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Journal of Threatened Taxa

Building evidence for conservation globally

www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

REVIEW

APPRAISING CARNIVORE (MAMMALIA: CARNIVORA) STUDIES IN BANGLADESH FROM 1971 TO 2019 BIBLIOGRAPHIC RETRIEVES: TRENDS, BIASES, AND OPPORTUNITIES

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26 November 2020 | Vol. 12 | No. 15 | Pages: 17105–17120

DOI: [10.11609/jott.6486.12.15.17105-17120](https://doi.org/10.11609/jott.6486.12.15.17105-17120)



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Appraising carnivore (Mammalia: Carnivora) studies in Bangladesh from 1971 to 2019 bibliographic retrieves: trends, biases, and opportunities

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Abstract: In contrast to <7% natural forest covers and >1,000 people living km², Bangladesh, one of the smallest countries in Asia, shelters 28 carnivorous mammals. The species are of six families, nearly half of the entire carnivore diversity of the Indian Subcontinent. Carnivores of Bangladesh are little understood and they are disappearing fast despite receiving stern protection. Yet, there has been no assessment on the status of existing knowledge. A review was aimed to assess the existing knowledge and evaluate the research trends in country's mammalian carnivores. Peer-reviewed works published from 1971 to 2019 were skimmed and categorized systematically according to five traits: publication type, research topic, time of publication, region, and species of study. In a total of 95 works examined, substantial numbers were on tiger (n=45) and the Sundarbans (n=47). In imbalance to action plans procured for tiger conservation, 14 carnivores have never been exclusively studied in Bangladesh. Of the research topics, preference was evident for wildlife management and conflict analyses as there were 31 scientific papers out of 63 in these categories. Inventory compilation for books (18 of 24) comprised the next preferred subject. The assessment could identify gaps in related knowledge in different regions of the country. Eastern region has experienced a meagre amount of work, although its mixed evergreen forests have larger combined area than the Sundarbans, and is known for its higher richness of diversity. Exclusive works outside legally defined protected areas were also low. We found no works in northwestern and southern Bangladesh. In the last two decades, the temporal trajectory of research effort has been more, and the topics have started to diversify. In order to improve conservation practices, we stress that gaps in knowledge pertaining to region or subject may be bridged with contemporary study techniques. This is crucial to highlight the status of carnivore species that are otherwise 'elusive', 'apparently absent', or 'least-known'.

Keywords: Bibliography, conservation priorities, meta-analysis, review.

Editor: L.A.K. Singh, Bhubaneswar, Odisha, India.

Date of publication: 26 November 2020 (online & print)

Citation: Akash.M & T. Zakir (2020). Appraising carnivore (Mammalia: Carnivora) studies in Bangladesh from 1971 to 2019 bibliographic retrieves: trends, biases, and opportunities. *Journal of Threatened Taxa* 12(15): 17105–17120. <https://doi.org/10.11609/jott.6486.12.15.17105-17120>

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Funding: Self-funded.

Competing interests: The authors declare no competing interests.

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Author contribution: MA conceived the research idea. MA and TZ designed the methodology. TZ collected necessary data and prepared the first draft. MA finalized the manuscript. Both authors reviewed and approved the manuscript.

Acknowledgements: The authors are thankful to the anonymous reviewers as their comments have inspired and assisted greatly.



INTRODUCTION

Carnivora that constitute the fifth largest mammalian order faces taxon-wide existential crisis (Inskip & Zimmermann 2009; Ripple et al. 2014). According to IUCN (2019), 88 species are threatened with a trend of decreasing population. Conserving carnivores is now a major concern worldwide (Treves & Karanth 2003).

The concern is in recognition of the fact that for a stable and diverse community of wild animals, carnivorous mammals exert intangible influences. They can act as apex predators and their absence often leads to trophic cascades (Prug et al. 2009; Ripple et al. 2014; Suraci et al. 2017). As the ecosystem services of a carnivore can be of an umbrella or keystone to conserve an ecosystem in its entirety (Sergio et al. 2008; Baker & Leberg 2018), human intervention in wildlife management practices cannot supersede or bypass a carnivore's natural impact in the wild (Gittleman & Gompper 2005; Ripple et al. 2014).

Bangladesh is the world's 92nd largest country covering an area of 147,610km² and the 8th most populous with about 165.6 million people. Also, the country is rich in biodiversity and harbors 138 extant mammals; 28 of which are carnivores (IUCN Bangladesh 2015; Khan 2015, 2018).

Geographically, Bangladesh is traversed by the Tropic of Cancer, and there exists a transition zone between the Indo-Himalayan and the Indo-Chinese sub-regions of the Oriental realm, which are considered advantageous to form wildlife habitats (Corlett 2007; Feeroz 2013; Khan 2018). Historical anecdotes indicate about the rich presence of carnivores all over Bangladesh once. Many carnivore species have now become restricted to certain areas or are known only from sporadic encounters (Khan 2015).

The carnivores of Bangladesh are in six terrestrial families: Viverridae, Felidae, Herpestidae, Canidae, Ursidae, and Mustelidae. The Bengal Tiger *Panthera tigris* is the country's national animal. Three other large carnivores, the Indian Wolf *Canis lupus*, Striped Hyena *Hyaena hyaena*, and Sloth Bear *Melursus ursinus* are deemed to be extinct in Bangladesh (Khan 2018). If compared to more diverse carnivore assemblages of neighboring India (57 species), Nepal (47), and Bhutan (39) and their respective habitat diversity, the inventory of Bangladesh is still considerable given its <7% natural forest cover and >1000 people living km⁻² (Wangchuk 2004; NFA 2007; Menon 2014; Amin et al. 2018).

Carnivores are still present in all the three major forest types of Bangladesh (IUCN Bangladesh 2015)

(Fig. 1). The Sundarbans mangroves support the only stable Tiger population in the country. Wet deciduous forests which once swathed from central to north and northwest, is now extremely fragmented, but continue to be known for civets, mongooses, *Felis* and *Prionailurus* cats. Concentrations of mixed evergreen forests are in eastern regions typified by hills, streams, rugged terrain, and, in cases, tea-gardens on the periphery. Eastern forests are long credited for every native carnivore. Apart from the forests, homestead jungle and wetland vegetation support small mammals. Although protected under several formal definitions, here, threats to wildlife and wildlife habitats are surmounting because of encroachment, alteration, destruction, high-dependency on forest products, agro-industries, trafficking, persecution, and retaliatory killings, to name but a few (Khan 2015, 2018).

We find no comprehensive assessment of the status of existing knowledge on mammalian predators of Bangladesh. But on global or regional scales, extensive reviews tend to highlight species in critical research needs, and steer conservation interventions to new perspectives as exemplified by Dalerum et al. (2008), Inskip & Zimmermann (2009), Periago et al. (2014), Broto & Mortelliti (2018).

For instance, Broto & Mortelliti (2018) highlighted the pattern of researches on mammals of Sulawesi Island in Indonesia with high insular endemism. Similarly, Periago et al. (2014) assessed the pattern and consequence of losing mammalian herbivores and frugivores in savanna woodland of Central South America. On a larger scale, Inskip and Zimmerman (2009) evaluated the nature and level of conflict between human and each of the wild feline species. Whereas, Dalerum et al. (2008) reviewed the status and decline of carnivore guilds in continental perspective. All these reviews were systemic in assessing literary works. These have stressed on knowledge gap and research bias only to envisage better and bolder scheming of conservation pursuits.

In order to make an appraisal of the works on mammalian carnivores of Bangladesh, here we have proceeded with three objectives: (1) to construct a systematic compilation of peer-reviewed researches, (2) to identify taxonomic and knowledge bias in these studies, and (3) to assess their geographic trend within the country and the temporal trajectories.

MATERIALS AND METHODS

Extent of the review

Within a period of four months between April 2019 and July 2019, we carried out the literature search. In order to meet our objectives, we picked five traits for any work: publication type, research topic, region in Bangladesh, time (year of publication), and the studied species. We have investigated the pattern in publication types and research themes. We recognized the most-studied and the least-studied carnivores. We compared the relevance of research to threatened status of the species. We have examined the geographic distribution of works, their aforementioned traits, and consideration for protected areas. Similarly, we have examined plots over year bands to understand a temporal trend. On any pertinent bias and gap, we conjectured on the possible factors in discussion.

Consideration of literature

We restricted our search to the following types of publications: peer-reviewed scientific papers, peer-reviewed book/book chapters, conservation action plans, and doctoral theses completed from 1971 to 2019. We observed project reports within this period but excluded them from analyses. We did not consider conference abstracts, MS theses and non-scholarly articles.

We have considered only mammalian carnivores reportedly living within the geopolitical boundary of Bangladesh. To enlist the extant carnivores for consideration, we consulted Khan (2018, 2015), and Ahmed et al. (2009). To obtain insight to assessment of threat at the regional and global levels, respectively, we used IUCN Bangladesh (2015) and IUCN (2019).

Sourcing literature

Works were collected using three primary research databases, i.e., Google Scholar, BioMedCentral, and Web of Science. To intensify in-depth search, we followed preset keywords in English. Our search protocol was based on Pullin & Stewart (2006), and we included 'species name' (scientific or common) and 'Bangladesh' in every attempt. In addition to the pair of obligatory words we used the following keywords in combination: 'attitude', 'behavior', 'camera-trap', 'coexistence', 'conflict', 'depredation', 'distribution', 'diversity', 'ecology', 'mortality', 'new record', 'prey', and 'zoonotic disease'. We followed the search pattern for every extant carnivore species of the country. We also looked for key wildlife biologists of Bangladesh during

Table 1. Terminologies applied for categorization of published studies on carnivore mammals of Bangladesh.

Research Topic	Scope of study
1. Inventory	Checklist of mammals of any study area.
2. Discovery and distribution update	Discovery, distribution update, new records, sighting documentations.
3. Ecology	Ecological study, breeding behavior, feeding behavior, territorial behavior, activity pattern, home range, habitat preference.
4. Wildlife management and conflict analysis	Ethno-zoological aspects, human-carnivore interactions, threat analysis, environmental impact, climatic impact, wildlife poaching and trade, anthropogenic effects and perceptions, conservation genetics, research in recovery strategies, conservation action plan.
5. Population dynamics	Population status, population size, population density.
6. Zoonotic and anthroponotic disease	Case studies on these diseases.
7. Consideration of protected area (PA)	
7.1. Inside PA	Researches that considered any protected area declared under international or regional definition, i.e., national park, wildlife sanctuary, reserve forest, ecologically critical area, eco-park, RAMSAR site as study site.
7.2. Outside PA	Researches that did not consider any of the above as study site.
7.3. Both	Researches that encompassed study area covering both protected and non-protected habitats.
8. Regions: As per Khan (2018)	
	8.1. Central, 8.2. North, 8.3. South, 8.4. Northeast, 8.5. Northwest, 8.6. Southeast and 8.7. Southwest

searches to obtain maximum results.

In addition to the three primary searches online, relevant books and journals were accessed from Professor Yousufzai Seminar Library repository of the Department of Zoology, University of Dhaka. This was carried out to acquire older works that could have missed digital indexing.

Categorization under pre-defined themes

We observed the respective aims and outcomes of the obtained works. Then, we categorized them under six pre-determined research themes. We construed the categorization after consulting verde Arregoitia (2016), Broto & Mortelliti (2018), and Inskip & Zimmermann (2009). The definition and scope for each category are given in Table 1.

Studies were examined to ascertain whether each of these dealt with a single species or multiple species or any particular group (taxa higher than genus). If multiple

species names were specified in a single work, we added the work to tally count of each pertinent species, however, if any study approached a group (for example, a taxonomic family), we kept it to the mentioned group. For example, Islam et al. (2013) assessed bears of Bangladesh, we counted the work for the 'ursids' rather than each of the three bears of the country. We also considered the works that covered all wildlife or all mammals or all carnivores of Bangladesh and kept the count to 'wildlife', 'mammals', and 'carnivores', consecutively (Table 1; Appendices 1–2).

Spatial and temporal classification

We followed Khan (2018) where seven geographical regions have been defined to characterize wildlife distribution in Bangladesh and recreated the map for the review (Table 1). We put a particular work to a specific region, considering whether the respective work's study area fell within the geographic region. If multiple regions were specified in a single work, we added the work to tally count of each respective region, however, if any work considers the country, we accredited the count to 'Bangladesh'.

The works were also classified on their consideration of protected area (PA) and assorted into three groups: outside PA, inside PA or both (Table 1).

To assess the research trajectory in time, we considered two trends: year-wise pattern and a cumulative rate. We assigned a study to the year it was published. For tracking changes in publication types and research topics, works were classified into six time periods, each of a decade: 1971–1980, 1981–1990, 1991–2000, 2001–2010, 2011–2019. Time trajectory was initiated from 1971; this was when Bangladesh had gained independence.

Analyses

We summed the total number of works for each pertinent species, and, thus, identified the most-studied and the least-studied species. We summed the number of studies tallied for a research topic to check the bias among topics. In manner alike, to point out the geographic/temporal pattern, we considered the total number of works assigned to a region or a year.

RESULTS

A brief on the reviewed literature

We found 95 peer-reviewed works on carnivores of Bangladesh completed within the considered timeframe, i.e., 1971–2019. Of these, 63 (66.3%) were peer-reviewed scientific papers, six (6.3%) doctoral theses, 24 (25.3%) books. There were two action plans (2.1%) on Tiger. In addition, we came across seven project reports (Appendix 1) that were excluded from our analysis. All these 102 works we extracted through literature search are provided in Appendix 2.

Out of total 95 references used for analysis in the study, 'wildlife management and conflict analysis' (n=42, 44.2%) appeared to be the most prolific research topic among all types. Topics dedicated to other studies are: Ecology (n=15, 15.8%); discovery and distribution update (n=9, 9.5%), inventory (n=24, 25.3%), population dynamics (n=3, 3.1%), and investigation of zoonotic and anthroponotic diseases (n=2, 2.1%) (Fig. 1).

When we compared the research topics to publication types, Figure 1 also showed a preference for books in terms of inventory build-ups (n=18). Although a few books covered the topic of wildlife management and conflict analysis, we found no book on other topics. We came across only nine papers on discovery and distribution update whereas 14 papers were there on ecology.

Species-wise trend in studies

Of the 28 extant carnivores of Bangladesh, seven are Critically Endangered (CR), three Endangered (EN), six Vulnerable (VU), five Near Threatened (NT), four Least Concern (LC), and two are Data Deficient (DD) (IUCN Bangladesh 2015). Large-toothed Ferret Badger *Melogale personata* was recorded for the first time from northeastern Bangladesh in 2008 (Islam et al. 2008), although it is not assessed or included in the IUCN Bangladesh (2015).

After segregating the number of publications which targeted at threatened carnivores on both national and global assessments, we found that 14 species were without any dedicated work at all. Table 2 shows the comparison and the species without any research. On the other hand, 66 studies were found exclusively dedicated to 14 carnivore species. The studies covered six felids, four mustelids, two herpestids and one for each of a canid and a viverrid species. There are 29 studies which considered higher or multiple taxa: two for the felids, two for the ursids, one for all carnivore mammals of Bangladesh, six for all mammals, and 18

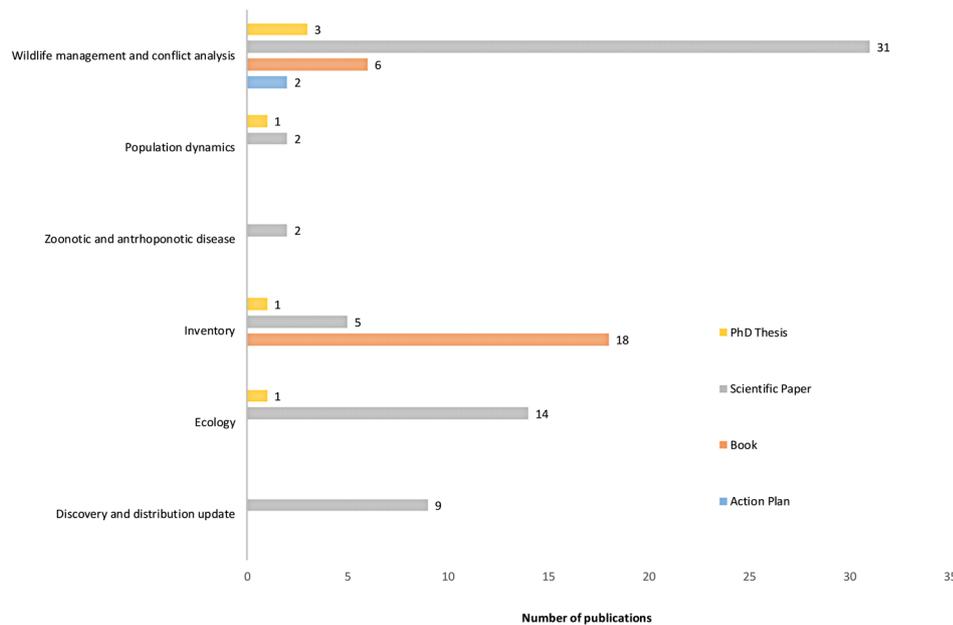


Figure 1. Characteristics of carnivore mammal studies in Bangladesh as the number of different publication types projected against different research topics. Appendices 1 and 2 detail out the works and the classification scheme used in these projections.

were inclusive of wildlife of Bangladesh (Appendix 1, Fig. 2, Table 2).

The most- and the least-studied species

The highest number of publications ($n=45$) was on Tiger. It experienced all types of publications. Considering the topic, wildlife management and conflict analysis were the most common subjects for studies on Tiger (Fig. 2). In Bangladesh, Tiger is the only carnivore with a conservation action plan that has been formulated twice (Ahmad et al. 2009; Aziz et al. 2018).

There were seven works on the Asian Golden Jackal *Canis aureus*, three on Fishing Cat *Prionailurus viverrinus*, two on Smooth-coated Otter *Lutrogale perspicillata*, one combined study on Masked Palm Civet *Paguma larvata*, and Small Indian Mongoose *Herpestes javanicus*. Only one study was found for each of the Asian Golden Cat *Catopuma temminckii*, Crab-eating Mongoose *Herpestes urva*, Yellow-throated Marten *Martes flavigula*, Large-toothed Ferret Badger, Leopard *Panthera pardus*, Leopard Cat *Prionailurus bengalensis*, Marbled Cat *Pardofelis marmorata* and Oriental Small-clawed Otter *Aonyx cinereus* (Fig. 2).

Region-wise trend in studies

A total of 47 studies were found in southwestern region, followed by 12 studies in southeast, 10 from northeast, and seven from central region (Table 3). Among all 95 references there are three studies accomplished by combining different regions in the

works by Feeroz et al. (2011), Islam et al. (2013) and Al-Razi et al. (2014). Bangladesh is considered as the study site in 22 studies (Appendix 1). We projected the regions according to number of works and number of species exclusively targeted across regions (Fig. 3). Since 1971, there is no study from southern and northwestern regions (Fig. 3a). Figure 3b indicates the inadequacy in consideration of the number of species in different regions.

Of the 95 works considered for the analyses, 25 carried out the research in both protected and non-protected areas, and 57 of these exclusively considered the protected areas. Only 13 works took non-protected areas as study sites (Appendix 1).

Year-wise trend in studies

Only after the year 2000, the number of scientific publications has started to show a noticeable increase (Fig. 4). The highest number of publications were in 2008, 2013, and 2018 ($n=7$ for each year) (Fig. 4a). We could not find any particular reason behind these spikes; 10 publications on Tiger were found from these three years ($n=4$ in 2008, 4 in 2013, 2 in 2018). No scientific paper, however, was found until 1974, perhaps because it took some time for the conditions to become conducive for field research after the independence. It was the two recent decades (2001–2010 and 2011–2019) when carnivore studies in Bangladesh gained momentum. These periods were also a leap for conservation science and inventory compilation ventures. Only the current

Table 2. Comparison between number of threatened carnivore mammals of Bangladesh based on any exclusive study done unto them.

CR—Critically Endangered | EN—Endangered | VU—Vulnerable | NT—Near Threatened | LC—Least Concerned | DD—Data Deficient | NE—Not Evaluated.

Not studied				Studied to different extents			
Global status	Number	Regional status	Number	Global status	Number	Regional status	Number
EN	1	CR	4	EN	1	CR	3
VU	5	EN	1	VU	4	EN	2
NT	1	VU	3	NT	2	VU	3
LC	7	NT	3	LC	7	NT	2
		LC	2			LC	2
		NE	1			DD	1
						NE	1

Carnivores species	Global status	Regional status
Binturong <i>Arctictis binturong</i>	VU	VU
Small-toothed Palm Civet <i>Arctogalidia trivirgata</i>	LC	DD
Common Palm Civet <i>Paradoxurus hermaphroditus</i>	LC	LC
Large Indian Civet <i>Viverra zibetha</i>	LC	NT
Small Indian Civet <i>Viverricula indica</i>	LC	NT
Indian Grey Mongoose <i>Herpestes edwardsii</i>	LC	LC
Jungle Cat <i>Felis chaus</i>	LC	NT
Clouded Leopard <i>Neofelis nebulosa</i>	VU	CR
Dhole <i>Cuon alpinus</i>	EN	EN
Bengal Fox <i>Vulpes bengalensis</i>	LC	VU
Sun Bear <i>Helarctos malayanus</i>	VU	CR
Asiatic Black Bear <i>Ursus thibetanus</i>	VU	CR
Hog Badger <i>Arctonyx collaris</i>	VU	VU
Eurasian Otter <i>Lutra lutra</i>	NT	CR

Table 3. Comparison of works across regions of Bangladesh based on publication types and research topics of carnivore mammal studies.

Region	Publication type				Research topic					
	Book	Scientific Paper	Doctoral Thesis	Action Plan	Discovery and distribution update	Ecology	Inventory	Zoonotic and anthroponotic disease	Population dynamics	Wildlife management and conflict analysis
Central		7				4		2		1
Northeast	1	9			6	2	2			
North		1			1					
Southeast	5	6	1		3		8			1
Southwest	5	37	5			10			3	34
Whole Bangladesh	13	7		2	1	1	14			6

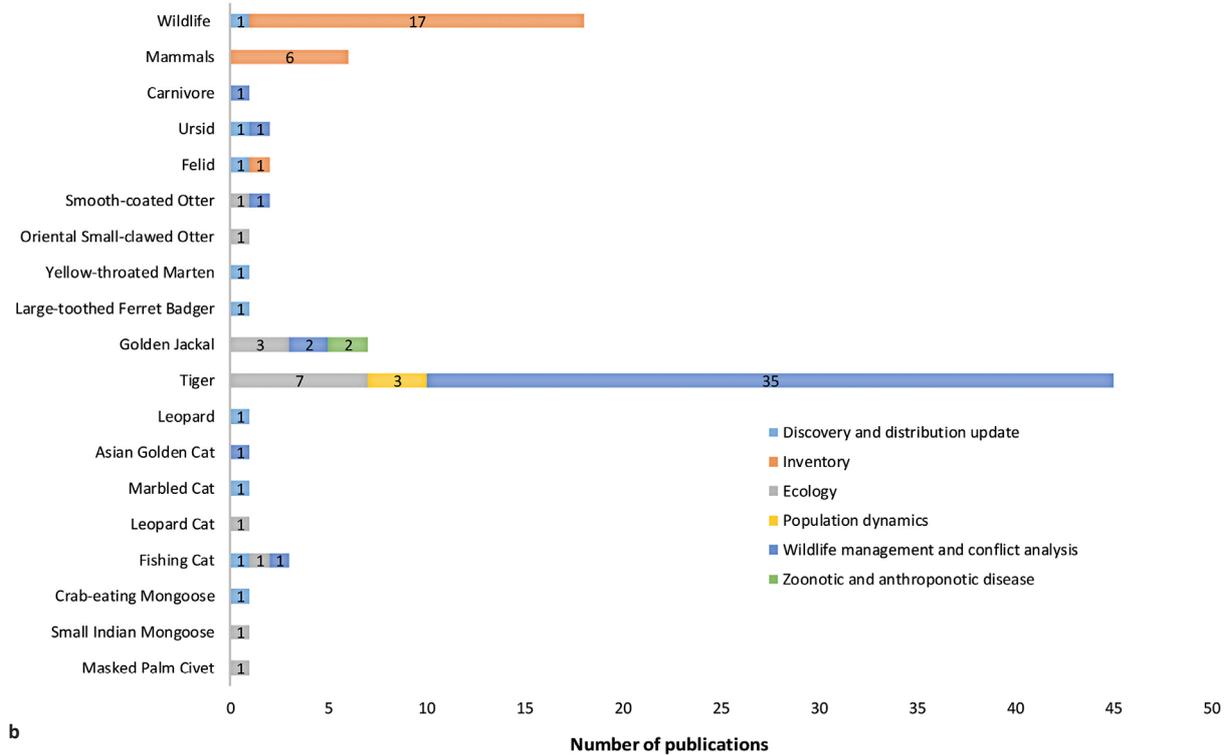
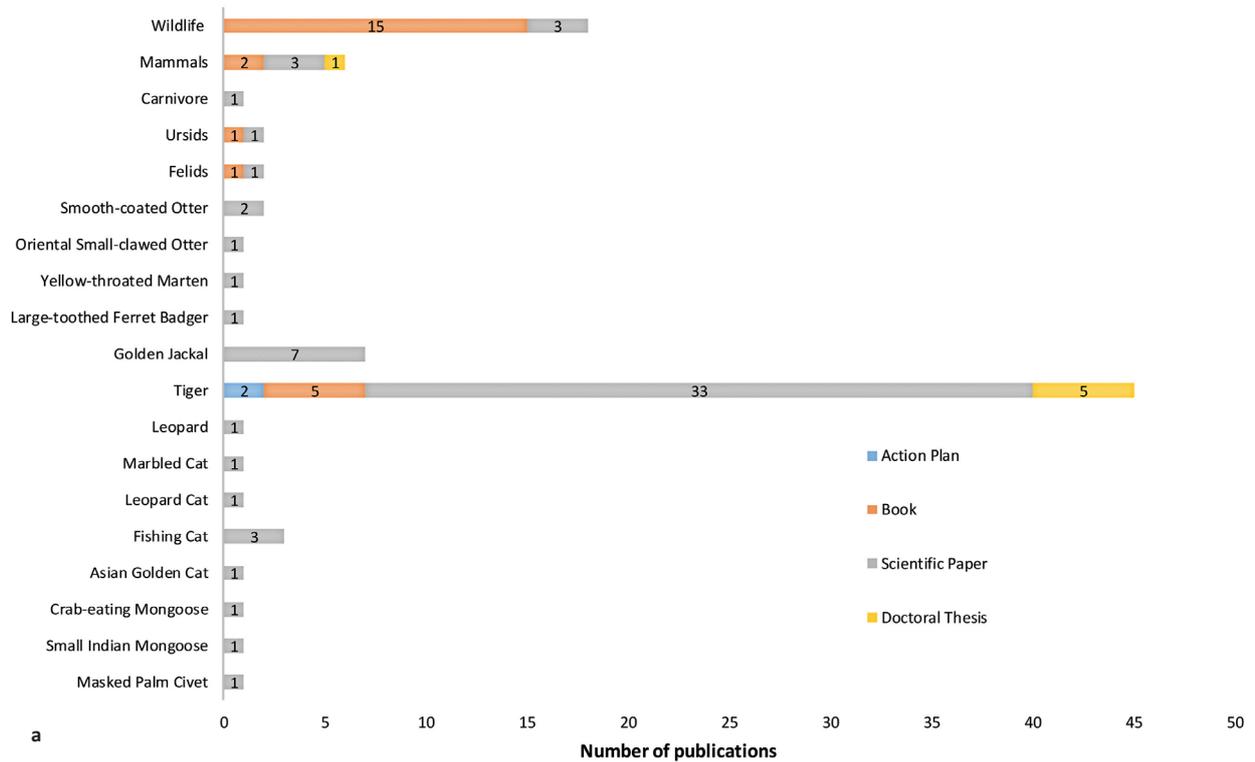


Figure 2. Species-wise preference in carnivore mammal studies in Bangladesh: a—based on different types of publication: action plan, book, scientific paper, and PhD Thesis | b—based on different research topics: discovery and distribution update, inventory, ecology, population dynamics, wildlife management and conflict analysis, and zoonotic & anthroponotic diseases. Appendices 1 and 2 detail out the works and the classification scheme used in these projections.

decade is the period in which we found all seven considered research topics (Fig. 4).

DISCUSSION

Severe discrepancies are evidently observed in research trends considering carnivore mammals of Bangladesh. Gaps and biases are present in every criterion that we considered. Species-wise preference, thematic trends, geographic distribution often leaned toward certain species or certain area, likely to have been influenced by conservation and management interests. Involvement in carnivore researches and interest in diverse species are on the rise. It is, however, worrisome that Bangladesh is at risk of losing more than half of its carnivore diversity, but, deployment of novel methodologies to study elusive and ‘apparently absent’ species is still very sketchy.

Highlighting the least-known and the least-understood species

Researches on Tiger, a flagship species of Bangladesh, make over half of all carnivore research counts. On the contrary, a single study was found on an occurrence record of leopard. The Indian Leopard *Panthera pardus* was thought to have been extirpated from Bangladesh. Among media reports, that may sometime form the beginning to a proper field research (Singh 2020), the term ‘leopard’ appears to be confused with that of Fishing Cat. In the last 12 years, based on verifiable media reports, however, there were instances of 16 Leopards appearing from northern and eastern corners of Bangladesh, each from different cases; six of which were killed as retaliatory responses (Akash et al. submitted). Bear is another charismatic carnivore yet got only one published scientific paper and one book chapter on status assessment (Sarker 2006; Islam et al. 2013; IUCN Bangladesh 2015). Some species are recorded in recent times (Binturong *Arctictis binturong*,

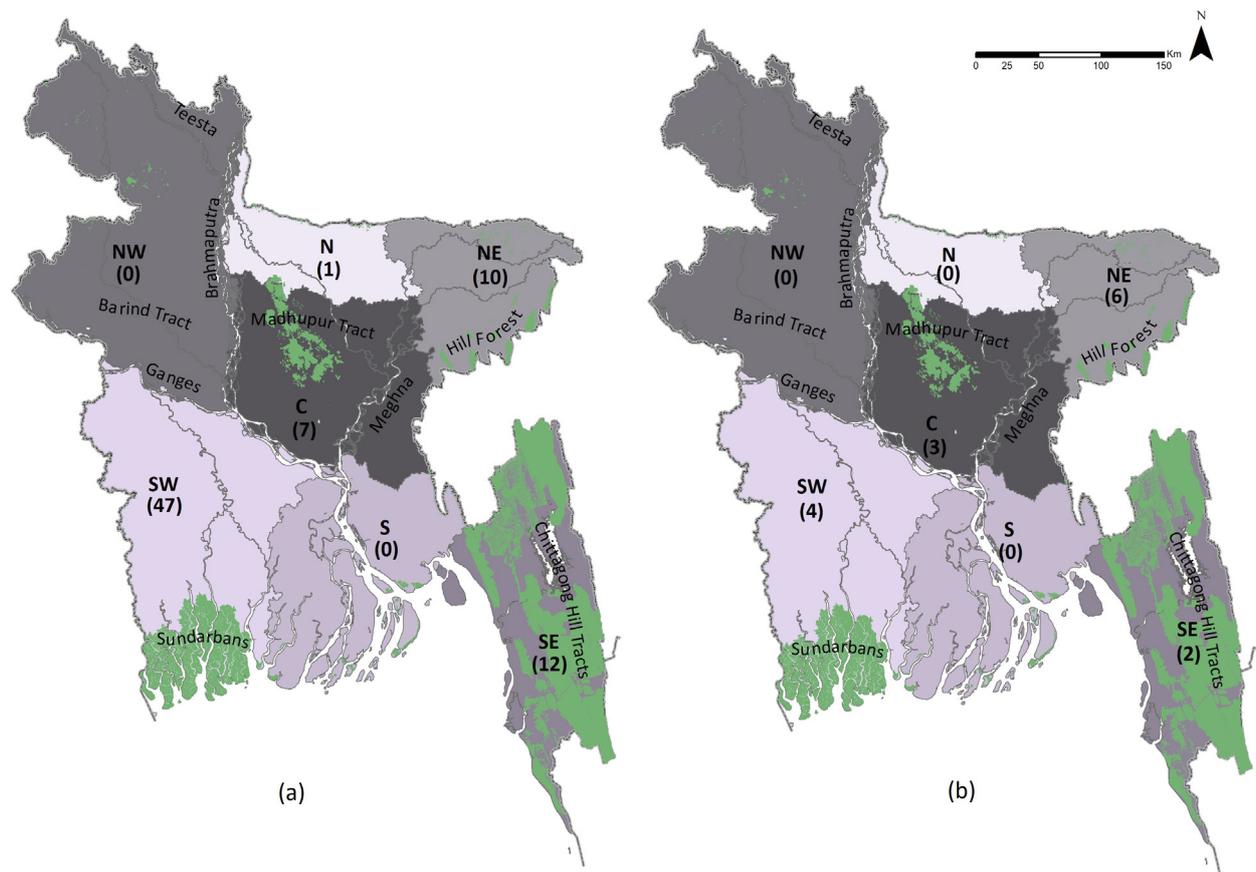


Figure 3. Spatial pattern of carnivore mammal studies in Bangladesh: a—based on different types of publication exclusively assignable to different regions | b—based on number of species exclusively considered and exclusively assignable to different regions. Regional classification is adopted from Khan (2018): N—North | NE—Northeast | NW—Northwest | C—Central | S—South | SE—Southeast | SW—Southwest. Number in parentheses indicates the number of works (in Fig. 3a) and the number of species (in Fig. 3b). Appendices 1 and 2 detail out the works and the classification scheme used in these projections.

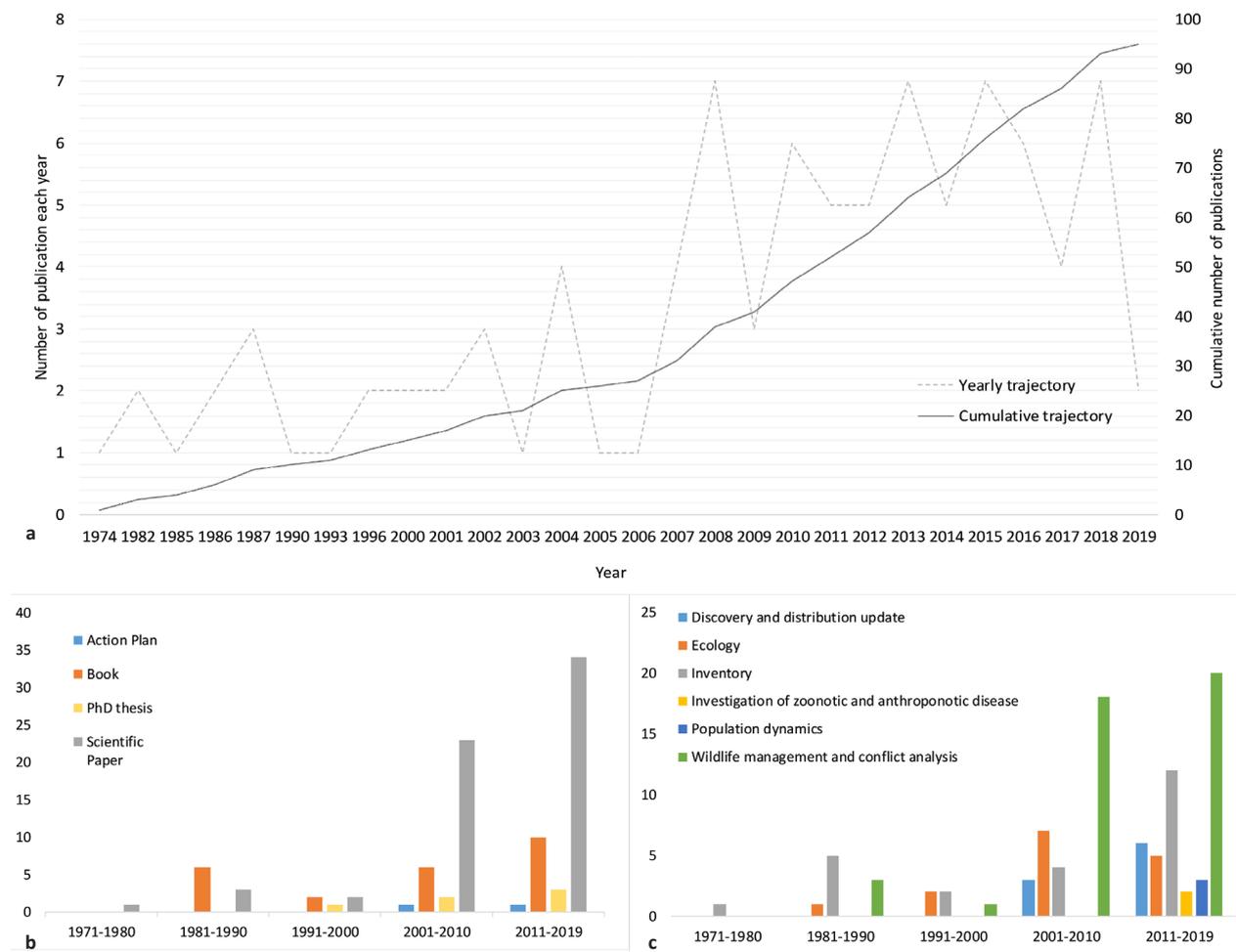


Figure 4. Temporal trajectories of carnivore mammal studies in Bangladesh from 1971 to 2019 showing a gradual increase: a—number of publications each year and their cumulative rate | b—number of different types of publication and | c—number of different research topics—both projected in five decadal periods. During the years 1971 through 1974, no publications of relevance could be accessed in this study. Appendices 1 and 2 detail out the works and the classification scheme used in these projections.

Crab-eating mongoose, Large-toothed Ferret Badger, Yellow-throated Marten, and Hog Badger *Arctonyx collaris*) or have only distant sightings (Small-toothed Palm Civet *Arctogalidia trivirgata*) but no further scientific investigations have been carried out. When the Tiger is the only carnivore to get its conservation action plan twice, 14 other extant carnivores of Bangladesh lack any sort of scientific documentation.

Approaching contemporary study techniques

Our review has highlighted the scattered and scarce data on 28 carnivores from 1971 to 2019 (Table 3, Fig. 4). It is also observed that IUCN Bangladesh (2015) assessed the country’s carnivores mostly through sighting records or expert opinions. Of course, as implied in Singh (2020), all technical accounts may not follow from planned, long-term field research. Figures 3 and 4 clarify the clear

lack in study effort. For example, although southeastern region is known for many carnivores, studies in this region have targeted only two species. Again, while there appears a preference for works like mitigation of conflicts and assessment of biodiversity, there is a certain deficit in species- or taxa-oriented ecological studies (Fig. 4). These can be attributed to challenges of encountering wild carnivores and the rugged terrain in certain areas. Non-invasive and novel technologies such as remote camera-trapping, radio-collaring, and systematic analytical approaches (species distribution modelling, density estimates) which can resolve these difficulties are limited to studies on the Tiger and, to a lesser extent, the jackal (Poche et al. 1987; Khan 2012; Aziz et al. 2018). It is true that, in many cases, the duration allowed and funds available determine the type of research work. Sometimes, these are opportunistic

or out of convenience to fulfil a target.

Emphasizing the hypothetical 'empty forest'

We found that the majority of studies (n=47) carried out in the Sundarbans, exclusively focused on Tiger-related management and conflict issues (Table 3, Fig. 3a). Southeastern Bangladesh, though ranked the second, lagged far behind relative to the number of publications (n= 12), and performed mostly on the diversity and richness of certain protected areas (Feeroz et al. 2012; Feeroz 2013, 2014; Karim & Ahsan 2016; Khan et al. 2016; Kabir et al. 2017). Northeastern Bangladesh too (n=10) has received less than expected attention, having been investigated mostly for Fishing Cat (Giordano & Feeroz 2013; Rahman & McCarthy 2014). When compared to the mangroves, no other forest of the country has experienced likewise focus on carnivore research. In particular, the moist evergreen forests of Bangladesh are often ignored, deemed as 'empty forest' with no sustainable large carnivore population. On the contrary, eastern forests together stand larger than the Sundarbans. Furthermore, Khan (2012), Feeroz (2013, 2014), Chakma (2015), Khan (2015), and CCA (2016) showed the presence of apex predators and umbrella species from these areas. On further interesting note, in the recent years, Rahman (2017) and Zakir (2019), two unpublished MS theses, targeted least-known carnivores of northeastern Bangladesh, carried out camera-trap surveys, and showed some remarkable findings including the Asian Golden Cat and the Asian Wild Dog *Cuon alpinus*. Therefore, it is necessary to plan for large-scale structured camera-trapping, that could reveal the status of the carnivore fauna and their ecological associates in these hypothetical 'empty forests'.

Addressing newer research scopes

For northwestern, central, northern, and southern regions, Figure 3b depicted an extreme gap in knowledge. The regions support small carnivores, e.g., Bengal Fox *Vulpes bengalensis*, Fishing Cat, Jungle Cat *Felis chaus*, Leopard Cat, Large Indian Civet *Viverra zibetha*, Small Indian Civet *Viverricula indica*, and Common Palm Civet *Paradoxurus hermaphroditus* (Khan 2015; Khan 2018). The species are at risk, continuously persecuted across Bangladesh, at forest peripheries, fragmented patches and homestead jungles. Whereas Tiger in Bangladesh has been studied under broad spectra, their ecology, risk assessment, local perception and conflict management for these lesser species living outside protected areas have never been tried. Future research can put small carnivores as umbrella species for the fast disappearing

village/peri-urban groves and wet deciduous forest.

Tiger is undoubtedly a flagship icon for Bangladesh, yet, the country harbors many other remarkable carnivores and unique habitats. Our knowledge on most of their ecology and management strategies are at a bare minimum. This paucity hinders adequate regional and global conservation attention and practices. Therefore, this assessment of the trend of research on mammalian carnivores highlights the gaps in research. Developing more comprehensive knowledge and researched data are expected to aid in future management across the regions where scientific investments have been traditionally low, the availability of data have been sparse and action for conservation is an exigency.

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Appendix 1. Reviewed literature with different categorization schemes.

Taxa/Species/Group	Theme	Region	Author
(A.) Peer-reviewed scientific papers			
Tiger	Ecology	Southwest	Reza et al. (2001a,b), Khan & Chivers (2007), Khan (2008a), Barlow et al. (2010, 2011)
	Population dynamics	Southwest	Khan (2012a), Aziz et al. (2017)
	Wildlife management and conflict analysis	Southwest	Gani (2002), Reza et al. (2002a,b), Azad et al. (2005), Islam et al. (2007), Muhammed et al. (2007), Barlow et al. (2008, 2010, 2013), Khan (2009), Loucks et al. (2010), Neumann-denzau & Denzau (2010), Aziz et al. (2013, 2017, 2018), Inskip et al. (2013, 2014, 2016), Mohsanin et al. (2013), Khanom & Buckley (2015), Rahim et al. (2015), Saif et al. (2016, 2018), Hossain et al. (2018), Mukul et al. (2019)
Leopard	Discovery and distribution update	Southeast	Kabir et al. (2017)
Asian Golden Cat	Wildlife management and conflict analysis	Southeast	Khan (2008b)
Marbled Cat	Discovery and distribution update	Northeast	Khan (2015)
Leopard Cat	Ecology	Southwest	Khan (2004a)
Fishing Cat	Discovery and distribution update	Northeast	Giordano & Feeroz (2013)
	Ecology	Northeast	Rahman & McCarthy (2014)
	Wildlife management and conflict analysis	Whole Bangladesh	Chowdhury et al. (2015)
Asiatic Golden Jackal	Ecology	Whole Bangladesh	Sarker & Ameen (1990)
		Central	Jaeger et al. (1996, 2007)
	Investigation of zoonotic and anthroponotic disease	Central	Khan et al. (2012), Yousuf et al. (2014)
	Wildlife management and conflict analysis	Whole Bangladesh	Brooks et al. (1993)
		Central	Pouche et al. (1987)
Oriental Small-clawed Otter	Ecology	Southwest	Aziz (2018)
Smooth-coated Otter	Ecology	Central, Southwest	Feeroz et al. (2011)
	Wildlife management and conflict analysis	Southwest	Feeroz et al. (2011)
Yellow-throated Marten	Discovery and distribution update	Northeast	Hasan et al. (2019)
Large-toothed Ferret Badger	Discovery and distribution update	Northeast	Islam et al. (2008)
Crab-eating Mongoose	Discovery and distribution update	Northeast	Hasan et al. (2018)
Small Indian Mongoose and Masked Palm Civet	Ecology	Central, Northeast	Al-Razi et al. (2014)
Felid	Discovery and distribution update	Whole Bangladesh	Khan (2004b)
Ursid	Discovery and distribution update	North, Northeast, Southeast	Islam et al. (2013)
Carnivore mammals	Wildlife management and conflict analysis	Whole Bangladesh	Rawshan et al. (2012)
All mammals	Inventory	Northeast	Aziz (2011)
		Southeast	Ahsan et al. (2008), Karim & Ahsan (2016)
All wildlife	Discovery and distribution update	Southeast	Khan (2012b)
	Inventory	Whole Bangladesh	Husain (1974), Gittins (1982)
(B.) Books/Book chapters			
Tiger	Wildlife management and conflict analysis	Southwest	Seidensticker (1986), Khan (1987a), Khan et al. (2003), Reza et al. (2004), Saif & MacMillan (2016)

Felid	Inventory	Whole Bangladesh	Khan (1986)
Ursid	Wildlife management and conflict analysis	Whole Bangladesh	Sarker (2006)
All mammals	Inventory	Whole Bangladesh	Khan (1985), Akonda et al. (2000)
All wildlife	Inventory	Northeast	Feeroz et al. (2011)
		Southeast	Feeroz et al. (2012), Feeroz (2013, 2014), Khan (2015), Khan et al. (2016)
		Whole Bangladesh	Khan (1982), Khan (1987b), Khan (1996), Ahmad et al. (2008), Khan (2010), IUCN Bangladesh (2015), IUCN Bangladesh (2010), Khan (2015), Khan (2018)
(C.) PhD theses			
Tiger	Ecology	Southwest	Reza (2000)
	Population dynamics	Southwest	Aziz (2017)
	Wildlife management and conflict analysis	Southwest	Khan (2004c), Barlow (2009), Saif (2016)
Mammals	Inventory	Southeast	Chakma (2015)
(D.) Conservation action plan			
Tiger	Wildlife management and conflict analysis	Whole Bangladesh	Aziz et al. (2018), Ahmad et al. (2009)
(E.) Project reports			
Tiger	Wildlife management and conflict analysis	Southwest	Rahman et al. (2009), Alam et al. (2011), Dey et al. (2015)
	Ecology	Southwest	Rahman et al. (2012)
	Population dynamics	Southwest	Hossain et al. (2012)
Ursid	Ecology	North, Northeast, Southeast	Islam et al. (2010)
All mammals	Discovery and distribution update	Southeast	CCA (2016)

Appendix 2. Publications on carnivores of Bangladesh in chronological order (1971–2019).

Scientific Papers	
1	Husain K.Z. (1974). An Introduction to the Wildlife of Bangladesh. Motijheel, Dhaka, Bangladesh.
2	Gittins, S.P. & A.W. Akonda (1982). What survives in Bangladesh? <i>Oryx</i> 16: 275–281. https://doi.org/10.1017/S003060530001752X
3	Poche, R.M., S.J. Evans, P. Sultana, M. Haque, M.E. R. Sterner & M.A. Siddique (1987). Notes on the golden jackal (<i>Canis aureus</i>) in Bangladesh. <i>Mammalia</i> 51: 259–270.
4	Sarker, N.J. & M.N. Ameen (1990). Food habits of jackals (<i>Canis aureus</i>). <i>Bangladesh Journal of Zoology</i> 18: 189–202.
5	Brooks, J.E., M.E. Haque & S. Ahamad (1993). Status of the golden jackal as an agricultural pest in Bangladesh. <i>Crop Protection</i> 12(8): 563–564. https://doi.org/10.1016/0261-2194(93)90118-3
6	Jaeger, M.M., R.K. Pandit & E. Hawque (1996). Seasonal differences in territorial behavior by golden jackals in Bangladesh: howling versus confrontation. <i>Journal of Mammalogy</i> 77(3): 768–775. https://doi.org/10.2307/1382682
7	Reza, A.H.M.A., M.M. Feeroz & M.A. Islam (2001a). Food habits of the Bengal tiger (<i>Panthera tigris tigris</i>) in the Sundarbans. <i>Bangladesh Journal of Zoology</i> 29(2): 173–180.
8	Reza, A.H.M.A., M.M. Feeroz & M.A. Islam (2001b). Habitat preference of the Bengal tiger, <i>Panthera tigris tigris</i> in the Sundarbans of Bangladesh. <i>Bangladesh Journal of Life Science</i> 13: 215–217.
9	Gani, M.O. (2002). A study on the loss of Bengal tiger (<i>Panthera tigris</i>) in five years (1996–2000) from Bangladesh Sundarbans. <i>Tigerpaper</i> 29: 7–12.
10	Reza, A.H.M.A., M.M. Feeroz & M.A. Islam (2002a). Man-tiger interaction in the Bangladesh Sundarbans. <i>Bangladesh Journal of Life Sciences</i> 14(1–2): 75–82.
11	Reza, A.H.M.A., M.M. Feeroz & M.A. Islam (2002b). Prey species density of Bengal Tiger in the Sundarbans. <i>Journal of Asiatic Society Bangladesh, Science</i> 28: 35–42.
12	Khan, M.M.H. (2004a). Food habit of the leopard cat <i>Prionailurus bengalensis</i> (Kerr, 1792) in the Sundarbans East wildlife sanctuary, Bangladesh. <i>Zoos' Print Journal</i> 19(5): 1475–1476.
13	Khan, M.M.H. (2004b). Status and distribution of wild cats in Bangladesh. <i>Bangladesh Journal of Life Sciences</i> 17(1): 69–74.
14	Azad, M.A.K., M.A. Hashem & M.M. Hossain (2005). Study on human Royal Bengal tiger Interaction of in situ and ex situ in Bangladesh. <i>Journal of Biological Sciences</i> 5(3): 250–252.
15	Islam, M.W., M.S. Alam & M.M. Islam (2007). Study of human casualties by Bengal tigers (<i>Panthera tigris tigris</i> L.) in the Sundarbans forest of Bangladesh. <i>Tiger Paper</i> 34: 11–15.

16	Jaeger, M.M., E. Haque, P. Sultana & R.L. Bruggers (2007). Daytime cover, diet and space-use of golden jackals (<i>Canis aureus</i>) in agro-ecosystems of Bangladesh. <i>Mammalia</i> 71(1–2): 1–10.
17	Khan, M.M.H. & D.J. Chivers (2007). Habitat preferences of tigers <i>Panthera tigris</i> in the Sundarbans East Wildlife Sanctuary, Bangladesh, and management recommendations. <i>Oryx</i> 41(4): 463–468. https://doi.org/10.1017/S0030605307012094
18	Muhammed, N., M.T. Kamal, F. Haque, M.S.H. Chowdhury & M. Koike (2007). A study on the Royal Bengal Tiger (<i>Panthera tigris tigris</i>) of the Sundarbans in Bangladesh with special reference to tiger–human conflict. <i>Journal of Social Research and Development</i> 4: 86–91.
19	Ahsan, M.F. & M.W. Chowdhury (2008). Mammals of the Chittagong University Campus, Chittagong. <i>Bangladesh Journal of Zoology</i> 36(2): 131–147.
20	Barlow, A.C., M.I.U. Ahmed, M.M. Rahman, A. Howlader, A.C. Smith & J.L. Smith (2008). Linking monitoring and intervention for improved management of tigers in the Sundarbans of Bangladesh. <i>Biological Conservation</i> 141(8): 2032–2040. https://doi.org/10.1016/j.biocon.2008.05.018
21	Islam, M.A., G.W. Chowdhury & J.L. Belant (2008). First record of the Large-toothed Ferret Badger <i>Melogale personata</i> in Bangladesh. <i>Small Carnivore Conservation</i> 39: 41–42.
22	Khan, M.M.H. (2008a). Prey selection by tigers (<i>Panthera tigris</i>) (Linnaeus 1758) in the Sundarbans East Wildlife Sanctuary of Bangladesh. <i>Journal of the Bombay Natural History Society</i> 105(3): 255–263.
23	Khan, M.M.H. (2008b). The neglected Asiatic golden cats of Bangladesh. <i>Cat News</i> 48: 20–21.
24	Khan, M.M.H. (2009). Can domestic dogs save humans from tigers <i>Panthera tigris</i> ?. <i>Oryx</i> 43(1): 44–47. https://doi.org/10.1017/S0030605308002068
25	Barlow, A.C., C.J. Greenwood, I.U. Ahmad & J.L. Smith (2010). Use of an action-selection framework for human-carnivore conflict in the Bangladesh Sundarbans. <i>Conservation Biology</i> 24(5): 1338–1347. https://doi.org/10.1111/j.1523-1739.2010.01496.x
26	Barlow, A.C.D, J. Mazak, I.U. Ahmad & J.L. Smith (2010). A preliminary investigation of Sundarbans tiger morphology. <i>Mammalia</i> 74(3): 329–331. https://doi.org/10.1515/mamm.2010.040
27	Loucks, C., S. Barber–Meyer, M.A.A. Hossain, A. Barlow & R.M. Chowdhury (2010). Sea level rise and tigers: predicted impacts to Bangladesh's Sundarbans mangroves. <i>Climatic Change</i> 98(1–2): 291. https://doi.org/10.1007/s10584-009-9761-5
28	Neumann-Denzau, G., & H. Denzau (2010). Examining certain aspects of human-tiger conflict in the Sundarbans forest, Bangladesh. <i>Tiger paper</i> 37(3): 1–11.
29	Aziz, M.A. (2011). Notes on the status of mammalian fauna of the Lawachara National Park, Bangladesh. <i>Ecoprint</i> 18: 45–53. https://doi.org/10.3126/eco.v18i0.9398
30	Barlow, A.C., J.L. Smith, I.U. Ahmad, A.N. Hossain, M. Rahman & A. Howlader (2011). Female tiger <i>Panthera tigris</i> home range size in the Bangladesh Sundarbans: the value of this mangrove ecosystem for the species' conservation. <i>Oryx</i> 45(1): 125–128. https://doi.org/10.1017/S0030605310001456
31	Feeroz, M.M., M.A. Aziz & P.K. Thanchanga (2011). Breeding activities of <i>Lutra perspicillata</i> in Bangladesh. <i>IUCN Otter Specialist Group Bulletin</i> 28(A): 38–44.
32	Feeroz, M.M., S. Begum & M.K. Hasan (2011). Fishing with otters: a traditional conservation practice in Bangladesh. <i>IUCN Otter Specialist Group Bulletin</i> 28(A): 14–21.
33	Khan, M.A.H.N.A., S.S. Khanm, J. Bashu, U.K. Rima, M. Pervin, M.Z. Hossain, M.A. Habib, G.A. Chowdhury & M.M. Hossain (2012). Visceral leishmaniasis is endemic in golden jackals of Bangladesh agricultural university campus, a threat for expanding future zoonotic visceral leishmaniasis. <i>Bangladesh Journal of Veterinary Medicine</i> 10(1–2): 101–109. https://doi.org/10.3329/bjvm.v10i1-2.15655
34	Khan, M.M.H. (2012a). Population and prey of the Bengal tiger <i>Panthera tigris tigris</i> (Linnaeus, 1758) (Carnivora: Felidae) in the Sundarbans, Bangladesh. <i>Journal of Threatened Taxa</i> 4(2): 2370–2380. https://doi.org/10.11609/JoT.o2666.2370-80
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ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

November 2020 | Vol. 12 | No. 15 | Pages: 17063–17170

Date of Publication: 26 November 2020 (Online & Print)

DOI: 10.11609/jott.2020.12.15.17063-17170

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