of Africa and Madagascar). Spectacled caimans (*Caiman crocodilus*) number in the millions and are the most numerous throughout Central and South America. Crocodilians favor freshwater habitats, although several members of Crocodylidae tolerate higher salinity. Estuarine (also known as saltwater) crocodiles live in freshwater tidal rivers, hypersaline creeks, and along coastlines. They are also able to travel at sea. Their ability to excrete excess salt through lingual salt glands and produce concentrated urine makes this possible. All species frequent freshwater and low-salinity areas

where available, including tidal rivers, freshwater marshes, and natural and artificial lakes and pools. Distribution is influenced by the density and diversity of prey, available nesting habitat, shelter for juveniles and adults, thermal conditions, seasonal changes, and competition between species. (Ross, 1998, Holiday and Adler, 1989).

1-4 Feeding ecology and diet

All Crocodylian species are carnivorous, but also have a generalist diet, including, a wide range of mammals, birds, reptiles, amphibians, crustaceans, mollusks, fishes, and insects. However, there are various restrictions according to the age and species. Young and juveniles are limited to small prey that enters or approach water, primarily insects, spiders, crustaceans, fishes, small reptiles, and amphibians. They feed regularly every day if possible. As they grow, the size and range of available prey increases so that large specimen can easily catch large mammals. Species with specialized characteristics of long and slender snout and sharp teeth (such as gharials) choose specific foraging strategies, including fish feeding preferences. Broad-snouted Alligatorids with strong bites and blunt teeth include hard-shelled and large prey in their diet. Many Crocodylidae possess jaws between these two extremes, reflecting a generalist diet influenced by prey distribution and seasonal availability. Larger crocodiles are often seen using the tail to herd small fish into shallow water to be scooped up with a sweep of open jaws (Grzimek's Animal Life Encyclopedia, 2003, Holiday and Adler, 1989 and Whitake, 1984).

1-5 Reproductive biology

Most of the crocodylian's basic breeding system is polygynous, in which one male mates with several females. Sexual maturity is reached after a period of 5 to 15 years depending on the availability of prey, the condition of the habitat and is dictated by size rather than age. The species have an annual cycle of reproductive activity and lay 10 to 60 eggs. Environmental characteristics and conditions such as changing temperature, rainfall, humidity, and length of day impose hormonal changes in each sex. Although most of the crocodylains lay one clutch per season, double clutches

have been reported in mugger crocodiles (*C. palustris*) and Nile crocodiles in captivity, influenced by extended environmental conditions favorable to breeding. (Grzimek's Animal Life Encyclopedia, 2003, Holiday and Adler, 1989, Whitaker, 1984, Ross, 1998)

All Crocodylians show two nesting strategies: hole and mound nesting. In the hole nesting species, the female selects a soft substrate, especially sand and sandy-clay, and excavates a flask shaped chamber using her hind legs. After laying her eggs, the chamber is filled with the substrate. In mound-nesting species, the female first scrapes material, such as vegetation, soil, or mud, into a mound using her front and hind legs. She also includes fresh vegetation. The constructed mound can be distinguished easily from the distance of 10 meters and is approximately 1 meter in height and 2 to 3 meters in diameter. Once the mound is complete, the female behaves like a hole nester and follows the same activities (Grzimek's Animal Life Encyclopedia 2003, Holiday and Adler, 1989).

Although most Crocodylidae and Gavialidae use the hole nests especially in dry season, some species are able to build nests typically during the wet season or in areas that inundate easily. The noteworthy advantage of the mound nest is that it provides additional height which reduces the risk of eggs being inundated by water. American and Cuban crocodiles have been reported to choose either hole or mound nests, depending on climate and habitat. Nesting site selection may be determined by different factors like available materials, proximity of water, temperature, and even social factors. In territorial species, females choose solitary nesting sites, isolated visually or by distance from those of other females. A suitable or favorite site may be reused each year by the same or different females (Grzimek's Animal Life Encyclopedia, 2003, Hutton and Webb, 1992). In addition, false nesting is quite usual in crocodile species.

Depending on age, feeding and habit situations clutch size varies greatly in and between the species; larger and healthy specimen lay more eggs than young females. Large species also lay more eggs than small, species. Similar to bird eggs, crocodile

eggs are hard shelled and contain the yolk (nutrient storage), albumen (water supply), leathery inner shell membrane, and hard, calcified outer shell membrane (protection, control of water and gas exchange). Temperature and humidity are the main variables that influence embryo development. Nest temperatures may have a temperature range of between 29°C and 34°C. Within such a temperature range, small changes could have significant effects. Depending on the temperature, on average, incubation time lasts 70 to 90 days. In high temperature, the incubation time could be decrease and in lower temperature the incubation time could increase.

Similar to sea turtles and some lizards, the temperature-dependent sex determination (TSD) is also found in crocodylians. That is, unlike genetic sex determination (GSD), the sex of the embryo is determined by temperature of the nest in a critical temperature-sensitive period during incubation (the middle third). In most of crocodylians, eggs can be incubated successfully at temperature of 30 to 33°C. However, incubation out of this range increases the mortality of the embryos. Temperatures above and below the range produce females (Hutton and Web, 1992, Holiday and Adler, 1989). The health and size of hatchlings, their growth rate, and even preferred basking temperatures are also influenced by incubation temperature too. All crocodylian species nest during the warm season which provides appropriate temperatures for incubation. The shade of the vegetation reduces the heat preventing while the sun provides additional warmth (Grzimek's Animal Life Encyclopedia, 2003, Holiday and Adler, 1989, Webb and Manolis, 2009).

Overheating and predators such as small mammals and monitor lizards are potential threats to the eggs (Holiday and Adler, 1989). Females of most species defend the nest. This nest and hatchling protection is well documented in crocodylians and in some species even the both female and male protect the nest, preventing predators from poaching the eggs (Holiday and Adler, 1989, Lang 1986).

1-6 Conservation Status

Five of the 23 crocodylian species, Chinese alligator, Cuban crocodile, Philippine crocodile, Siamese crocodile and Gharial, are considered Critically Endangered, with

a further additional one, the Tomistoma, is listed as Endangered and considered at risk of extinction. Furthermore, three species American crocodile, Mugger and Dwarf Crocodiles are listed as vulnerable in the IUCN Redlist. The other species are not listed as threatened species (CSG Action plans 2010). The species previous decline was attributed primarily to overhunting (for skins) and habitat loss. Recovery was due to a combination of species protection, habitat protection, suppression of illegal trade, and more effective management programs promoting the sustainable use of wild populations as an incentive for their conservation. Nowadays, habitat loss and destruction in different forms, specially degradation and changing of wetlands along with illegal hunting, is believed to be the main factors threatening crocodile species (Grzimek's Animal Life Encyclopedia, 2003, Ross, 1998). Illegal trade of crocodilian species and their products remains as an important factor in the illegal harvesting of the species.

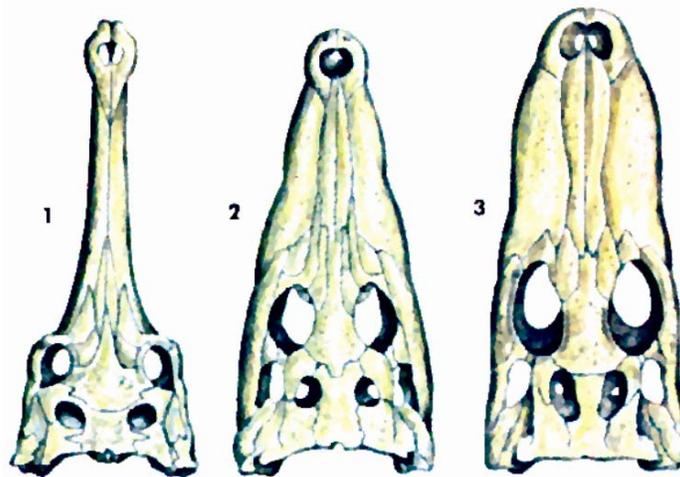


Figure 1: Difference of the skull in 3 crocodilaina familires: 1- Gavilalidae, 2- Alligatoridae, 3: Crocodylidae

Table 1: The species of family Alligatoridae and some information on them (www.iucnsg.org/publications/action plans)

The species	Global population	Clutch size	CITES	IUCN	Distribution	English Name
<i>Alligator mississippiensis</i>	More than 10 th.	40-45	II	LR	South east of US	<i>American Aligator</i>
<i>Alligator sinensis</i>	Less than 200	10-50	I	CR	China	<i>Chinese Aligator</i>
<i>Melanosuchus niger</i>	1 million	50-60	I	LC	Peru, Bolivia, Ecuador, Colombia	<i>Black Caiman</i>
<i>Paleosuchus trigonatus</i>	More than 1 m.	10-20	II	LR	Brazil, Venezuela, Peru, Bolivia, Ecuador, Colombia	<i>Dwarf Caiman</i>
<i>Paleosuchus palpebrosuss</i>	More than 1 m.	10-25	II	LR	Brazil, Ecuador, Bolivia, Colombia, Paraguay,	<i>Cuvier Smooth Fronted Caiman</i>
<i>Caiman crocodylus</i>	More than 1 m.	14-40	II	LR	South Mexico to Brazil	<i>Common Caiman</i>
<i>Caiman latirostris</i>	250-500 th.	20-60	I	LR	Brazil, Uruguay, Paraguay, Argentina	<i>Broad- Snouted Caiman</i>
<i>Caiman yacare</i>	100-200 th.	21-38	II	LR	Brazil, Bolivia, Paraguay, Argentina,	<i>Yacare Caiman</i>

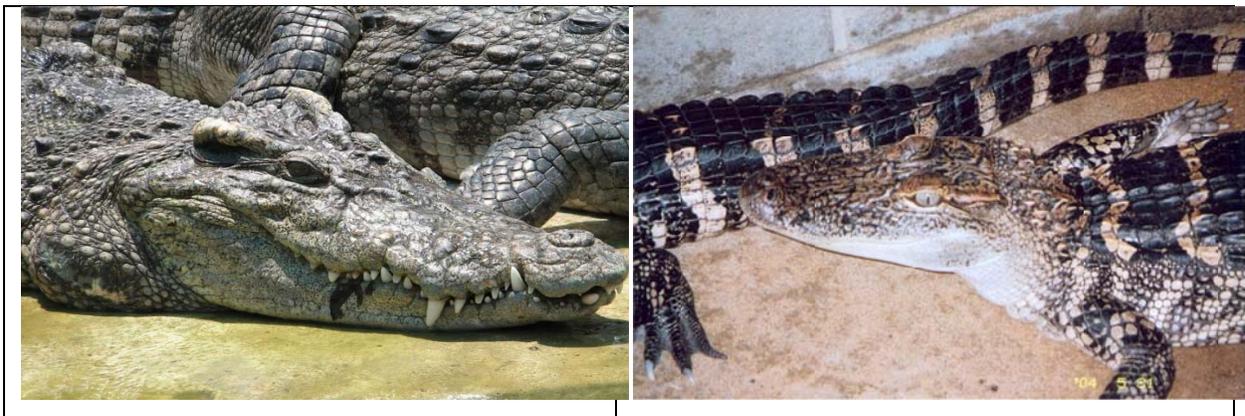


Figure 2: difference in the appearance of a crocodile with an alligator (photo: A. Mobaraki)

Table 2: The species of family Crocodylidae and some information on them
([www.iucnecsg.org/publications/action plans](http://www.iucnecsg.org/publications/action%20plans))

	Species	Global population	Clutch size	CITES	IUCN	distribution	English Name
1	<i>Corocodylus niloticus</i>	250-500 Th.	45-50	II	LR	Central and South America	<i>Nile Crocodile</i>
2	<i>Corocodylus catahracutus</i>	about 50 Th.	16		DD	West and Central Africa	<i>Slender Snouted Crocodile</i>
3	<i>Corocodylus Proosus</i>	200-300 Th.	40-60		LR	Australia, India, Philippines	<i>Salt Water Crocodile</i>
4	<i>Corocodylus palustris</i>	5-10 Th.	25-30		VU	India, Pakistan, Sri Lanka, Nepal	<i>Mugger Crocodile</i>
5	<i>Corocodylus Siamensis</i>	Less than 5 Th.	20-50		CR	South Asia	<i>Siamese Crocodile</i>
6	<i>Corocodylus novaguineae</i>	50-100 Th.	22-45	II	LR	New Guinea	<i>New Guinea Crocodile</i>
7	<i>Corocodylus johnsoni</i>	50-100 Th.	13	II	LR	North Australia	<i>Australian Crocodile</i>
8	<i>Corocodylus acutus</i>	10-20 Th.	30-60		VU	Mexico, US, Central America, Cuba	<i>American Crocodile</i>
9	<i>Corocodylus intermedius</i>	250-1500	40-70		CR	Colombia, Venezuela	<i>Orinoco Crocodile</i>
10	<i>Corocodylu moreleti</i>	10-20 Th.	20-40		LR	Mexico, Belize, Guatemala	<i>Morelet's Crocodile</i>
11	<i>Corocodylus rhombifer</i>	4 Th.	30-40		CR	South West Cuba	<i>Cuban Crocodile</i>
12	<i>Corocodylus mindorensis</i>	Less than 200	10-20		CR	Philippines	<i>Philippine Crocodile</i>
13	<i>Tomistoma schlegelii</i>	Less than 2500	20-60		EN	Thailand, Malaysia, Indonesia	<i>Tomistoma</i>
14	<i>Osteolaemus tetraspis</i>	250-100 Th.	10		VU	West Africa	<i>Dwarf Crocodile</i>

2- Mugger Crocodile: *Crocodylus palustris* (Lesson, 1831)

The Mugger is a medium-sized crocodile (maximum length 4 to 5 meters), and has the broadest snout of any living member of the genus *Crocodylus*. The species is the most similar crocodile species to American Alligators and they may have similar behaviors (Britton in crocodilian.com, 2013). The length of the snout is 1.3-1.5 meters of its width and the upper part of the body is armoured with 4-6 rows of scutes. In each row there are 16-18 of scutes. Behind the head there are two pairs of bony plates, each in one side, followed by a square composed of six larger plates. The species is principally restricted to the Indian subcontinent where it may be found in a number of freshwater habitat types including rivers, lakes and marshes. In India, Pakistan, Sri Lanka and Iran, *C. palustris* has adapted well to reservoirs, irrigation canals and man-made ponds. The Mugger can even be found in coastal saltwater lagoons and estuaries (de Silva and Lenin, 2010). In some areas of northern India and Nepal, the Mugger tends to occupy a habitat that is marginal for Gharial (*Gavialis gangeticus*), but will sometimes compete for basking and nesting banks where they are sympatric. When found together with Gharial, the Mugger will bask on midstream rocks or muddy banks (da Silva and Lenin, 2010).

The Mugger is a hole-nesting species, with egg-laying taking place during the annual dry season. Females become sexually mature at approximately 1.8-2 meters, and lay 25-30 eggs (Whitaker and Whitaker 1989). Nests are located in many habitats, and females sometimes nest at the opening of, or inside, their burrow (B.C. Choudhury pers. comm., in the IUCN Redlist *Crocodylus palustris*). In captivity, some Muggers are known to lay two clutches in a single year (Whitaker and Whitaker, 1984), but this has not been observed in the wild. Incubation is relatively short, typically lasting 55 to 75 days (Whitaker, 1987). Whitaker and Whitaker (1989) provide a good review of the behaviour and ecology of this species. Similar to a number of other crocodilians, burrowing is one of the main behaviors of the *C. palustris*. Whitaker and Whitaker (1984) referred to Mugger burrows in Sri Lanka and India (Gujarat and South India) and noted that yearling, sub-adult and adult Muggers dig burrows.

In Iran they are sometimes known to dig two burrows close to each other, which may be used by one or more crocodiles (Mobaraki, 2002). These burrows are presumably utilized as an effective refuge from hot daytime ambient temperatures. These burrows play a critical role in the survival of crocodiles living in harsh environments (Whitaker *et al.*, 2007), allowing them to avoid exposure to excessively low and high temperatures (<5°C and >38°C respectively) for long periods of time, which may be lethal (Lang, 1987).

The Mugger is known to undertake long-distance overland treks in Gir (India) (Whitaker, 1977), Sri Lanka (Whitaker and Whitaker, 1979) and Iran (Mobaraki and Abtin, 2007). Some Muggers are killed while crossing roads in Iran (Mobaraki and Abtin, 2007).

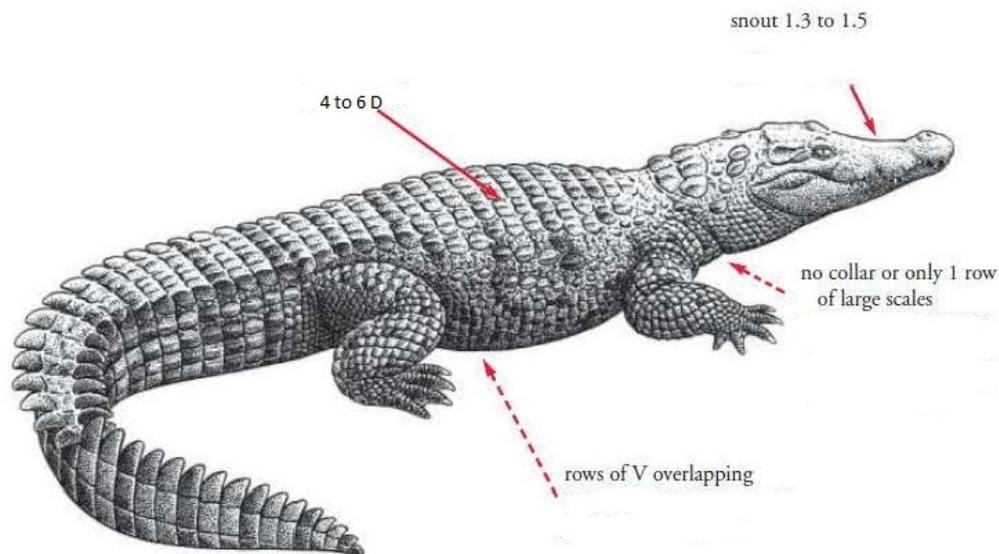


Figure 3 : the appearance and characteristics of Mugger crocodile (CITES identification Guide 1995)

2-1 Conservation and Status:

While the illegal skin trade was a major problem in the past, especially in the 1950s to 1960s, the principal threats to the Mugger were previously identified as habitat destruction and fragmentation, drowning in fishing nets, egg predation by people, and the use of crocodile parts for medicinal purposes (Ross, 1998, da Silva and Lenin,

2010). In the prepared action plan for the Mugger crocodile, da Silva and Lenin (2010) state that changes to habitat and mortality in fishing nets continue to be the major threats to the species, while other threats such as egg collection and the medicinal use of Mugger parts are marginal. Although adequate survey data are lacking for India, Pakistan, Iran and Sri Lanka, existing records indicate that populations while generally small and isolated, are widespread. The current global wild population is estimated at 5400 to 7100 non hatchlings. There is no collation of data to suggest whether the overall wild *C. palustris* population is increasing or decreasing.

Numbers of non-hatchling Mugger crocodiles in National Chambal Sanctuary (India) have apparently increased from 105 to 226 in 16 years (R.K.Sharma, data collected for the Madhya Pradesh Forest Department; Sharma *et al.* 1995). Human- Mugger conflict has been reported from different parts of the country (Whitaker 2007, 2008), indicating that it could be possibly due to increases in population and/or growing of the Muggers to larger sizes. Based on the available reports, the number of Mugger crocodiles in captivity in Indian crocodilian farming and ranching facilities reaches to several thousand specimen. With more than 2000 mugger crocodiles, the Madras Crocodile Bank alone has the highest record. Egg production at these facilities has either been stopped or eggs are routinely destroyed. If suitable habitats in protected areas of the Muggers' former range are identified, surplus stock from these facilities can be used in reintroduction programs. Bangladesh and Bhutan are both candidates for this approach as well as several states in India (da Silva and Lenin, 2010).

As a threatened species, Mugger crocodile has been categorized as "Vulnerable" in the IUCN Redlist with criteria of A2cd, indicating a population decline of 30% over three generations (75 years). The threatened listing is due to direct observations of decline in abundance, reductions in range and habitat quality and extirpation from part of the range. The total global population of the species is estimated to be less than 8700 non-hatchlings and seems to be almost increasing or even stable in the range, but the populations are fragmented (B.C. Choudhury pers. comm., in IUCN Redlist *Crocodylus palustris*)

This species is listed under Appendix I of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES). Management of the species at global level is largely based on the legal protection of wild populations and captive breeding for restocking natural populations.

Between 1978-1992 in India, a total of 1,193 captive bred individuals have been used to restock populations in 28 protected areas (Ross 1998). However, in 1994 due to overcrowding in captive centers, the production of new offspring was ceased by the Indian Government. Protection is moderately effective in protected areas in India, Sri Lanka, and Iran.

Education and public awareness regarding the importance of crocodiles to their habitats is needed and continued monitoring of the populations is required (Redlist 2015). In the Crocodile Specialist Group (CSG) Action plan, the species received the following categories (da Silva and Lenin, 2010):

- Availability for survey data: poor
- Need for wild population recovery: High
- Potential for sustainable management: moderate

Based on the status and the situation of the species at the global range, some projects with levels of ‘High’ and ‘Moderate’ priority have been defined for the conservation of the species, including: (da Silva and Lenin, 2010):

High priority: Conservation and Management plan, population monitoring, protection of habitats, monitoring of restocked Muggers in India, identification and minimization of negative anthropogenic influences, integration of local people into conservation programs;

Moderate priority: Species competition, public awareness and education about crocodiles, sustainable use schemes, eco-tourism;

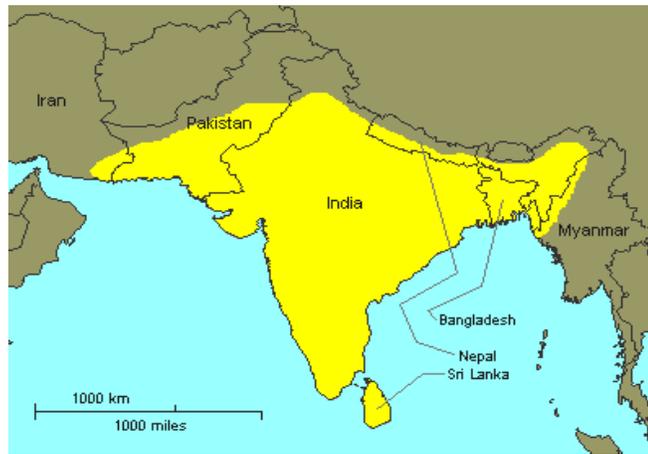


Figure 4: Global distribution map of Mugger crocodile (da Silva and Lenin, 2010)

2-2 Distribution of Muggers in Iran:

Southeastern most part of Islamic Republic of Iran is supposed to be the western most global range for the Mugger crocodile (Tuck 1975, Anderson 1979). A small population of Mugger crocodiles is distributed in southeastern part of the country in Sistan and Baluchestan province. The population seems to be isolated and it has been divided to several sub-populations as well as being scattered in the area. Their habitats are along three main rivers of the area: Sarbaz, Kaju and Bahukalat rivers and their related headwaters and ponds. Some parts of this area, with an extent of about 465000 hectares, because to its importance as crocodile habitat was designated as "protected area" in 1971 and was named Bahukalat and renamed to "Gandou" in 1982 (Tuck, 1975, Riazi, 1993). Gandou, as a Balouchi word, is the local name for the crocodiles in the area (Kami and Saghari, 1993, Mobaraki, 2000).

The main distributional area of the Mugger crocodile in Iran starts from near Rask along the Sarbaz River and southeastern part of Nikshahr along the Kaju River, which joins to Sarbaz River on its course to the sea. The Sarbaz River is renamed Bahukalat after the village with same name. The Kollany village and its ponds near Govater Bay are considered as the end of the crocodile range in Iran. However, because water habitats are affected by seawater, crocodiles will not nest in this habitat. The exception is if fresh water is abundant in this ecosystem.

Currently, there is no evidence that Iranian crocodiles inhabit saltwater. Some part of this area, due to its diverse fauna and flora, especially bird species, was designated as the 19th international Ramsar site in 1999. This Ramsar site was named Govater Bay and Hur-e-Bahu and consists of an area of 75000 hectares.

According to the provided information, the site consists of different types of wetlands including riverine and estuarine wetlands of the lower Sarbaz River, including permanent freshwater pools and marshes, mangrove swamps and intertidal mudflats, and the sandy beach of the adjacent Gulf of Oman coast in the extreme southeast of Iran (Persian Baluchestan) to the border with Pakistan” (Scot, 1995). The distribution of the crocodiles in Iran was believed to be restricted to above mentioned areas but new surveys identified other populations of crocodiles along the Nahang River and related water bodies in the north eastern part of the Gandou protected area. In the classical Persian literature, Nahang is defined as “Crocodile”. The population in Nahang and some parts close to the national border in the Gandou area may be a shared population between Iran and Pakistan.

The main characteristic of the mugger crocodile populations in Iran is that they are scattered in their range and not limited only to natural bodies of water. That is, they are sometimes found in artificial ponds in the villages. In normal situations and with adequate availability of water, crocodiles can move between the habitats. Owing to the construction of dams, the population has been divided into several sub-populations along the main rivers and existing habitats. Moreover, because of the extent of the area,, the interaction between sub-populations and populations of Iran and Pakistan crocodiles appears to be very rare.

The extent of the occurrence of the species is directly related to the availability of water. Although it was reported that Muggers use coastal lagoons in India (Whitaker,1984), evidence supporting this behavior has not been observed in Iran. Such behavior was thought to occur in some habitats in remote areas, particularly in the permanent or seasonal ponds close to the border with Pakistan. However, due to some restrictions like insecurity and being in border area without controls, it is not possible to visit that area. One other natural pond at the end of the main river close to

the sea, about 20 km and named Djor, is affected in high tide by the sea water, which makes the river brackish as opposed to fresh water. In this case, the crocodiles leave the river to the ponds inside the adjacent village. The last time the pond was inhabited was in August 2014 which caused some problems to the local people.

As the lack of water is a very critical concern to the area, particularly in the context of agricultural needs, large dams have been constructed on the Kaju and Sarbaz rivers. Although the dams have separated crocodile populations, the reservoir lakes act as a permanent water body and play a strong role in providing a habitat for the crocodiles. Most individuals seems to move to the lake from the upper parts of the area which are dry for extended periods of time. The Zirdan and Pishin dams now have created large lakes thereby guaranting the survival of many crocodiles. During the author's last visit to these parts in November 2014 both dams had close to maximum amount of capacity in the event of little rainfall during the year. These reservoirs have an essential role in the provision of water for the downstream ponds which are important habitats for the crocodiles.

Distribution of the species is dependent on water resources and water availability, as during the rainy seasons when most of the ponds have water. However, in dry seasons in which most the ponds and water bodies lack adequate water, only the ponds along the main rivers that have water will have crocodiles.



Figure 5: Mugger crocodiles in their habitats (photo by: mobaraki)



Figure 6: Gandou Protected area (Yellow outlined) t the southeastern corner of the county

2-3 Reproduction

As the crocodile population is quite scattered and the river banks as nesting sites are unavailable due to thick vegetation, finding or studying the hatchlings and hatched nests is used as an indication for reproduction success of the population. To better understand the reproductive cycle of crocodiles, the most important and suitable habitats with mature crocodiles were investigated by the author in late March for the recording of mating behaviors to predict the nesting time. The knowledge of local people and the Iranian Department of Environment rangers were of great assistance in developing a timeframe for the investigation. Based on the studies as well as on existing information from older studies, the nesting season for Mugger crocodiles in Iran appear to be from April to May (Mobaraki, 2013).

Crocodile habitats were visited during the hatching season during the day and night. During the daytime, long-term investigation and observation were conducted specially on physically suitable places with vegetation, shelter and calm water in an effort to identify hatchlings surfacing to breath. When trying to hide, the hatchlings were caught using the long handed nets. During nighttime, the spot light method with a boat was used to locate the exact place of the hatchlings. The hatchlings were caught by long handed nets or by hand. They were weighted and measured by digital caliper and balance with 0.00 grams and centimeter accuracy and were released back into the habitat after marking them by cutting the tail scutes. The length between snout and pre-anal measured as body length and pre-anal to the end of the tail measured as the tail length (Table 1 and 2).

The main part of the observation on hatchlings and all the capture specimens were made in the Pishin Dam pond (26° 01' 13.1" N, 61° 41' 12.6" E) , Shirgovaz dam reservoir (25° 24' 25.1" N, 61° 28' 28.2" E) and Hoot Gat-E- Bala pond (25° 47' 32" N, 61° 29' 45.8" E). Visiting the habitats during the hatching season from 2010-2012 it was possible to collect 19 hatchlings and, based on the measurements, the mean length and weight were 31.12 cm and 84.88 grs respectively. All the hatchlings were newly born with egg tooth and the suture on the belly (Mobaraki and et al, 2013). The clutch size and number of the hatchlings observed in each nursery site indicated that the mortality of the hatchlings is considerable. Natural threats like the predators belonging different groups including large water birds like grey heron (*Ardea cinerea*) and birds of prey, Bengal monitor (*Varanus bengalensis*) and small mammals specially mongoose (*Herpestes edwardsii*) are abundant in the region.

Another opportunity for studying the reproduction of Mugger crocodiles in Iran is found in the rearing facilities that have been established for conservation of the species by Iranian Department of the Environment. Some crocodiles in different life stages are kept in the rearing facility and one of the females had successful nesting for 4 subsequent years up to 2011. However, hatchings were not successful in 2012 as only a few of the eggs hatched in her nest. With regard to other individuals, the

eggs did not develop because the nesting site was not suitable. The crocodile, along with another specimen, also nested in 2014, but, unfortunately, eggs in both of the nests did not hatch, although they reached the development phase. When checking the eggs, the author realized that the hatchlings died inside the eggs. It seems that overheating was the main cause for the mortality of the hatchlings. The results for the measurements of the nests in 2014 are provided in table 3. The results of measurements for the nests of the only nesting female in previous years have been provided in table 4 (Mobaraki and et al, 2013).

Based on the data observed on the hatched nests in different localities, it may be safe to assume that in most areas, the crocodile has successful reproduction, but given the many threats, the loss of the hatchlings is high which in the case ranching programs, could be a potential factor to take into consideration for successful outcomes.

Table3: measurement of the crocodile nests in 2014

Nest	Clutch size	Mean length	Mean width
1	19	76.83	48.1
2	18	79.09	47.55

Table4: measurement of the crocodile nests

nest	Year	locality	No of eggs	Mean length	Mean width
1	2008	Pishin Dam	21	76.87	48.6
2	2009	Dargas Station	16	77.85	48.28
3	2010	Dargas Station	25	72.33	46.83
4	2012	Riko kash	16	78.12	47.49
mean				76.29	74.8

Parental care was obvious during the observational period, particularly when studying the nests and catching the hatchlings, when the female crocodile were at the nest and defending it or close to the hatchlings. With regard to the data on the unhatched nests in July 2014, the female was present and close to the nest and threatening to the

investigators. In some ponds which are larger, the remaining hatchlings are very dispersed which makes them much more vulnerable to predators. Moreover, at different times it could be possible to capture a single hatchling without the presence of others in vicinity, or sometimes it would become possible to observe all hatchlings of a clutch as a crèche in one place. False nesting also has been recorded for Muggers in Iran in which a male crocodile kept in captivity nested without having mated with clutch size of 21 eggs of which all were infertile (Mobaraki and Abtin, 2011).

Table 5 : results of the measurements on Mugger crocodile hatchlings (Mobaraki and et al 2013)

	Nest/Hatchlings*	body leng (S. to V.)	Tail length (V. to T.)	Total Length (cm)	Weight (g)	Date	Locality & GPS Coordination
1	1/5	13.98	15.52	29.50	85.00	July 05	Hoot Gat-E- Bala 25° 47' 32" N 61° 29' 45.8" E
2		13.82	15.18	29.00	85.00		
3		14.20	15.80	30.00	85.00		
4		14.00	15.00	29.00	75.00		
5		14.10	15.40	29.50	95.00		
6	2/3	14.50	15.50	30.00	83.00	July 05	Pond of Pishin Dam 26° 01' 13.1" N 61° 41' 12.6" E
7		14.50	14.6	29.10	84.00		
8		14.50	15.50	30.00	83.00		
9	3/1	15.80	16.20	32.00	90.30	July 06	Pond of Pishin Dam
10	4/1	15.90	15.70	31.60	89.90	July 09	Pond of Pishin Dam
11	5/1	16.33	17.57	33.90	87.50	July 10	Hoot Gat-E- Bala
12	6/2	14.15	14.73	28.89	64.70	July 10	ShirGovaz Dam reservoir
13		14.49	15.29	29.79	67.60		
14	7/3	16.57	17.34	33.91	105.40	August 11	Hoot Gat-E- Bala
15		16.49	17.07	33.56	94.40		
16		16.71	17.92	34.63	101.70		
17	8/3	15.18	16.99	32.17	82.2	August 11	ShirGovaz Dam 25° 24' 25.1" N 61° 28' 28.2" E
18		15.79	16.94	32.73	92.9		
19		16.19	17.12	33.31	109.4		
20	9/3	15.94	17.15	33.09	84.9	August 11	End of ShirGovaz Dam reservoir
21		13.35	14.04	27.39	46.8		
22		15.46	16.06	31.52	74.6		

Table 6: mean size of crocodile hatchlings

	N	Mean (Min-Max)	Std. Error
Weight (grams)	22	84.88 (46.8- 109.4)	2.94
Total length (cm)	22	31.12 (27.39-33.91)	0.44

Considering the tick vegetation, locating and finding nests is very difficult and in the most cases the nesting sites were identified after hatching. The nesting sites have different locations and in some occasions have very high elevations indicating that the female crocodile has the ability to move up on the high slopes to construct her nest. Visiting the nesting sites in Dempak village pond and Shorgovaz dam, the remaining of the hatched egg shells were at the entrance of the burrow, but was not clear if the eggs were layed inside the burrow or not. Trial nests are quite usual in the each nesting sites 1 or 2 and even more trial nests could be found (Mobaraki, 1998, Mobaraki, 2002). The trial nests could be thought of as tool to mislead predators. In a nest that was fond in the wild in 1998, the hole was 41 cm and 20 cm in length and width, and there were 2 trial nests close to the main part (Mobaraki, 1998). The nest was under the shadow of Tamarisk trees and with very soft substrate. The nests in Rikokash rearing center in the past 4 years have been always been found under the shade of a tree close to the water. Using of this site for subsequent years could be an indication for nesting site fixity, although it is not obvious if the site has been used by one crocodile.

Growth rate in Mugger crocodile hatchlings in Iran

The Mugger crocodile has been reported to be a fast growing crocodilian and, in case of suitable conditions, could grow up to 1 meter length in one year (Halliday and Adler, 1989). In different occasions the author recorded the growth rate of the hatchlings in captivity and in the wild. Some captured hatchlings are kept in captivity to study their growth and behaviors. Capturing them in different times from the wild provides an idea on their situation and growing conditions. The results of

measurements of three hatchlings caught from the wild in different date shows their growth rate in the natural situation.



Figure 7: Nest, eggs and hatchlings of Mugger crocodile in Iran (Photo by: Mobaraki)

Table 7: growth rate of the mugger crocodile hatchlings in the wild

Date of measurement	Total length	Growth time since hatching time(days)	Growth rate from mean size (30 cm)	Monthly Growth (cm)
27 Sep.	42	67	12 cm	5.45
23 Sep.	42	62	12 cm	5.82
3 Aug.	79	377	49 cm	3.92

In 2012, 9 hatchlings were captured from different sites which had average length of 28.76 cm and after 6 month the average size was 40.68, indicating 11.92 cm growth in 6 month and about 2 cm in each month, the largest size of those crocodiles in July 2014 was 67 cm in length with healthy situation, almost 38 cm in 2 years.

Feeding

Depending on the type of water bodies, crocodiles may use any available resources as food. When studying the feeding habits of the crocodiles the author used both the fecal sample collection and investigation on stomach contents of the newly dead crocodiles. With regard to the collecting of fecal samples, the banks of some ponds were investigated. In an artificial dam, named Kalsakan, in July 2014, the author collected one sample composed of hair from a goat. In this area, crocodile attacks on livestock are not unusual. Another sample from other ponds contained only. Similar to other crocodilians, Muggers are opportunistic predators and use all available resources as food. But considering existing resources, it seems that they are mainly dependent on fish stock. In India their main food items are beetles, rats and frogs (Whitaker and Whitaker, 1984). Anderson in his report states that feeding of Mugger crocodiles on Mallard (*Anas platyrhynchos*) have been reported by Kinunen (Anderson, 1979). He includes the reports of Minton in 1966 which stated that fish and turtles seem to be main food of crocodiles in Pakistan and also refers to Neil's

work in 1971, stating that the food of Muggers include fishes, frogs, sizable aquatic mammals and smaller mammals and birds. He further states that the possible food items for crocodiles in Iran Baluchistan are: Cyprinid fishes, Mud-skipper in lower parts, palm squirrels, ground squirrels, mongooses and gazella (Anderson, 1979). Mobaraki in his report describes some fecal samples of crocodiles which were composed of beetle elytra and legs, fish remains and kingfisher or similar birds' feathers (Mobaraki, 1999, 2000). Although fecal samples were an important method to understand food items, in most times, the fecal samples were completely composed of soil (clay) indicating that the crocodiles try to use bottom resources like fish species, especially that fish species in the region are bottom dwelling species like *Glosogobus giuris*, *Cyprinion watsoni* and *Cyprinus carpio*. Information gained from different occasions of 3 newly dead crocodiles killed by a car strike (Abtin and Mobaraki, 2007) while investigating the stomach contents revealed some interesting findings, body parts, including the remains of a snake was found although it was not possible to identify the species due to the size of the sample. In another carcass, the remains of fresh water crab was found in the stomach.

In all three cases there were different numbers of stones in the stomach, *Gastroliths*, in almost similar size averaging approximately 4 grams in weight. These stones could assist the digestion of food. This is usual in American alligators (Whitaker and Whitaker, 1984). Generally, it seems that they rely mainly on fish and amphibian species in the habitats. Common Skittering Frog (*Euphlyctis cyanophlyctis*) and Olive Toad (*Bufo olivaceus*) are the most common amphibian species living in the crocodile habitats may be one of the main food sources.

In most habitats the crocodiles have close contact with local people. Crocodiles normally attack the livestock of the local people. Sometimes villagers complain about aggressive crocodiles (Mobaraki, 1999). Attack on the feral dogs and wild aquatic birds have also been reported and observed during the studies. Evidence on attacks on other crocodiles and feeding on hatchlings was not observed. In most parts, the local people have experiences on seeing crocodile's attacks to feral dogs and their livestock.

Crocodiles are not overly dangerous to humans, given the very close contact of crocodiles and local people, as well as the usual daily activities such as swimming, washing clothes and dishes, harvesting of water etc. In fact, reports of crocodile attacks on local people are very rare.

Up to now, there has been only one attack ending to mortality of a young boy in a local pond which was in the prolonged drought season in 2003-2008, Most of the time, it is usual to see children swimming and playing in the ponds and local women doing the washing, without any fear from crocodiles. Even the wild, Mugger crocodiles in times of food scarcity, easily accept artificial feeding. For instance, during periods of draught when most of the ponds have dried up and food was very limited, the remaining crocodiles were fed live or dead chicken by Department of Environment rangers. Another example, during flooding season, some crocodiles inhabit the in overflow pool of the Pishin dam which has no food resources. During this period, they are fed live or dead chickens, until it becomes possible to catch and release them (Abtin and et al, 2007). Attacks on the villager's livestock is quite usual in crocodile habitats in Iran and it is the major problem in crocodile-human conflict, as they are in close and direct contact with each other.



Figure 8: Fecal samples of Mygger crocodiles in Iran (photo by: Mobaraki)

The habitats of crocodiles

Although named *palustris*, the Mugger is mainly a river and lake inhabitant, adjusting to a wide range of habitats. In India, it has been reported that they also inhabit large man made reservoirs, annual or seasonal water tanks, large rivers, irrigation channels, hill streams and jungle pools. Habitat preference may be limited by their hole nesting habits. In Sri Lanka, it has been reported that they inhabit lowland rivers, lakes, forest pools and salt pans and associated lagoons (Whitaker and Whitaker, 1984).

Mugger crocodiles have adapted well with all existing fresh water habitat types in its distribution area in Iran. Generally their habitats could be categorized into two main “Natural” and “Artificial” habitats. It seems that they use all available suitable water bodies in the region; especially that water scarcity is a usual condition in this environment.

The main natural habitats are small or large ponds (palustrines) with deep enough water as well as vegetation cover along the rivers. Most of these ponds have characteristics that are similar and provide suitable habitats including very thick vegetation along and banks with clay as the main substrates; some have a depth of more than 6-7 meters. Generally, crocodiles avoid from shallow and running parts of the rivers. The upstream of Sarbaz River has a running bed with very few ponds along, so in these parts it is very unusual to find crocodiles, although in drought period some try to enter this part in order to find a suitable habitat. In this case, crocodiles take strides along the river bed to avoid the harsh and dry situation. Sometimes they create problems to local people, as the communities are close to the water body. The natural ponds and swamps have almost reliable food resources, specially fish and amphibians. Some of these ponds are subject to drought in dry season, and the inhabitant crocodiles use to leave there.

Common Reed (*Phragmites australis*), Bulrush (*Typha latifolia*) and Tamarisk (*Tamarix*) are the main plant species along the ponds and inside the water. Moreover pond weed (*Potamogeton sp*) is quite abundant as aquatic weed and plays a critical role as shelter for hatchlings, juveniles and even adult crocodiles. Most of these ponds are close to human settlements and are the main water source as well as for agriculture.

As the second most important habitat type, different kinds of artificial water bodies also play an essential role as crocodile habitats. Most water bodies of this type are small or large ponds, close, beside or inside the villages, and are named "Hootak". They are mainly built for rain water storage. The water of the Hootaks is utilized for daily usages of the local people as well as for their livestock. As the villages are dispersed in the area, the related Hootaks have a dispersed pattern too, and provide an intermediate habitat for the crocodiles. These ponds are very suitable for crocodiles given their features like vegetation cover, water depth and availability of food. In addition, given sufficient rainfall, they could become permanent water resources. They have also suitable nesting sites and in different visits hatchlings and nest location have been observed. During the dry season, these ponds dry out and the crocodiles leave the ponds to find other suitable places or use their burrowing behavior to remain to wait for rain.

Dams in different sizes and capacity which are built by the community or the government are another example of artificial habitats. The Pishin dam, with more than 170 million m³ is one of the most important bodies of water in the distribution area of crocodiles. The same situation exists along Kaju River in the Zirdan Dam. These two large dams, managed by government, have a vast reservoir with plenty of fresh water and, even in dry season, as permanent water bodies that provide an important role in supporting the Mugger crocodile population in Iran.

During the long dry seasons, these reservoirs lose the main part of their water, causing the aggregation of all dispersed crocodiles. These reservoirs are very suitable habitats for fish stock which are the main food resource for the crocodiles. During different visits, most of the observed crocodiles are very large specimens indicating the suitability of the reservoirs, especially in providing food and shelter. During the final visits to these two reservoirs in December 2014, despite of low raining, it was observed that both had considerable water close to their maximum capacity.

Although the reservoir of the dams provide suitable habitat for the crocodiles, their positive or negative roles regarding the reproduction of the crocodiles is under investigation. Considering the rise in the level of water, and the topographical condition of the reservoirs, suitable nesting sites are lacking due to substrate and vegetation cover. The creation of dams has an ambiguous effect as the original, complex, well vegetated marshy habitats are replaced by simpler reservoir lakes with bare shores. Consequently the crocodile population may decline (Ross, 1989). The remaining and most suitable places for nesting are usually at the end part of the lake which has some vegetation and soil to construct the nest. During different times of survey on the Pishin Dam reservoir in the nesting season, only occasional observations on hatchlings at the end part of the lake were made. Occasionally two nests have been observed in the main area of the lake of Pishin Dam, but with very unsuitable substrate, without any vegetation cover and poached by natural predators. Regardless of the negative effects of the dams, it seems that, due to the specific conditions of the area and prolonged droughts, they play a very important role in supporting the crocodile population by providing adequate habitats and water for the ponds in the downstream.

Small dams with capacity of averaging more than 200 thousands m³ such as the Seyd Abad, Dargas, Kahirborz, Rahpeyma dams, among others, also are very important habitats for Mugger crocodiles. They provide permanent water all year long including during the wet season and during most of the dry season. These dams have a potential to keep and reserve the running water in wet seasons, but with a small modifications, such as the construction of walls at the exiting part to enhance their potential and capacity in conserving water. The water is used for daily and has a critical role in agricultural activities. Enough depth in water, good vegetation covers, suitable substrate for nesting, vast area, available food and shelter are the main characteristics of these small artificial dams. These habitats are important reproducing sites for the crocodiles and are part of main survey sites for the population and reproduction monitoring.



Figure 9: Natural habitats of Mugger crocodiles in Iran (photo by: Mobaraki)

Habitat Suitability of Mugger crocodiles

A good part of the information on the Mugger crocodile habitat suitability comes from the works conducted by Elham Abtin in 2010 in which she used Habitat Evaluation Procedure (HEP) to define and identify the best and most suitable habitats for Muggers. A Habitat Suitability Index (HSI), a nominal index representing habitat capacity for providing the needs of the species, was used to compare habitats where related values range between 0 (worst habitat) and 1 (best



Figure 10: Artificial habitats of the Mugger crocodiles in Iran (photo by: Mobaraki)

habitat). In the study, ten natural ponds along the Sarbaz River were selected for the study. listed from up to downstream and climatic, physical and chemical characteristics of soil, water and vegetation cover, as well as some ecological characteristics, were used in the study and were based on monthly surveys over the period of September 2008 to January 2010. Information on fauna (fishes and amphibians) and flora diversity, water depth, habitat slope and area of ponds and number of crocodiles in habitats were also included in the study.

The area of the ponds has been considered as the initial criterion for selection of the habitats as study stations as well as the highest population density, number of nests and occurrence of juvenile and adult crocodiles, based on the direct observation on crocodile occurrence in the habitats. Climatic variables also (e.g. mean temperature, humidity, evaporation, and rainfall) were compiled from existing meteorological stations at Bahu-kalat and Sarbaz.

In the conducted work, the monthly data were averaged for each parameter, and analyzed using SPSS (correlation between factors). The significant variables were scored using Analytical Hierarchy Process (AHP) and IDRISI KLIMANJARO 8.4 software and the HSI for each habitat calculated. Cluster analysis was used to classify the habitats based on their main characteristics.

There were no significant differences between habitats with respect to variables such as air and soil temperature, humidity, water and soil pH, and soil structure and elements of the habitats. Moreover, the correlation test indicated a significant relationship between parameters and crocodile population only in 6 variables for which significance was recorded. Based on AHP all data, and significant parameters, could be classified into one of three main categories: cover (vegetation cover, depth, slope); food (fish and amphibian species); and, chemical specification of water Like DO and Conductivity.

The HSI for Pishin Dam pond was 1 (highest suitability) (Fig. 2), followed by Shirgovaz, Dargas, Hutkat-e-bala, Hutkat-E-pain respectively (0.96, 0.84, 0.75 and 0.74). Azadi, Firuzabad and Shekar Jangal had similar HSI (0.3-0.5) and Kollani had the lowest HSI (0.2), indicating that it was the most unsuitable habitat. Each index received a value and using the equation of $((C_b.C_{nn} \text{ or } C_{nt})^{1/2})$ the overall HSI Model prepared for the determination of the habitat suitability value for each habitat:
HSI: $24.37 X_1 + 2.9 X_2 + 5.52 X_3 + 4.5 X_4 + 2.54 X_5 + 4.9 X_6$

in which the X values are the significant parameters. In general, Muggers prefer habitats with 2 to 4 meters water depth, mean vegetation cover of 35%, mean slope of 25-35% and high density of fish and amphibians (Behrouzi and et al 2010).

Main habits

Like other reptilians and crocodile species, the daily activities of Mugger crocodile consist of some behaviors that are for physiological regulation and control. Basking for long hours under the sun, swimming on the water surface, stopping in a set point in water are the main usual daily activities. But, the most specific and important

behavior of Mugger is burrowing. This behavior has been reported in other crocodilians species including the American and Chinese Alligators. The burrows are used as refuge to avoid heat during hot and or even cold hours of days and may be also used for other purposes. The behavior is observed in different conditions and forms that seem to be related to the habitat condition. Burrowing of the Muggers has been reported in all range states: Sri Lanka, Pakistan and India by Whitaker (Whitaker and Whitaker, 1984). He also noted that yearlings and sub-adults dig burrows. Whitaker and Whitaker stated that some burrows have up to 6 meters in length under the root system of trees and are the only available refuge during the hot season. The burrows play a critical role in the survival of crocodiles that live in harsh environments and allows them to avoid high and low temperatures for long periods of time (da Silva and Lenin, 2010).

The observed tracks on early morning close to tracks indicate that they leave the tunnels at night and wander the area to search for food (Mobaraki, 1999). In some occasions two burrows were found close together but it was not obvious if they are used by one or several crocodiles (Mobaraki, 2002). Two burrows close to each have been observed several times and in different locations, but it not clear why the crocodiles construct two burrows. Burrows at the end part of Shorgovaz dam, for example, had enough length and were less than 1 meter from each other. In an older observation in Djor at the river, two burrows were about 2 meters in distance, but the tracks between them were indicating that the crocodile(s) use both burrows.

In other burrows observed in the Djor pond in December 2014, the two were less than 1 meter length and may not have been used by the crocodiles. In another occasion in the Djor pond at the end part of Bahukalat River, 5 burrows were observed along an almost dried pond with a length of 200 meters. In 2 of the burrows it was possible to observe crocodiles inside and, surprisingly, one hatchling inside one of burrows was found, but it remains unclear if this behavior represents care provided by parents or the hatchling itself found the refuge. Some observed burrows had 1 to 2 meters in length but most were no more than 4 meters. In artificial ponds in the villages burrowing is also usual and depending on the situation 1 to 2 more burrows could be

observed at the bank of the ponds. All the burrows are very close to the water and in some occasions the entrance of the burrows are at the water surface level.

During 2008-2010, 8 to 10 crocodiles in different sizes, adult and juvenile used an artificial burrow in Dragas rearing facility without causing harm to each other. It seems that they are very patient in such conditions and may be able to tolerate others and share the refuge, but it is not clear if in the wild they can share a burrow or only use it individually. Small size burrows show that juvenile specimens can and did construct burrows.

Table 8: results of measurements on some mugger crocodile burrows in the wild

location	Length of the burrow	Width of entrance	Height of entrance
Djor	1.90 m	30 cm	25 cm
Gjor	1.10 m	38 cm	40cm
Dempak 1	1.70 m	60 cm	30 cm
Dempak 2	3.5 m	58 cm	24 cm
Dempak 3	1 m	27 cm	15 cm
Shorgovaz 1	2.5 m	35 cm	24 cm
Shirgovaz 2	2.3 m	34 cm	22 cm

In the Pishin Dam pond which the rocks and stones prevent the digging of burrows, the crocodiles use the water leading tunnels as refuge in the dry season and the water released from the reservoir. Many tracks are evident inside the tunnels and in one occasion a crocodile was observed walking to the tunnel. This may indicate that they use artificial places that provide optimal conditions as refuge.



Figure 11: Burrows of the Mugger crocodile in Iran (photo by: mobaraki)

Overland travel by Muggers is also another important behavior which is well documented and, in India, they travel overland at night to the nearest tank when the water dries in summer (Whitaker and Whitaker, 1984). Movement of crocodiles between the habitats is another recorded behavior in the area. Movement between the habitats appears to be related to searching for new habitat. Based on the observations, this behavior seems to be more usual with juvenile crocodiles. During field work, the tracks of crocodiles in different sizes were followed between the water bodies in varying short and long distances. The powerful hind limbs make the Mugger crocodiles able to tolerate its weight and travel long distances on the ground. This feature is unique among all crocodiles (Haliday and Adler, 1989).

Unfortunately this behavior may be a potential threat for the crocodiles, for example, when they cross the roads and car strikes cause death. Crocodiles struck by

automobiles were recorded several times in different life stages in the roads (Mobaraki & Abtin, 2007). This has been also observed on hatchlings where a dead hatchling was found on the road heading to river. On another occasion one sub adult crocodile with a length of 1.8meters was found dead on a road in Dashtiari, kilometers away from a water body. Visiting an important habitat in Pirshohrab area, in late August 2014, a track of a crocodile which had left a dried pond along Kajou River was followed. The pond extended to more than 2 km and ended in a small artificial dam. Considering that most of the crocodile habitats are close to villages, crocodiles may pass through the houses in their movements, causing fear to people. During the rainy season, most of the ponds have sufficient water, and short distance movements of the crocodiles between the ponds are more usual. There are records from local people that crocodiles in Iran-Pakistan border area move between the water bodies of the two countries.

Contact with local people

The numerous villages with natural and artificial ponds inside or close to dams are a potential factor increasing close contact between local people and crocodiles. Moreover in some parts, most of the villages and human settlements are by or close to rivers and natural ponds. This feature explains that local people and crocodiles lived in close proximity and have contact with each other. Ponds are visited many times during the day by the local people, especially the women and children, for daily usage and swimming. With such close contact of crocodiles and local people, the most important factor preventing harm to crocodiles is the cultural and religious beliefs and respect held by the community to crocodiles.

In Baluchistan, due to water shortage, crocodiles are respected as a water living creature meaning that of the existence of crocodiles point to the availability of water. Despite of such close contact, direct human-crocodile conflict is very rare and crocodiles rarely attack people, including children swimming in the ponds. The most serious attack was during the prolonged drought seasons in 2000 in which a young boy swimming with his friends was drowned by an adult crocodile in a very small

pond. Sometimes attacks to the children by juvenile crocodiles are reported too. There is not an exploitation and harvest of crocodiles and local people do not harm the crocodiles. In fact, they very often prevent others from doing so. This feature is unique in all crocodile habitats all around the world providing a suitable potential for conservation measures.

But the main problem in human-crocodile conflict is that crocodiles usually attack livestock for food causing economic loss for the local community. The number of these attacks according to the distribution pattern of crocodiles is considerable and is detrimental to the local people. The attacks are sometimes very severe when there is a very large crocodiles in a small pond with small amounts of food causing the crocodile to become a nuisance. It happens that crocodiles may kill 2 to 3 goats a month, and when the numbers of crocodiles increases, the number of the attacks also increases. As in most parts, local people are poor, and such an economic loss causes hardships to their livelihoods.

In some places where food resources are scarce, sometimes the crocodiles enter the villages and settlements to find some food and hunt chickens or other animals. However, there is compensation program for local people who have suffered such attacks. They are provided by the Department of Environment offices. Regrettably, the compensation at times is not provided in sufficient time or amount. Plans are underway to expand the program and to provide more support for local people. In general, the nuisance crocodiles are a potential problem which harms the livelihoods of local people, but in most cases the crocodiles are captured and translocate to larger and remote habitats like the Pishin Dam reservoir, which affords less contact with local people.

Number of Muggers in Iran

There are different records on the number of crocodiles in Iran. Tuck (1975) in his report has estimated the numbers of Muggers in Iran 50 and may be 100. In another older survey, Bosch, Kinunen and Bullock (1970) estimated the crocodiles to



Figure 12: local people are in close contact with Mugger crocodile habitats(photo by: mobaraki)

be about 50 specimen (Bosch and et al, 1970). In another study, Kami reported the number of crocodiles to be about 120 (Kami 1994). The result of a census conducted in 1999, estimates the number of crocodiles to be 200-300 (Mobaraki, 2000).

After years of change in the area caused by drought, flooding and construction of dams along the rivers, and a lack of reliable information on size and changes of the Mugger population, a survey program was conducted over a 10-day period in May 2012. A key feature of the program was that local people, in cooperation with Department of Environment staff, were engaged directly in the survey activities after receiving training. Crocodiles were counted by direct observation during the day and night. Most available habitats were visited at night, and spotlights used to locate and identify crocodiles.

Potential habitats along the Nahang River were excluded, as well as some remote ponds in the area, due to uncertainty of water availability at the time of the survey. Forty-three different survey sections were visited during the survey period, from Firooz Abad pond near Rask to the Sarbaz and Bahookalat Rivers to Djoor, close to Govatr Bay, as well as the existing artificial ponds and reservoirs in the area. Some parts of the Kajo River were also included. These areas reflected a total survey distance of about 150 km. Except for river mainstreams and ponds associated with

them, other important habitats visited were artificial ponds and reservoirs close to villages mainly in "Gando Protected area" (around 465,000 hectares).

A total of 326 crocodiles was observed, with Pishin Dam Reservoir (120 crocodiles) and Shirgovaz Regulatory Dam Reservoir (35 crocodiles) reporting the highest counts. Most crocodiles were juveniles or adults, with almost all crocodiles in Pishin Dam Reservoir being of large size (Mobaraki and Abtin, 2013). The number of the crocodiles in different parts indicates that the main part of the wild population is concentrated at the Pishin Dam reservoir thus indicating the importance of this site as a crucial habitat for crocodiles in Iran. It could also reflect a negative factor as any disaster in this region could devastate the main crocodile population. The primary reason for Pishin dam as the main habitat for crocodiles is the availability of water and food as well as the environment of the Dam which is completely under protection. Other smaller and regulatory Dams also have a critical role in supporting crocodile populations by providing them with adequate habitats. In some cases like the drought and capture of nuisance specimens, the crocodiles are translocated to the Pishin dam reservoir as the most adequate place. The same situation occurs in the Kaju River caused by the construction of the Zirdan dam. Apparently, crocodiles in upper part of the river are aggregating in the reservoir of this dam.

Main threatening factors

The most common threats for Mugger crocodiles are from natural threats rather than anthropogenic ones. As mentioned earlier, there is respect for crocodiles by local communities and little harm or exploitation of the species. However, the natural threat of drought and flooding are the two most important factors that are detrimental to the crocodiles and their habitats. The periodicity of these factors has not been well studied, but from time to time these factors impose deaths to the crocodile population. Flooding is rarer than drought and occurs in short periods. Drought usually takes longer and there have been times of prolonged drought for more than 5 years in 1997-2002. Hatchlings and juveniles receive the highest mortality rates but even dead adults have also been affected. As the most ponds are small, specially the artificial

ones, they dry very rapidly and crocodiles leave them to find other places or use the burrows.

In this situation sometimes the individual crocodiles aggregate in the available water body in the area. As the water is also used for agricultural activities, the ponds dry much faster, making the situation worse for the crocodiles. As the crocodiles lose their food resources by drought, so even in case of survival, they become very weak, as we have records of about 5 kg for a 1.7 meter crocodile. The normal weight would be closer to more than 20 kg. Drought in hatching time is a serious problem to hatchlings as lack sufficient food and shelter.

In some occasions, flooding, as another feature of the area, destroys most of the nests and nesting sites, and, after hatching, causes death for most of the hatchlings in one year, and even more for the juvenile and larger crocodiles. In some occasions, the flood carries the large crocodiles from the Pishin Dam reservoir to the downstream and cause mortality by entrapment in an overflow tank in which there is no food and escape is impossible. In such cases, survival depends on capture and released (Abtin and et al, 2007)

Natural predators like the different species of the reptiles (Bengal monitor lizard) and mammals (fox, jackal, mongoose) and large water birds (herons) are potential threat for nests and hatchlings. Several times the footprint of the predators have been observed in nesting sites of the crocodiles, indicating that the nests are used by the predators, especially the Bengal monitors and mongoose which are abundant in the area.

Fortunately, as previously mentioned, due to traditional and religious beliefs there is an absence of hunting and exploitation as well as harm to crocodiles in Iran. But human-crocodile conflict to livestock of local communities is detrimental to the livelihoods of local people. Consequently, local communities have been known to create obstacles to the burrows to prevent movement by crocodiles.

The most evident and direct effect of human activities which cause mortality for Muggers are car strikes on roads found in crocodile distribution ranges (Mobaraki

and Abtin, 2007). Crocodiles in their movement have to cross the roads and since their movements are often nocturnal, many are struck by automobiles.

Agriculture is the main activity of the local people and its development may be detrimental to crocodile habitats, banana farms being a case in point. In this regard, in some places the farmers try to expand their land by destruction of the vegetation along the rivers causing the destruction of the habitat used by crocodiles.

Population's Status and conservation needs

The Mugger crocodile has been classified as Vulnerable (VU) in IUCN Redlist based on Criteria: A2cd with the justification of decline of 30% over 3 generations (75 years) in extent of occurrence, reductions in range and habitat quality and extirpation from part of the range, populations are restricted between drainages, regions and countries and not in contact- therefore fragmented and no single population estimated to be more than 1,000 mature individuals (Chaudry and da Silva, 2014). Moreover the species is included in Appendix I of CITES, which prohibits commercial international trade in the species.

While the illegal trade in skins was a major problem in the past (1950s to 1960s), the principal threats to the Mugger have been identified as habitat destruction and fragmentation, drowning in fishing nets, egg predation by people, and the use of crocodile parts for medicinal purposes (Ross 1998).Habitat changes and mortality caused by fishing activities remains the important threat to the species while egg collection and the medicinal use of Mugger parts seem to be decreasing. Although adequate survey data are lacking for the range states, available records indicate that mugger populations in spite of being generally small and isolated are widespread in their distribution area. The current global wild population is estimated at 5400 to 7100 non hatchlings. Lack of reliable data prevents assumptions that suggest that the global wild population *C. palustris* is increasing or decreasing.. In India, Human-Mugger conflict has been reported from different parts of the country (Whitaker, 2007, 2008), indicating possible increases in population and/or Mugger reaching

larger sizes. There are several thousand Mugger in captivity in Indian crocodilian breeding facilities. The Madras Crocodile Bank alone has over 2000. Considering that the captive population of the mugger crocodile in India increased considerably, without suitable habitat for releasing and reintroduction programs, the breeding programs in the facilities and the wild have been stopped. Bangladesh and Bhutan are both candidates for this approach as well as several states in India (da Silva and Lenin, 2010).

In Bangladesh and Bhutan, the Mugger crocodile have been extinct in the wild and in Myanmar, it seems that the species has no individuals in the wild. The population of the species in Pakistan is estimated to be more than 600 in Sindh and Baluchestan, with some captive breeding facilities in the country. Nepal has been reported to have a small population of 200, but the recent situation is not clear (da Silva and Lenin, 2010).

Based on the national rules and regulations, the Mugger crocodiles are listed as “Endangered Species” in Iran and are legally protected. Based on these regulations any hunting or exploitation on the crocodiles is prohibited and there is a fine for such activities. The fine was for illegal killing and capture of a crocodile is 100 million Rls (about US\$ 3000). The respect of local people to crocodiles, gives more support for the conservation of crocodiles in Iran.

Considering these factors and the need for conservation activities a "national management plan for the Mugger crocodile population in Iran" was prepared and submitted to Department of the Environment for proper planning and implementation (Mobaraki and Abtin 2008). The budget for activities is supposed to be secured by the Department of Environment and international external support would be welcome. The plan consists of 4 main approaches and several activities defined for each approach, and include:

- 1- Research and complementary studies
- 2- Conservation of the crocodiles in their natural habitats
- 3- Captive breeding/Ranching
- 4- Public awareness / Education and Ecotourism

In the past years, two centers in Dargas and Rikokash have been established for the purpose of rehabilitation, keeping of nuisance crocodiles during short periods and rearing/reproduction of some crocodiles. Currently, there are 50 crocodiles kept in captivity in these 2 centers. There are plans to expand the facilities as farming/ranching facility as well as a research center for the crocodiles in the country. Efforts were made to engage local people in the centers. Regular surveys and research works are being conducted annually on crocodiles and the needed data on their biology and ecology are collected. The number of crocodiles is increasing in the centers by capture of nuisance specimen and in case of proper management reproduction of its crocodiles would be more successful. These centers are used as public awareness and education and provide some experiences regarding crocodile farming too.

Sustainable use of Mugger Crocodiles

Conservation of the crocodylian populations is highly dependent upon providing incentives to maintain crocodiles and their habitats in a relatively undisturbed state, and a willingness to accept management practices that allow crocodiles and humans to co-exist (Ross, 1998). Sustainable use has become a key element in the conservation of crocodylian species, but such an approach could become complex as it is necessary to consider both the effects on target species and effects on non-target species and ecosystems. The challenge for researchers and management responsible for crocodylian is to establish programs where there is high probability that use is sustainable, which can only occur if the resource and habitats are conserved (Ross, 1998). Sustainable use of Crocodylians can provide the necessary economic incentives to encourage people to maintain crocodylians and their habitats in a natural state. Different countries have long and reliable experiences on successful sustainable use of crocodylians, like Australia, USA, Venezuela and Zimbabwe. In spite of differences in the used scheme, there are similarities in the programs, all tried to

increase or maintain the wild population of the crocodile species that supports the economical level of exploitations.

Although the first crocodile farms were primarily for conservation goals, different values and uses of crocodilian species, specially the skin and meat, was a main reason leading to establishment of crocodile farms with economic aims and purposes.

Crocodiles have been bred in farms since the early 20th century. The majority of these farms were tourist attractions with wild caught alligators or crocodiles under captivity. Decline of the wild populations led to the prohibitions around the world. In crocodile farming operations, the idea is to obtain skins, meat and other products without stressing wild populations (Tosun, 2013). But most of the small and large farms, nowadays, have their own breeding stock produced in captivity. Global statistics on trade in crocodiles mostly depends on the annual reports submitted to CITES by the Parties to the Convention. Limitations of the data are directly related to Parties that fail to submit annual reports. Based on the twentieth report produced by UNEP-WCMC for the International Alligator and Crocodile Trade Study (IACTS), from 2009-2011, global commercial exports of crocodilian skins from the main taxa reported to be totally 1,330,166 skins. The main taxa are: *Alligator mississippiensis*, *Crocodylus acutus*, *Crocodylus johnstoni*, *Crocodylus niloticus*, *Crocodylus moreletii*, *Crocodylus siamensis*, *Crocodylus novaeguinea*, *Crocodylus porosus*, *Caiman crocodylus*, *C.C.fuscus*, *Caiman yacare* and *Caiman latirostris* (Caldwell 2013).

Crocodilians can be used sustainably by several methods, hunting of wild crocodilians, ranching, farming or captive breeding. Each of these methods has advantages and disadvantages in terms of conservation value, ease of regulation and economic costs and return (Ross, 1998). Depending on the situation, a combination of the different methods could be applicable and more likely to be sustainable.

Sustainable use schemes, eco-tourism

Placing a value on crocodiles is a proven technique for gaining acceptance of them from local people. Eco-tourism could potentially bring in additional income to local

communities, and provide economic incentives for people to be more tolerant of crocodiles. The surplus captive animals and recent human-crocodile conflicts have made the sustainable utilization (ranching or farming) of this species a potential alternative management strategy. The feasibility of limited commercial use needs to be examined as a means to invigorate the crocodile conservation program. In several other parts of the world the crocodiles are a profitable resource - a conservation strategy that can, if implemented correctly, be far more dynamic and successful than simple, well-meaning protective legislation (da Silva and Lenin, 2010).

In Iran, several factors seem to provide a very unique and suitable situation for planning and conducting of sustainable use of Mugger crocodiles. National legislation and regulations, religious and traditional believes, the distribution patterns of the crocodile habitats and finally close contact of crocodiles and local people are the factors that provide preliminary needs and fundamentals for sustainable use programs. As previously mentioned, most of the artificial ponds are inside human settlements which have 1 or 2 or more crocodiles inside. In the past years, demand for crocodilian species has been increased as some people like to use them in different facilities, like zoos, animal fairs, wildlife parks, wildlife related facilities and touristic attractions. This situation caused some legal and illegal trade on exotic species like Nile, Saltwater and Siamensis crocodiles.

Responding to these demands using the native Mugger crocodile species would provide a great chance to gain both conservation and economic benefits, leading to a potential increase in the population of the species. Using the natural situation of the Mugger crocodile in Iran, along with a robust management plan, it would be possible to plan breeding programs in the area and use the wild specimen as breeding stock for captive breeding programs. In parallel, ranching activities could be tool to increase and recover the wild populations and even increase the number of crocodiles in the wild. By providing rearing animals to the local people and training them to rear them, not only they would be more careful about the wild crocodiles, but also it would be

and incentive for them to conserve it and receive a compensation for their respectful traditional believes.

Socially, most of the people in Mugger crocodile range are poor or very poor. Moreover, lack of facilities, job opportunities, resources, basic needs and harsh climatic conditions has created a difficult situation for local people. Using the potential of existing crocodiles in the area, it could become possible to change the situation for most of the local communities, instead of developing new banana farms, which bring with it increased water usage and less profitability. The story of American alligator could be a suitable example in this regard. Sustainable use of the species and using the natural resources to provide more healthy and wealthy situation for the local people has been emphasized by international treaties like the Convention on Biological Diversity. In the Goals use the Aichi targets as possible indicators, and in these goals and targets the subject is well defined:

***Strategic Goal A:** Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society*

Target 1: “By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.”

Target 2: “By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.” (Secretariat of CBD, 2014)

Discussion

In the action plan prepared by Crocodile specialist Group for the Mugger crocodile (da Silva and Lenin, 2010), the potential for sustainable management of the species lies in “Moderate” level and “Sustainable use schemes” receives moderate priority. The current global wild population of the species is estimated to be more than seven thousands non-hatchling specimens, in case that there are thousands in breeding farms without any specific uses in India and some farms have been established in other countries like Pakistan. Based on the number of the crocodiles, it seems that

there is enough stock and technical support to introduce Mugger farming for commercial purposes in some range states, including in Iran.

Considering the situation in Iran, especially the respect of local people to the species, and the legal protection afforded to the species, as well as the artificial habitats provided to the crocodiles by the local people, introduction of private crocodile farming initiative with close supervision and control of government in different phases and steps, could potentially be a successful conservation and management enterprise with commercial benefits to the local people. This would require the provision of breeding stock through ranching or farming activities managed or supervised by the government, using the capacity of interested private sectors.

More public awareness and education activities, training workshops and courses, preparing educational and training materials, breeding and rearing regulations, financial support to local people and securing the survival of the wild population would be the basic preliminary needs. The local and artificial ponds in most of the villages, some of which are used by crocodiles, could be a very practical model to be used as a breeding system, but with some oversight, like regularly feeding of the crocodiles and providing them more safe and secure places. However, as a CITES Appendix I listed species, commercial international trade is the species is prohibited. Based on the CITES Resolutions and Decisions, some possible solutions related to ranching of the species could be introduced in the range states, such as using of the F2 generations.

Given that the species is globally threatened species and listed in Appendix I of CITES Appendix I, a series of programs could be conducted in all range states to increase the population size to improve the status of the species. The existing farms in India could play a critical role in providing the breeding stock for other states, such as Iran, along with some training and capacity building programs. To be introduced in international markets, the species should meet the one of the criteria for obtaining trade permits under Appendix II of CITES: *Scientific Authority of the State of export*

has advised that such export will not be detrimental to the survival of that species (Article IV, paragraph a of CITES).

Recommendations:

- 1- Establishment of Mugger crocodile Farms with conservation aims
- 2- Conducting of proper public education and awareness programs
- 3- Conducting of farming/ranching programs and juvenile crocodile release to natural habitats
- 4- Designation of sanctuaries for introduction and release programs
- 5- Using the capacity of local people for conservation and research plans
- 6- Engagement of the local people in captive breeding programs
- 7- Preparing of sufficient breeding stock for private sectors, specially local people,
- 8- Improvement of local tourism, Eco-Tourism plan and activities which provides incentive and incomes for the local people.
- 9- International cooperation of the Mugger crocodile range states to establishment and expanding of crocodile farms and meeting CITES criteria for international trade of the species
- 10- Conducting proper and needed conservation activities in all range states to change the “threatened species” status of the species as a

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