

Saikat Kumar Basu^{1*}, Subhamoy Das², William Cetzal-Ix³

¹PFS, Lethbridge, Alberta, Canada; *saikat.basu@alumni.uleth.ca

²Department of Zoology, Mahishadal Raj College Mahishadal, Purba Medinipur, West Bengal, India

³Tecnológico Nacional de México, Instituto Tecnológico de Chiná, Chiná, Campeche, México

Indian Saltwater crocodiles (*Crocodylus porosus* Schneider, 1801) and their conservation perspective

Introduction

Saltwater crocodile (*Crocodylus porosus* Schneider, 1801), also known as estuarine crocodile, Indo-Pacific crocodile, marine or sea crocodile, is the largest living reptiles found in the brackish and saltwater regions of estuaries and coastal areas in parts of Southeast Asia, Northern Australia, and some parts of the Indian subcontinent (Fig. 1).

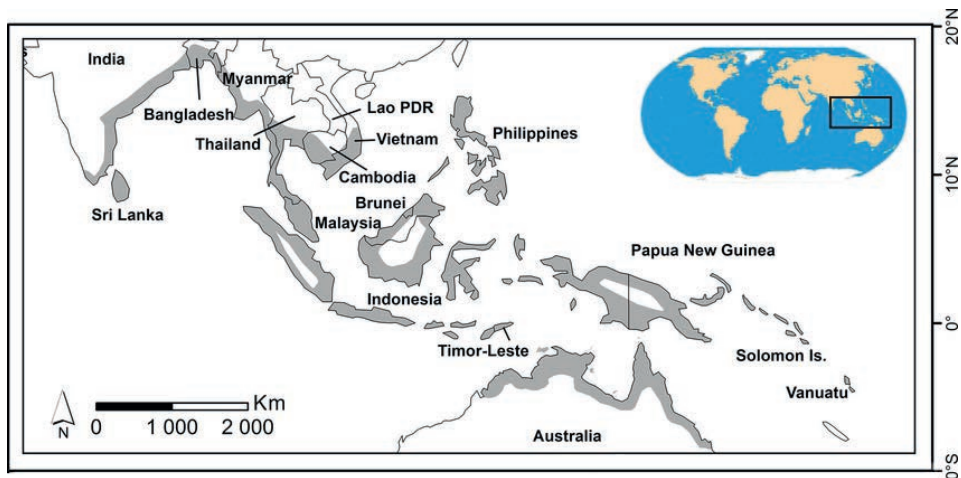


Fig. 1. The range of occurrence Saltwater crocodiles (*Crocodylus porosus* Schneider, 1801) in the world (Source: Fukuda et al., 2015 – changed)

This species belongs to the family Crocodylidae Cuvier, 1807 or true crocodiles, order Crocrodilia Owen, 1842, and class Reptilia Laurenti, 1768 (Kumar et al., 2012). Saltwater crocodile is an old taxon that evolved between 12 and 6 million years ago

(Oaks, 2011). Genetic studies have shown that the Saltwater crocodile is more closely related to other living Asian crocodile species, but there is some uncertainty as to which group could be considered the most primitive. Other species with wide jaws, such as the pond crocodile (*Crocodylus palustris* Lesson, 1831) and the Siamese crocodile (*C. siamensis* Schneider, 1801), seem to be the most closely related of all living species (Man et al., 2011). The Saltwater crocodile has a very large head and a large, massive body (Fig. 2A – Appendix 1). This species has two ridges of bony growths, running from the eyes through the centre of the snout, resembling rosary beads (Ross, Mayer, 1983). Adult individuals are usually dark in colour, a composition of dark green and grey, sparsely dotted with patches of lighter brown. Many different coloration types are known (Fig. 2A-D – Appendix 1), with some adults retaining completely light skin, while others appear to be black. The ventral side is white or yellow and remains so throughout the life of Saltwater crocodiles. The stripes are visible on the lower parts of both sides of their bodies, but do not extend to the belly. The tail is grey with dark stripes (Fig. 2B-C – Appendix 1) (Lanworn, 1972).

The established populations of Saltwater crocodile occur in Sri Lanka (partly), Indonesia – Borneo, Sumatra, and Papua New Guinea, the Solomon Islands and North Western Australia. Partly extirpated populations are in the south-eastern coasts of India (de Vos, 1984), Bangladesh, Myanmar, Thailand, Cambodia, Vietnam, the Philippines to Palau Islands (Singh, Kar, 2006; Fukuda et al., 2015; *Current distribution of Saltwater crocodile*, 2018). They are often found in mangrove forests, estuaries, river deltas, lagoons and lower reaches of rivers (Fukuda et al., 2011; Kumar et al., 2012; Sideleau et al., 2016). As predators, they occupy the top of the food chain in the ecosystems they inhabit (Mazzotti et al., 2009; Hanson et al., 2015; Somaweera et al., 2019; 2020). They are capable of preying on a wide range of animals, including fish, birds, and mammals, making them a formidable species in their ecosystem (Daltry et al., 2016; Sideleau et al., 2016; Patro, Padhi, 2019). Male Saltwater crocodiles can reach 6.3 m in length and weigh 1,360 kg. Typical sizes of adult males range from 4.3–5.2 m in length and 400–1000 kg in weight, but larger specimens also occur (Grigg, Kirshner, 2015; Kumar et al., 2012).

There are approximately 200,000–300,000 Saltwater crocodiles in the world (Kumar et al., 2012). They are known for their adaptability to both saltwater and freshwater environments and are excellent swimmers (Webb et al., 2010). Although Saltwater crocodiles are widespread, they are listed in CITES Appendix I as threatened due to overexploitation and habitat loss (except in Australia, Papua New Guinea and Indonesia). According to the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, this species is currently classified as: LC or LR/lc – Least Concern (Webb et al., 2021). The species has been considered endangered throughout most of their range due to poaching, illegal international trade and commercial hunt-

ing for their skin since the early 1940s. Currently, populations of this crocodile have recovered in Northern Australia and the Solomon Islands, following the introduction of conservation measures in the 1970s and 1990s (Webb et al., 2010; Fukuda et al., 2011; van der Ploeg et al., 2019). In other countries, such as India (de Vos, 1984; Fukuda et al., 2022) or Myanmar (Thorbjarnarson et al., 2000, 2006; Rao et al., 2013; Zinn, 2019; Than et al., 2020), observing unfavourable changes in the number of this crocodiles, attempts have also been made to strengthen the population of this species. Of course, there are many different economic and social aspects involved, but only by addressing these kinds of challenges can populations of this important for Asian deltaic and riverine ecosystems taxon be preserved.

The aim of this study is a short review of the threats, prospects for protection, and the most important problems and tasks arising from the implementation of this protection of Indian populations of Saltwater crocodiles (*Crocodylus porosus*).

Current status of Saltwater crocodiles in India

Saltwater crocodiles are listed as a “Schedule I” species in the *Wildlife Protection Act of India*, which provides them with legal protection. In India, the Saltwater crocodile is found in the eastern states of Odisha, West Bengal, Andhra Pradesh and Tamil Nadu, as well as the Nicobar and Andaman Islands (Kumar et al., 2012). Several sanctuaries and reserves in India, such as the Bhitarkanika National Park (20°45'N 87°0'E) in Odisha and the Sundarbans National Park (21°50'17'N 88°53'07'E) in West Bengal (Fig. 2 – Appendix 1), are known for their bigger Saltwater crocodile populations (Patro, Padhi, 2019). Additionally, there are 32 Zoological Parks in India breeding Indian Saltwater crocodiles (Kumar et al., 2012). Thanks to this, behavioural observations of this species and public education on this subject are possible, which is of great importance in its protection and in avoiding human-crocodile conflicts.

Back in 1975, the *Union Ministry of Forest and Environment* and the *United Nations Development Program* started a Saltwater crocodile breeding and rearing project in the Bhitarkanika National Park. From just 96 in 1974, the local crocodile population increased to 1,793 in 2023 (Fig. 3). Annual censuses of this species are carried out in the area of this Park. During this year's census, 569 hatchlings, 388 yearlings, 325 juveniles, 166 sub-adults and 345 adult reptiles were recorded. Last year, 564 hatchlings, 378 yearlings, 338 juveniles, 158 sub-adults and 346 adult reptiles were recorded (Senapati, 2023; Singh, Kar, 2023). These data also indicate a favourable trend in the age structure of this population.

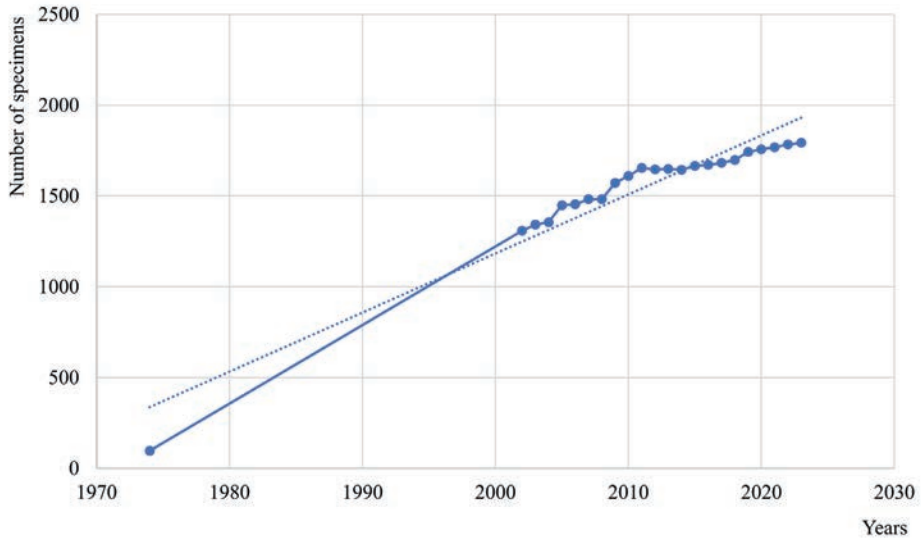


Fig. 3. Population growth of Saltwater crocodile (*Crocodylus porosus* Schneider, 1801) from 1974 to 2023 recorded in Bhitarkanika National Park, West Bengal, India; the dotted line indicates the trend (Source: Senapati, 2023; Singh, Kar, 2023)

Factors impacting population decline

The earlier decline in Saltwater crocodile populations in India, as in many parts of their range, was primarily due to several important factors. The key factors contributing to their decline included: habitat loss (their degradation and fragmentation too), poaching, human-crocodile conflicts, pollution, disease, climate change, egg collection and others (Khan et al., 2020).

Destruction of mangrove habitats, estuaries, and nesting sites due to urban development, agriculture, and industrial activities led to a loss of critical breeding and nesting areas for crocodiles (Oo, 2002; Richards, Friess, 2016). Pollution of water bodies and contamination of estuarine ecosystems from industrial and agricultural runoff harmed crocodile populations. This is often the reason for the weakening of the health of the population and the intensification of various diseases (e.g. conjunctivitis and/or pharyngitis, systemic lymphoid proliferation with nonsuppurative encephalitis (SLPE), lymphonodular skin lesions (LNS) – Shilton et al. 2006). Rising sea levels and changes in temperature and precipitation patterns due to climate change can affect the nesting and breeding habitats of Saltwater crocodiles (Rao et al., 2013). Illegal hunting and poaching for their valuable skin, meat, and other body parts posed a significant threat to crocodiles. Before 1971, Saltwater crocodile hunting was not controlled. This has brought the populations of this species to the brink of extinction. They were hunted not

only for valuable skin, but also for pleasure (Kumar et al., 2012). Saltwater crocodile leather products are expensive, with prices for the skins running into the thousands. It's not hard to find companies selling crocodile skin products made from farmed crocodile skins online. There are farms that raise crocodiles until they are old enough to be skinned to make leather goods. For an farmed crocodile, as much as 80% of the total value comes from the sale of its skin, 15% from the meat, and 5% from the sale of by-products such as the head/skull and feet (Isberg et al., 2005). Unfortunately, this is also a big incentive for poachers. The main countries importing Australian Saltwater crocodile skins are France, Japan, Singapore and Italy (Mac Namara et al., 2003).

People also kill crocodiles out of fear because they fear them due to their large size and reputation as man-eaters. In Australia, where there are special programs to research and educate people about the crocodile, 14 people have died in 27 years. In most cases, the victim swam in places where they should not (Kumar et al., 2012). As human populations encroached upon crocodile habitats, conflicts between people and crocodiles became more frequent, leading to retaliatory killings of these animals. Collection of crocodile eggs for illegal trade and consumption further reduced their population (Hlaing, 2019; Fukuda et al., 2022). Due to ongoing habitat destruction, coastal areas where *C. porosus* usually occurs are disappearing. This causes the species to disperse and migrate in search of new homes. In this situation, it may accidentally encounter people and mistake them for predators or prey. Therefore, education and awareness of people about this species are so important to ensure the safety of both humans and crocodiles (Kumar et al., 2012).

Conservation efforts, including stricter legal protection, captive breeding programs, and community-based conservation initiatives, have helped mitigate these threats and led to the recovery of Saltwater crocodile populations in India. It helped stabilise their populations to some extent. However, ongoing vigilance and conservation measures are essential to ensure their long-term survival (Sideleau, et al., 2016; Fukuda et al., 2022).

Conservation challenges

Conserving Indian Saltwater crocodiles presents several challenges despite the progress made in protecting their populations (Webb et al., 2010; Kumar et al., 2012; Nayak et al., 2018; Fukuda et al., 2022). Some of the ongoing conservation challenges include: biotope protection, alleviating human-crocodile conflicts (Khan et al., 2020), reducing of poaching and illegal trade, reducing pollution, reducing harmful impacts affecting climate change, limiting the entry of invasive species, disease prevention, expanding public awareness and education, constant research and monitoring (Lanworn, 1972, Nayak, Padhi, 2011; Sideleau, et al., 2016; Fukuda et al., 2022).

Biotope loss and degradation due to urban development, industrial activities, and

aquaculture continue to threaten crocodile habitats, especially mangrove ecosystems and estuaries. As human populations expand into crocodile habitats, conflicts can arise. Balancing the needs of local communities with crocodile conservation is an ongoing challenge. The illegal hunting of Saltwater crocodiles for their valuable skin, meat, and body parts still remains a big threat. Efforts to combat poaching and the illegal trade in crocodile products are essential. Additionally, pollution of water bodies and contamination of estuarine ecosystems from industrial, agricultural, and domestic sources can harm crocodiles and their prey species. Climate change can impact nesting sites, alter temperature-dependent sex determination in crocodile eggs, and affect the health of estuarine ecosystems (Hlaing, 2019; Fukuda et al., 2022). Environmental pollution and the effects of climate change cause habitat disturbance, which opens the way for the entry of alien species, often invasive ones. This applies to both the flora and fauna of these areas. Invasive species can disrupt crocodile habitats and prey populations, affecting the crocodiles' food sources. Uncontrolled disease outbreaks caused by weakening populations can have a significant impact on crocodile survival. Monitoring and managing disease risks are crucial, especially in the conditions of breeding these animals. Diseases have a significant impact on the number of crocodiles that can be farmed commercially. For example, there is evidence of widespread herpes infection in breeding populations of crocodile species, which may be associated with other infectious disease syndromes (Shilton et al., 2016). The same diseases may appear in weakened wild populations. For these reasons, raising awareness and educating local communities about the importance of crocodile conservation and safety measures in crocodile-prone areas is essential. Continuing research on crocodile populations, behaviour, and health is crucial for effective conservation strategies (Ross, Meyer, 1983; Nayak, Padhi, 2011; Sideleau, et al., 2016; Patro, Padhi, 2019).

Conservation agencies, wildlife organisations, and the government of India have been working to address these challenges through policies, regulations, and community-based conservation programs. Ensuring the long-term survival of Saltwater crocodiles in India requires sustained efforts to protect their habitats and reduce human-crocodile conflicts while fostering coexistence between people and these remarkable reptiles (Khan et al., 2020).

Conservation measures to protect the Indian Saltwater crocodile populations

Conservation measures to protect Indian Saltwater crocodile populations involve a combination of legal protection, habitat management, research, and community engagement (de Vos, 1984; Fukuda et al., 2011; Nayak, Padhi, 2011; Sideleau, et al., 2016; Patro, Padhi, 2019). Their schematic summary is shown in Fig. (4).

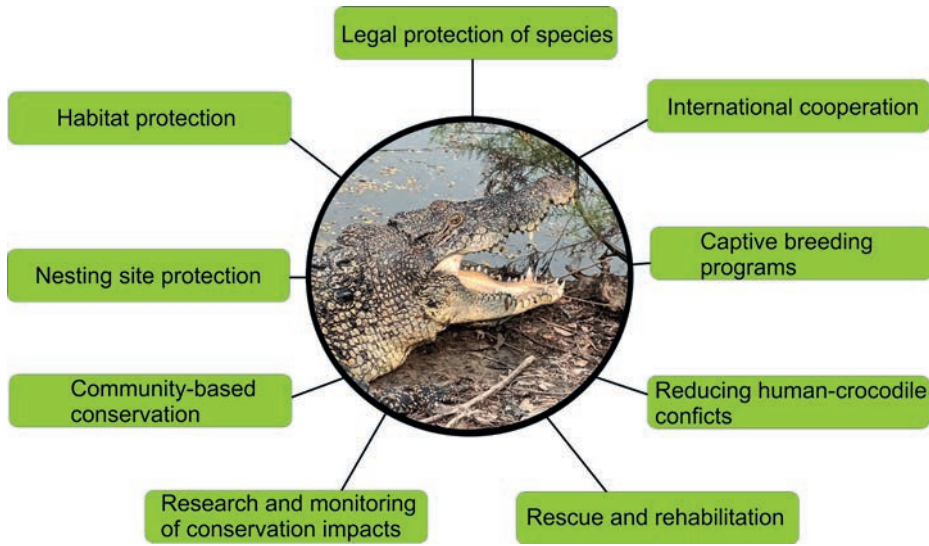


Fig. 4. Basic protective measures to protect the population of Saltwater crocodiles (*Crocodylus porosus* Schneider, 1801)

Indian Saltwater crocodiles are protected under the *Wildlife Protection Act of 1972*, which makes it illegal to hunt, capture, or harm them. They are listed under Schedule I of this Act, providing them with the highest level of protection. The conservation of mangrove habitats and estuaries (biotope protection) are crucial for crocodile survival. Establishing and maintaining protected areas and sanctuaries for crocodiles are essential. Identifying and safeguarding nesting sites is a priority. Eggs are at risk from human disturbance, and protection efforts include relocating nests to safer areas if necessary (Fukuda et al., 2022).

Engaging local communities in crocodile conservation is vital. This may involve education programs, raising awareness about the importance of these reptiles, and providing training in safety measures for people living in crocodile-prone areas. Ongoing research on crocodile populations, behaviour, and health helps inform conservation efforts (Nayak, Padhi, 2011; Sideleau, et al., 2016; Patro, Padhi, 2019; Singh, Kar, 2023).

Monitoring programs track population trends and identify emerging threats. In cases of injured or orphaned crocodiles, rescue and rehabilitation centres may be established to provide medical care and later release the animals back into the wild. Implementing strategies to reduce conflicts between people and crocodiles, such as erecting barriers or signage in high-risk areas and developing protocols for the safe relocation of crocodiles that pose a threat are required. In some cases, captive breeding programs are established to support the recovery of crocodile populations. Collaborating with international organizations and neighbouring countries on research and conservation

initiatives can help protect crocodile populations across their range (Kumar et al., 2012; Patro, Padhi, 2019; Fukuda et al., 2022; Singh, Kar, 2023).

These conservation measures are aimed at ensuring the long-term survival of Indian Saltwater crocodile populations and maintaining their ecological importance in the region. Success relies on a combination of legal enforcement, habitat preservation, community involvement, and ongoing research. Without serious long term conservation efforts, Saltwater crocodiles in India may be subjugated to a bleak future (Sideleau, et al., 2016; Patro, Padhi, 2019; Singh, Kar, 2023).

Success and failures related to Indian Saltwater crocodile conservation efforts

Successes and failures related to Indian Saltwater crocodile conservation efforts have evolved over time, reflecting the complexity of conservation challenges (Daltry et al., 2016; Patro, Padhi, 2019; Khan et al., 2020). In table (1) some notable examples of both are set.

Tab. 1. The main successes and failures related to Indian Saltwater crocodile (*Crocodylus porosus* Schneider, 1801)

Successes	Failures
Population recovery	Continued habitat loss and fragmentation
Legal protection	Poaching and illegal trade
Habitat conservation	Human-crocodile conflicts
Community engagement	Pollution of water
Research and monitoring	Climate change

The recovery of Saltwater crocodile populations in India has been one of the major successes. Through dedicated conservation efforts, populations in key areas like Bhitarkanika National Park in Odisha and the Sundarbans in West Bengal have increased. The inclusion of Saltwater crocodiles in Schedule I of the Wildlife Protection Act has provided them with strong legal protection, leading to reduced hunting and poaching. Efforts to protect and restore mangrove habitats and estuaries have helped provide secure breeding and nesting sites for crocodiles (Fukuda et al., 2022). Conservation programs that engage local communities in crocodile conservation and safety awareness have helped reduce human-crocodile conflicts and foster coexistence. Ongoing monitoring and research have provided valuable insights into crocodile behaviour, population dynamics, and health, allowing for more informed conservation strategies (Singh, Kar, 2006; Fukuda et al., 2022).

Despite conservation efforts, habitat loss due to urban development, industrial activities, and aquaculture remains a significant concern. Poaching and Illegal

Trade: The illegal hunting and trade of crocodile products continue to be a threat, and enforcement efforts sometimes fall short. While there have been improvements in reducing conflicts, incidents continue to occur, resulting in fatalities and retaliatory killings of crocodiles (Khan et al., 2020). Pollution of water bodies and contamination of estuarine ecosystems pose ongoing risks to crocodile populations and their prey. The long-term impacts of climate change on crocodile populations are still a concern, particularly in terms of altered nesting sites and changing sex ratios in hatchlings (Fukuda et al., 2022).

Balancing the successes and challenges in Indian Saltwater crocodile conservation remains an ongoing process. While significant progress has been made, addressing persistent threats and adapting to new challenges, such as those related to climate change, is essential for the continued survival of these iconic reptiles. Conservation efforts require ongoing commitment and adaptation to protect this species and its habitat (Singh, Kar, 2006; Webb et al., 2010).

Future of the Indian Saltwater crocodiles from multiple perspectives

The future of Indian Saltwater crocodile populations depends on continued conservation efforts, research, and adaptation to ongoing challenges. Several factors will influence their future. Sustained conservation initiatives are essential to protect and enhance crocodile populations (Singh, Kar, 2006; Webb et al., 2010; Daltry et al., 2016; Khan et al., 2020; Fukuda et al., 2022). These include habitat protection, legal enforcement, community engagement and others. Efforts to restore and protect mangrove habitats and estuaries are critical. Restoration projects can help ensure the availability of suitable breeding and nesting sites. Crocodile populations may face challenges due to climate change. Strategies to adapt to rising sea levels and changing temperature patterns are important for their survival. Ongoing research and monitoring will provide insights into population health, behaviour, and emerging threats. This knowledge is crucial for informed conservation strategies (Ross, Mayer, 1983; Grig, Kirshner, 2015; Fukuda et al., 2022; Senapati, 2023).

Effective programs to reduce human-crocodile conflicts and raise awareness about safety measures are necessary for peaceful coexistence. Collaborating with neighbouring countries and international organizations can contribute to the protection of crocodile populations across their range (Khan et al., 2020).

The future of Indian Saltwater crocodile populations is promising as long as these measures continue to be prioritised and adapted to evolving challenges. With dedicated conservation efforts and the active involvement of local communities, it is possible to ensure the survival of these iconic reptiles and their vital role in India's ecosystems (Daltry et al., 2016; Singh, Kar, 2006, Khan et al., 2020; Fukuda et al., 2022).

Conclusions

Conserving the Indian Saltwater crocodile is important for several reasons. Saltwater crocodiles are a keystone species in their ecosystems. They help maintain the ecological balance by regulating prey populations and supporting the overall health of their habitats. Their presence is an indicator of the health of the estuarine and mangrove ecosystems they inhabit. Healthy crocodile populations are often associated with thriving ecosystems. Crocodile populations contribute to genetic diversity, which is essential for species' long-term survival and adaptation to changing environmental conditions. These crocodiles are charismatic species that can drive ecotourism, benefiting local economies. They also serve as important educational tools for raising awareness about wildlife conservation. Studying Saltwater crocodiles can provide insights into their behaviour, physiology, and ecological roles, which can have broader applications in biology and ecology. In some regions, Saltwater crocodiles have cultural and traditional significance. Conserving them helps preserve cultural heritage. Healthy ecosystems, which rely on top predators like crocodiles, provide valuable services such as flood control, carbon storage, and fisheries support. In summary, conserving Indian Saltwater crocodiles is not only about protecting a single species but also about safeguarding entire ecosystems, preserving biodiversity, and maintaining the services these ecosystems provide to both nature and humans.

Conflict of interest

The authors declare no conflict of interest related to this article.

References

- Current distribution of Saltwater crocodile* (2018). Vajiram and Ravi IAS Study Centre. Available online: <https://vajiramias.com/current-affairs/saltwater-crocodiles/5c1df423209937354633b2c1/> [Accessed on 26-th November 2018]
- Daltry, J.C., Langelet, E., Solmu, G.C., van der Ploeg, J., van Weerd, M., Whitaker, R. (2016). Successes and failures of crocodile harvesting strategies in the Asia Pacific Region. In: *Tropical conservation: Perspectives on local and global priorities*, Publisher: Oxford University Press. p. 345–362.
- de Vos, A. (1984). Crocodile conservation in India. *Biological conservation*, 29(2), 183–189. [https://doi.org/10.1016/0006-3207\(84\)90076-4](https://doi.org/10.1016/0006-3207(84)90076-4)
- Fukuda, Y., Webb, G., Manolis, C., Delaney, R., Letnic, M., Lindner, G., Whitehead, P. (2011). Recovery of saltwater crocodiles following unregulated hunting in tidal rivers of the Northern Territory, Australia. *The Journal of Wildlife Management*, 75(6), 1253–1266. <https://doi.org/10.1002/jwmg.191>
- Fukuda, Y., Manolis, Ch., Saalfeld, W.K., Zuur, A. (2015). Dead or alive? Factors affecting the survival of victims during attacks by Saltwater crocodiles (*Crocodylus porosus*) in Australia. *PLoS ONE*, 10(5), e0126778. <https://doi.org/10.1371/journal.pone.0126778>
- Fukuda, Y., McDonald, P.J., Crase, B. (2022). Lost to the sea: predicted climate change threats to Saltwater crocodile nesting habitat. *Frontiers in Ecology and Evolution*, 10, 839423. <https://doi.org/10.3389/fevo.2022.839423>
- Grigg, G., Kirshner, D. (2015). *Biology and Evolution of Crocodylians*. CSIRO PUBLISHING.

- Hlaing, M.M. (2019). Crocodile conservation and breeding management – issues and constraints: Experience of Myanmar. *Fish for the People*, 17(2), 26–34.
- Hanson, J.O., Salisbury, S.W., Campbell, H.A., Dwyer, R.G., Jardine, T.D., Franklin, C.E. (2015). Feeding across the food web: the interaction between diet, movement and body size in estuarine crocodiles (*Crocodylus porosus*). *Austral Ecology*, 40(3), 275e286. <https://doi.org/10.1111/aec.12212>.
- Isberg, S. R., Thomson, P. C., Nicholas, F. W., Barker, S. G., Moran, C. (2005). Quantitative analysis of production traits in Saltwater crocodiles (*Crocodylus porosus*): I. reproduction traits. *Journal of Animal Breeding and Genetics*, 122(6), 361–369. <https://doi.org/10.1111/j.1439-0388.2005.00548.x>.
- Khan, W., Hore, U., Mukherjee, S., Mallapur, G. (2020). Human-crocodile conflict and attitude of local communities toward crocodile conservation in Bhitarkanika Wildlife Sanctuary, Odisha, India. *Marine Policy*, 121, 104–135. <https://doi.org/10.1016/j.marpol.2020.104135>
- Kumar, A., Kumar, S., Zaidi, Y.F., Kanaujia, A. (2012). A review on status and conservation of salt water crocodile (*Crocodylus porosus*) in India. In: *International Day for Biological Diversity: Marine biodiversity Report*. 22 may 2012. Uttar Pradesh State Biodiversity Board. p. 141–148.
- Lanworn, R. (1972). The book of reptiles. New York, NY: The Hamlyn Publishing Group Ltd.
- MacNamara, K., Nicholas, P., Murphy, D., Riedel, E., Goulding, B., Horsburgh, C., Whiting, T., Warfield, B. (2003). *Markets for skins and leather – from goat, emu, ostrich, crocodile and camel industries*. A report for the Rural Industries Research and Development Corporation – Publ. No 02/142, Canberra. <https://agrifutures.com.au/wp-content/plugins/pdf-analytics/tracking.php?file=wp-content/uploads/publications/02-142.pdf>
- Man, Z., Yishu, W., Peng, Y., Wu, X. (2011). Crocodylian phylogeny inferred from twelve mitochondrial protein-coding genes, with new complete mitochondrial genomic sequences for *Crocodylus acutus* and *Crocodylus novaeguineae*. *Molecular Phylogenetic and Evolution*, 60(1), 62–67, 2011. <https://doi.org/10.1016/j.ympev.2011.03.029>
- Mazzotti, F.J., Best, G.R., Brandt, L.A., Cherkiss, M.S., Jeffery, B.M., Rice, K.G. (2009). Alligators and crocodiles as indicators for restoration of Everglades ecosystems. *Ecological Indicators*, 9(6), S137eS149. <http://doi:10.1016/j.ecolind.2008.06.008>.
- Nayak, L., Padhi, M.P. (2011). Conservation and management of Saltwater crocodile (*Crocodylus porosus*) in relation to some physico-chemical parameters from Bhitarkanika Sanctuary, Orissa. *Nature, Environment and Pollution Technology*, 10(3), 389–394.
- Nayak, L., Das Sharma, S., Pati, M.P. (2018). Conservation and management of Saltwater Crocodile (*Crocodylus porosus*) in Bhitarkanika Wildlife Sanctuary, Odisha, India. *Environmental Management of Marine Ecosystems*, 10(3), 307–321.
- Oaks, J. R. (2001). A time-calibrated species tree of Crocodylia reveals a recent radiation of the true crocodiles. *Evolution*, 65(11), 3285–3297. <https://doi.org/10.1111/j.1558-5646.2011.01373.x>.
- Oo, N., 2002. Present state and problems of mangrove management in Myanmar. *Trees – Structure and Function*, 16(2e3), 218e223. <https://doi.org/10.1007/s00468-001-0150-6>
- Patro, S., Padhi, S.K. (2019). Saltwater crocodile and human conflict around Bhitarkanika National Park, India: a raising concern for determining conservation limits. *Ocean and Coastal Management*, 182, 104923. <https://doi.org/10.1016/j.ocecoaman.2019.104923>
- Rao, M., Htun, S., Platt, S.G., Tizard, R., Poole, C., Myint, T., Watson, J.E.M. (2013). Biodiversity conservation in a changing climate: a review of threats and implications for conservation planning in Myanmar. *Ambio*, 42, 789–804. <https://doi.org/10.1007/s13280-013-0423-5>
- Richards, D.R., Friess, D.A. (2016). Rates and drivers of mangrove deforestation in Southeast Asia, 2000–2012. *Proceedings of the National Academy of Sciences of the United States of America*, 113(2), 344–349. <https://doi.org/10.1073/pnas.1510272113>.

- Ross, F.D., Mayer, G.C. (1983). On the dorsal armor of the Crocodylia. In: A.G.J. Rhodin, K. Miyata, (eds.), *Advances in herpetology and evolutionary biology*. Cambridge: Museum of Comparative Zoology (Cambridge, Mass.), p. 306–331.
- Shilton, C.M., Jerrett, I.V., Davis, S., Walsh, S., Benedict, S., Isberg, S.R., Webb, G.J.W., Manolis, C., Hyndman, T.H., Phalen, D., Brown, G.P., Melville, L. (2016). Diagnostic investigation of new disease syndromes in farmed Australian Saltwater crocodiles (*Crocodylus porosus*) reveals associations with herpesviral infection. *Journal of Veterinary Diagnostic Investigation*, 28(3), 279–290. <https://doi.org/10.1177/1040638716642268>
- Somaweera, R., Brien, M.L., Platt, S.G., Manolis, C., Webber, B.L. (2019). Direct and indirect interactions with vegetation shape crocodylian ecology at multiple scales. *Freshwater Biology*, 64(2), 257–268. <https://doi.org/10.1111/fwb.13221>
- Somaweera, R., Nifong, J., Rosenblatt, A., Brien, M.L., Combrink, X., Elsey, R.M., Grigg, G., Magnusson, W.E., Mazzotti, F.J., Pearcy, A., Platt, S.G., Shirley M.N., Tellez, M., van der Ploeg, J., Webb, G., Whitaker, R., Webber, B.L. (2020). The ecological importance of crocodylians: towards evidence based justification for their conservation. *Biological Reviews*, 94, 936–959. <https://doi.org/10.1111/brv.12594>
- Senapati, A. (2023). Saltie census 2023: 1,793 estuarine crocodiles including 20 whitish ones counted in Bhitarkanika. *Wildlife and Biodiversity*, Available online: <https://www.downtoearth.org.in/news/wildlife-biodiversity/saltie-census-2023-1-793-estuarine-crocodiles-including-20-whitish-ones-counted-in-bhitarkanika-87134> [Accessed on 14-th January 2023]
- Sideleau, B.M., Edyvane, K.S., Britton, A.R.C. (2016). An analysis of recent Saltwater crocodile (*Crocodylus porosus*) attacks in Timor-Leste and consequences for management and conservation. *Marine and Freshwater Research*, 68(5), 801–809. <https://doi.org/10.1071/MF15354>
- Singh, K., Sudhakar Kar, S. (2023). *Crocodyle – The King of Water (Panira Raja Kumbhira) (in Odia with English sections)*. Edición Kindle, pp. 276.
- Singh, L., Kar, S.K. (2006). Status of the Saltwater crocodile in Orissa: an overview. *Journal of Bombay Natural History Society*, 103(2/3), 274.
- Than, K.Z., Strine, C.T., Sritongchuay, T., Zaw, Z., Alice C. Hughes, A.C. (2020). Estimating population status and site occupancy of Saltwater crocodiles *Crocodylus porosus* in the Ayeyarwady delta, Myanmar: Inferences from spatial modeling techniques. *Global Ecology and Conservation*, 24, e01206. <https://doi.org/10.1016/j.gecco.2020.e01206>
- Thorbjarnarson, J., Platt, S.G., Khaing, S.T. (2000). A population survey of the estuarine crocodile in the Ayeyarwady Delta, Myanmar. *Oryx*, 34(4), 317–324. <https://doi.org/10.1046/j.1365-3008.2000.00135.x>
- Thorbjarnarson, J., Platt, S.G., Ko, W.K., Myo, K.M., Khaing, L.L., Platt, K., Holmstrom, B. (2006). Crocodiles in Myanmar: species diversity, historic accounts, and current population status and conservation. *Herpetological Natural History*, 10, 77–89.
- Webb, G.J.W., Manolis, C.S., Brien, M.L. (2010). *Saltwater crocodile (Crocodylus porosus)*. *Crocodyles. Status survey and conservation action plan*. 3Ed. SC Manolis and C. Stevenson. Crocodile Specialist Group: Darwin, p. 99–113.
- Webb, G.J.W., Manolis, C., Brien, M.L., Balaguera-Reina, S.A., Isberg, S. (2021). *Crocodylus porosus*. *The IUCN Red List of Threatened Species 2021*: e.T5668A3047556. <https://dx.doi.org/10.2305/IUCN.UK.2021-2.RLTS.T5668A3047556.en>. [Accessed on 29-th November 2023].
- van der Ploeg, J., Ratu, F., Viravira, J., Brien, M., Wood, C., Zama, M., Gomese, C., Hurutarau, J. (2019). *Human-crocodile Conflict in Solomon Islands*. Honiara. MECDM & WorldFish, Solomon Islands. Program Report: 2019–02. <https://digitalarchive.worldfishcenter.org/bitstream/handle/20.500.12348/2670/2019-02.pdf?sequence=1&isAllowed=y>
- Zinn, S.T. (2019). *Croc-bite to fisherman in Bogalae*. Retrieved from. <https://burma.irrawaddy.com/news/2019/02/22/184262.html> [Accessed on 22-nd February 2019]



Fig. 2. Saltwater crocodiles (*Crocodylus porosus* Schneider, 1801) at the Jharkhali Biosphere Reserve, Sunderban mangrove forest, West Bengal, India; morphology: A – massive head with part of the trunk, B – shape of the whole body (side view), C – massive tail with two rows of characteristic appendages, D – front view of the body (Photo. S. Kumar Basu)

Indyjskie krokodyle różańcowe (*Crocodylus porosus* Schneider, 1801) i ich perspektywy ochrony

Streszczenie

Populacja krokodyla różańcowego (*Crocodylus porosus* Schneider, 1801) w Indiach utrzymuje się obecnie na stosunkowo stabilnym poziomie. Gatunek ten jest wymieniony w indyjskiej ustawie o ochronie dzikiej przyrody, co zapewnia mu ochronę prawną. Jednakże kilka czynników naturalnych i antropogenicznych łącznie stwarza poważne wyzwania dla skutecznej ochrony różnych populacji i subpopulacji krokodyli różańcowych w całym Indiach, w ich naturalnych siedliskach. Dlatego ważne jest, aby zrozumieć czynniki wpływające na obniżanie liczebności tych populacji oraz określić strategie i polityki niezbędne do skutecznej, długoterminowej ochrony tego majestatycznego gatunku gada w jego naturalnych siedliskach. Obecny przegląd stanowi wielopunktową introspekcję udanych i nieudanych działań ochronnych indyjskich populacji krokodyla różańcowego.

Słowa kluczowe: zmiany klimatyczne, ochrona, ekosystem, siedlisko, Indie, populacja, krokodyl różańcowy

Received: [2023.10.20]

Accepted: [2023.11.29]