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Habitat Ecology and Intraspecific Variations in Estuarine Crocodile *Crocodylus porosus* Schneider, 1801 (Reptilia: Archosauria: Eusuchia: Crocodylia: Crocodylidae) in Two Contrasting Estuarine Ecosystems of Eastern India

Debanik Mukherjee[1], M. Vijay[2]

[1]Centre for Environmental Management of Degraded Ecosystems, University of Delhi, Delhi – 110 007, India
Email: *tomistoma[at]gmail.com*

[2]Regional Museum of Natural History, Gangtok, Sikkim, India – 737 135
Email: *m.vijay[at]nic.in*

Abstract: ***The estuarine crocodile (Crocodylus porosus), the largest extant reptile, occupies a wide range of coastal and estuarine habitats across the Indo-Pacific. We compared habitat ecology and population structure of C. porosus between two contrasting estuarine systems of eastern India: Bhitarkanika National Park (BNP, Odisha) and the Sundarbans Biosphere Reserve (SBR, West Bengal). Field surveys conducted during March–April 2026 recorded 52 individuals across both sites, revealing marked intraspecific variation in size distribution, habitat utilization, and ecological pressures. Bhitarkanika, a relatively geomorphologically stable and semi-isolated estuarine system, exhibited higher population density, restricted trophic resources, and increased intraspecific competition. In contrast, the Sundarbans, a dynamic mega delta with strong marine connectivity and exchange, supported broader trophic niches, spatial dispersal, and reduced territorial conflict. We interpret these differences within the framework of trophic ecology, spatial ecology, and evolutionary adaptation, highlighting the role of habitat connectivity in shaping crocodilian population dynamics and conservation outcomes.***

Keywords: estuarine crocodile, habitat ecology, population structure, trophic adaptation, crocodile conservation

1. Introduction

Modern crocodilians (Suborder- Eusuchia; Infraorder-Crocodylia) comprise 27 extant, taxonomically valid species distributed primarily across tropical and subtropical regions excepting *Alligator mississippiensis*, *A. sinensis*, *Caiman yacare* and *Crocodylus acutus* as they are found in temperate zones also. Phylogenetically, they represent the only surviving lineage of non-avian archosaurs alongside Aves (birds), with evolutionary origins tracing back to the Triassic (~245–235 Ma) within Archosauria. The modern Crown-group crocodilians (Eusuchia) evolved during the Late Cretaceous (~100 Ma) and diversified throughout the Cenozoic.

Although often termed wrongly as "l**iving fossils**," crocodilians may be better considered as **evolutionary relicts**, a much-corrected biological term; long after the extinction of their several closely related and coexistent lineages the modern Crocodilians survived till today as the last living branch. Although retaining a conservative morphology they exhibit significant ecological plasticity with a slow rate of speciation. Modern living Crocodilians are largely semi-aquatic ambush predator a secondary adaptation rather than their ancestral traits.

Among them, *Crocodylus porosus* stands out as a highly adaptable, euryhaline apex predator capable of exploiting marine, estuarine, to partial brackish riverine ecosystems.

In India, three crocodilian species are there: semi-altirostral *C. porosus*, *C. palustris*, and longirostral monotypic *Gavialis gangeticus*. Of these, *C. porosus* exhibits the broadest ecological amplitude. However, population structure and ecological dynamics vary significantly across habitats, particularly between semi-isolated estuaries and large deltaic systems.

This study aims to:

1) Compare habitat structure and geomorphology between Bhitarkanika and the Sundarbans
2) Assess intraspecific variation in size and habitat use in *C. porosus*
3) Interpret ecological differences in the context of trophic resources, spatial connectivity, and competition

2. Materials and Methods

Study Areas

- Bhitarkanika National Park (BNP): 20.73°N, 86.87°E
- Sundarbans Biosphere Reserve (SBR): 21.68°N, 88.30°E

Survey Protocol

Field surveys were conducted between March–April 2026 from 11:00 to 16:00 hrs. Visual encounter surveys were used to record individuals, estimating total length (TL) and categorizing individuals into:

- Adult males
- Adult females
- Sub-adults
- Juveniles

Sex determination was based on size dimorphism (SSD), with males exceeding females significantly in total length.

3. Results

A total of 52 individuals were recorded:
- 21 adult males (9 individuals in Sundarbans exceeding 5–5.7 m TL)
- 17 adult females
- 9 sub-adults (mostly submerged)
- 5 juveniles (active on mudbanks)

Key Observations:
- Larger individuals were more frequent in the Sundarbans
- Juveniles preferred exposed mudbanks
- Females were frequently associated with shaded mangrove microhabitats

Habitat Comparison
Bhitarkanika National Park (BNP)

Bhitarkanika represents a geomorphologically stable estuarine system, characterized by:
- Anastomosing tidal creeks
- Oxbow-like channels
- Reduced marine exchange
- Increasing terrestrialization

Anthropogenic pressures (encroachment, altered riverbanks) have contributed to:
- Habitat fragmentation
- Reduced mangrove cover
- Altered tidal flow

Sundarbans Biosphere Reserve (SBR)

The Sundarbans is the world's largest deltaic mangrove system, defined by:
- High sediment influx from Himalayan rivers
- Strong tidal exchange with the Bay of Bengal
- Dynamic geomorphology
- Extensive habitat heterogeneity

4. Discussion

Trophic Ecology and Resource Limitation
Bhitarkanika populations appear constrained by:
- Limited trophic diversity
- Reduced prey base
- High population density

This leads to increased intraspecific competition, consistent with density-dependent ecological regulation.

In contrast, the Sundarbans provides:
- Diverse prey assemblages
- Greater spatial dispersal
- Access to marine resources

Supporting broader trophic niches and reduced competition.

Spatial Ecology and Connectivity
Hydrological connectivity emerges as a key driver:
- **Bhitarkanika**: Semi-isolated → restricted dispersal → territorial conflicts
- **Sundarbans**: Open system → dispersal into marine zones → ecological release

This aligns with metapopulation dynamics and gene flow theory.

Behavioural Ecology and Conflict
In Bhitarkanika:
- Increased territoriality
- Habitat compression
- Movement into human-dominated landscapes

Resulting in elevated human–crocodile conflict.

In the Sundarbans:
- Spatial buffering reduces encounters with humans
- Resource competition is partitioned across spatial and trophic levels

Evolutionary Interpretation
The large body size observed in Sundarbans individuals may reflect:
- Access to high-energy marine prey
- Reduced ecological constraints
- Selection pressures consistent with evolutionary arms race dynamics (Red Queen framework)

This parallels Indo-Australian populations of *C. porosus*, where vast marine ecosystems and availability of large prey base such as large Ichthyofauna or other marine species supports attaining a larger body size.

5. Conclusion

This study demonstrates that habitat connectivity and geomorphological dynamics fundamentally shape the ecology of *Crocodylus porosus*. Semi-isolated systems like Bhitarkanika promote competition and conflict, whereas open deltaic systems like the Sundarbans facilitate ecological expansion and exploration, dispersal, and population stability.

These findings highlight the importance of: Maintaining estuarine connectivity, reducing anthropogenic habitat fragmentation and integrating ecological dynamics into crocodile conservation strategies.

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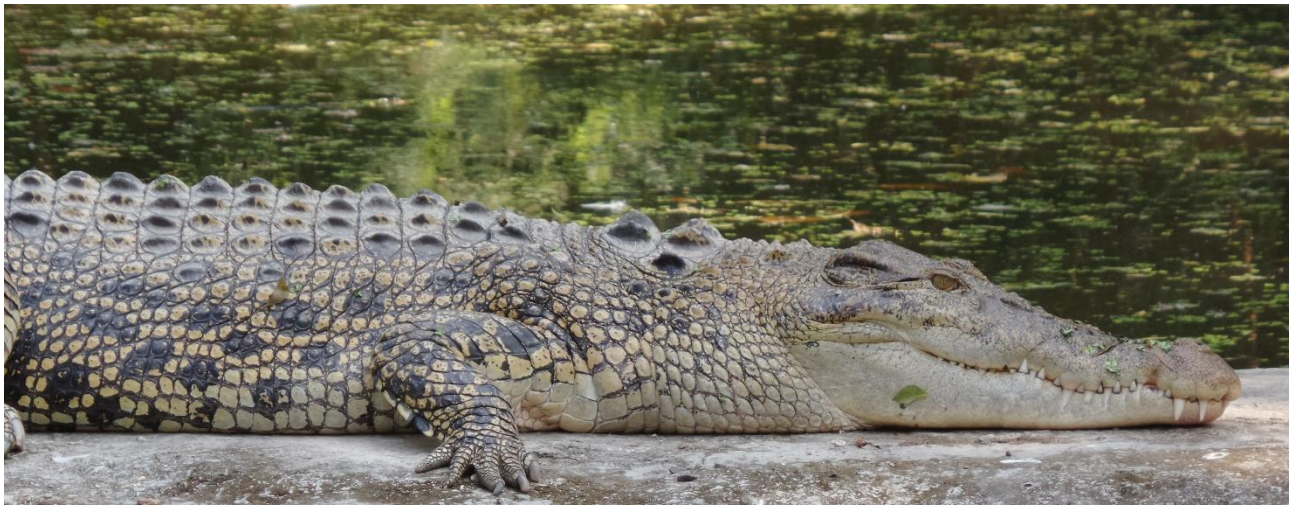
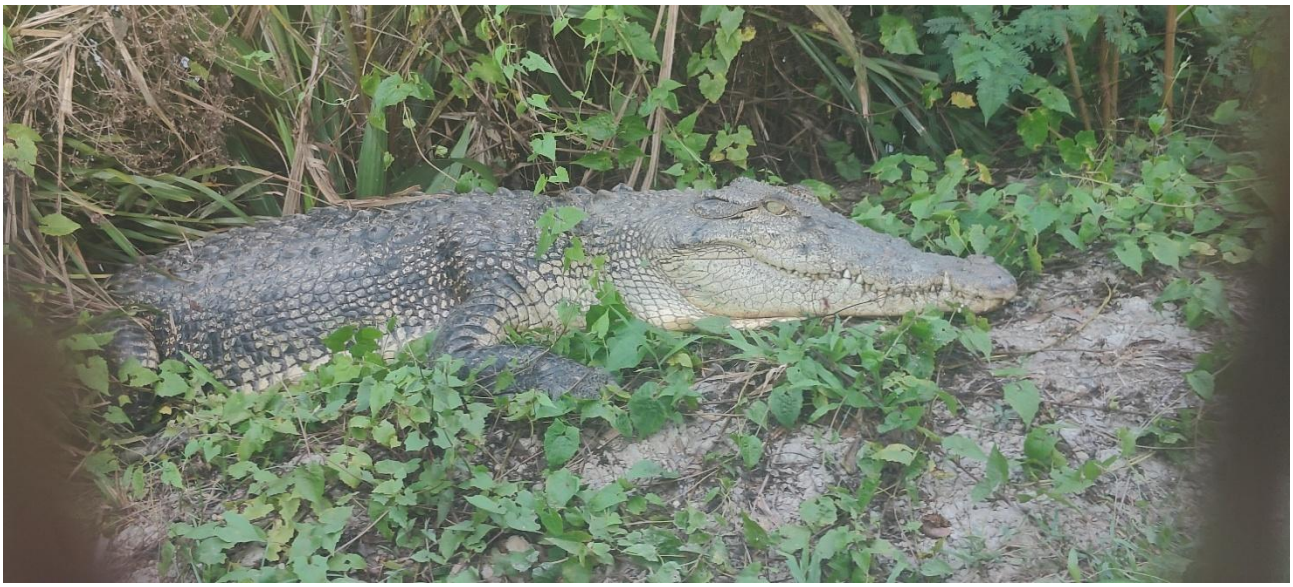
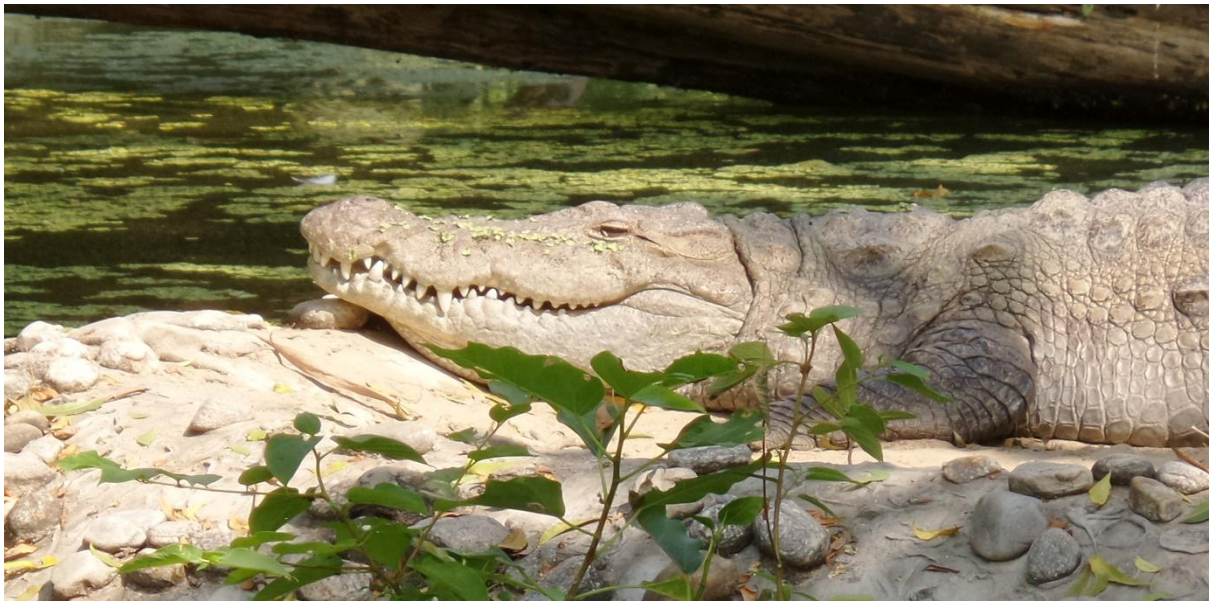
Sundarbans Biosphere Reserve (SBR) – riverine connectivity with the sea (the Bay of Bengal).

Mangrove dominant isolated islands in Bhitarkanika National Park (BNP).





(top) male and female *C. porosus* may be morphologically distinguished from marsh or freshwater muggers *C. palustris* – by the presence of prominent inter-orbital ridges; absence or weakly developed post occipital scutes and presence of usually four large compact nuchal scutes.



C. palustris marsh or muggers – a fresh water riverine species often sympatric with long snouted Gharials *Gavialis gangeticus*