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RESEARCH ARTICLE

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Predation of Endangered crowned river turtles *Hardella thurjii* by golden jackals *Canis aureus* in Keoladeo National Park, India

GOURAV SONAWANE[1], GAURAV. S SINGH[1], ADITI MUKHERJEE[1*], SHIRISH S. MANCHI[1] & H.N. KUMARA[1]

[1]Sálim Ali Centre for Ornithology and Natural History, (South India Centre of Wildlife Institute of India, Ministry of Environment, Forest and Climate Change), Anaikatty (Post), Coimbatore 641108, Tamil Nadu, India

[*]Corresponding author e-mail: mukherjee.aditi20@gmail.com/aditi.sacon@wii.gov.in

ABSTRACT – The predation of an endangered species by its natural predators can severely impact its survival, even in protected areas. We report on the predation of the Endangered crowned river turtle *Hardella thurjii* by golden jackals *Canis aureus* in Keoladeo National Park in India. There were 48 predation instances over five months, particularly of gravid females during the breeding season. The concentration of predated carcasses along turtle breeding trails raises concerns about demographic impacts. These findings underscore the need for targeted conservation measures, such as monitoring jackal movement, installing barricades in predation hotspots, and providing care for injured turtles to reduce losses of *H. thurjii*.

INTRODUCTION

Predators have critical roles to play in the preservation of ecosystems (Ray, 2005) but depensatory predation can lead to the extinction of prey species, while regulatory predation allows prey species to thrive (Garrott et al., 2008). The current record of the predation of crowned river turtles *Hardella thurjii* by golden jackals *Canis aureus* raises concerns regarding the vulnerability of this Endangered species (Ahmed et al., 2021a). This observation, coupled with past unquantified records of predation on this species of turtle by jackals, vultures and eagles during the dry season in Bharatpur (Das & Bhupathy, 2009), has thrust *H. thurjii* into the spotlight as a species of conservation concern.

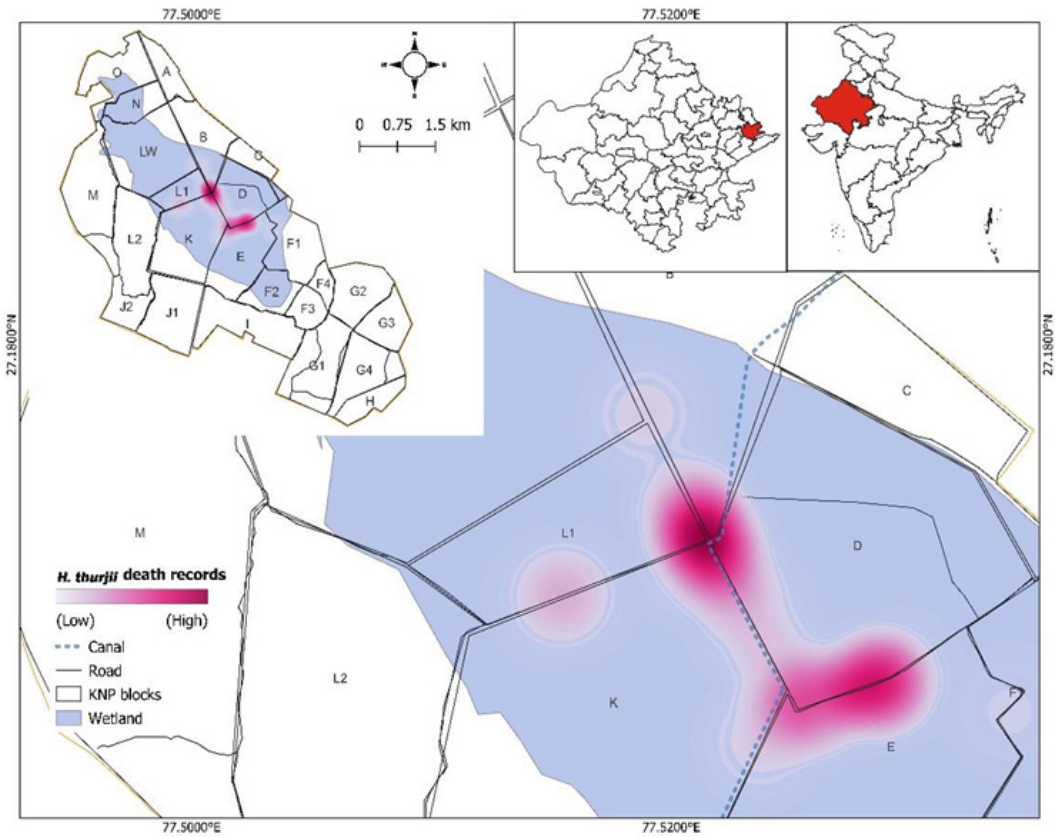

Figure 1. Heat map of mortality of *Hardella thurjii* at KNP

Hardella thurjii is an iconic species inhabiting the Ganga-Brahmaputra basin in Bangladesh and northern India, and the Indus basin in Pakistan and north India (Iverson, 1992). The IUCN classifies this species as Endangered, and its threats include loss of habitat, poaching and the pet trade (Das & Bhupathy, 2009). Female *H. thurjii* nest in sandbanks (Das & Bhupathy, 2009) where they lay 30–100 eggs in multiple clutches, each containing 8–13 eggs (Basu, 1998), and in a recent study, six dissected females were observed carrying 6–22 eggs each (Singh et al., 2022). It is not known whether females lay communally.

We address here the predation of *H. thurjii* during the breeding season by golden jackals in Keoladeo National Park (KNP), and its potential consequences on *H. thurjii*. KNP has an exceptionally high density of golden jackals (14.84 individuals/km^2) (Singh et al., 2016). However, there is a significant knowledge gap regarding their prey and feeding habits in KNP across all seasons, specifically their interaction with the *H. thurjii* and other reptiles. While studying the Indian rock python *Python molurus* and its coexisting fauna, we encountered opportunistic interactions between golden jackals and *H. thurjii*, leading to systematic monitoring. With few natural predators inside the park except pythons, which occasionally feed on golden jackals (Bhupathy et al., 2014), the unchecked increase in the jackal population could affect the park's ecosystem and its threatened species. While previous observations of interactions between golden jackals and *H. thurjii* exist (Das & Bhupathy, 2009), our study marks the first systematic effort to quantify these encounters. Through systematic observations and analysis, we seek to elucidate patterns of predation, spatial dynamics and the broader ecological implications of these interactions. By so doing, we aim to contribute valuable insights that can inform targeted conservation strategies for the coexistence of these threatened species within the delicate ecosystem of KNP.

MATERIALS & METHODS

Study area

KNP is situated in the Indian state of Rajasthan, and lies between latitudes 27° 07'06'' N and 27° 12'02'' N and longitudes 77° 29'05'' E and 77° 33'09'' E in the semi-arid zone (province 4A) of India (Fig. 1). The park has significant international ecological importance, and was declared a Ramsar site in 1981 and a World Heritage site in 1985. The park has a mosaic of habitats, including forest, woodland, scrub woodland, savannah woodland, low grasslands with scattered trees and scrub, plantations, and wetlands (Mathur et al., 2009).

Methodology

This study is part of an ongoing project on the Indian rock python, which aims to comprehensively understand the pythons' habitat use, behaviour and prey base by deploying camera traps throughout KNP. This project also focuses on the pythons' interactions with other species, including jackals. While undertaking regular fieldwork for this project, we encountered a series of *H. thurjii* mortalities from 6 August 2023 onwards. After encountering six mortalities within a short span of three days, we decided to systematically monitor specific areas where the occurrence of predation was concentrated. We positioned ten Browning Strike Force Pro DCL camera traps in areas exhibiting high turtle mortality from August to December 2023. Due to the daytime use of the trails by tourists, the traps were placed along the trails only from the hours of 18:00h–06:00h. While the cameras were removed during daylight hours, the sites were routinely monitored. The ten camera traps were programmed to capture three rapid photographs with a 1-second delay, while five traps were set to record 20-second videos in full HD with a 1-second

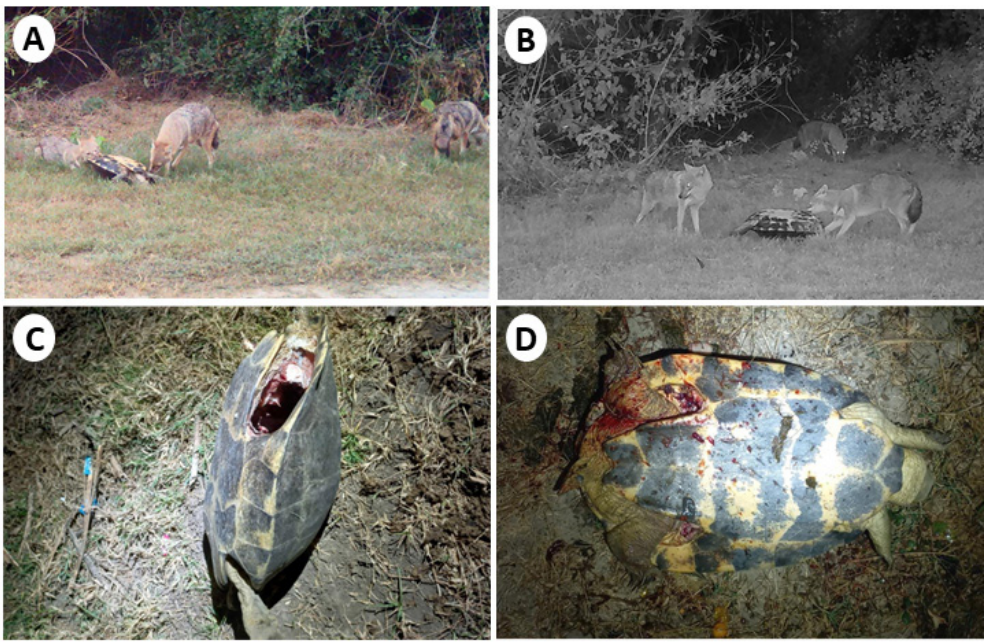

Figure 2. Predation of *Hardella thurjii* by golden jackals at KNP - **A.** & **B.** Camera trap images of jackal feeding and dragging the turtles, **C.** & **D.** Dead *Hardella thurjii*

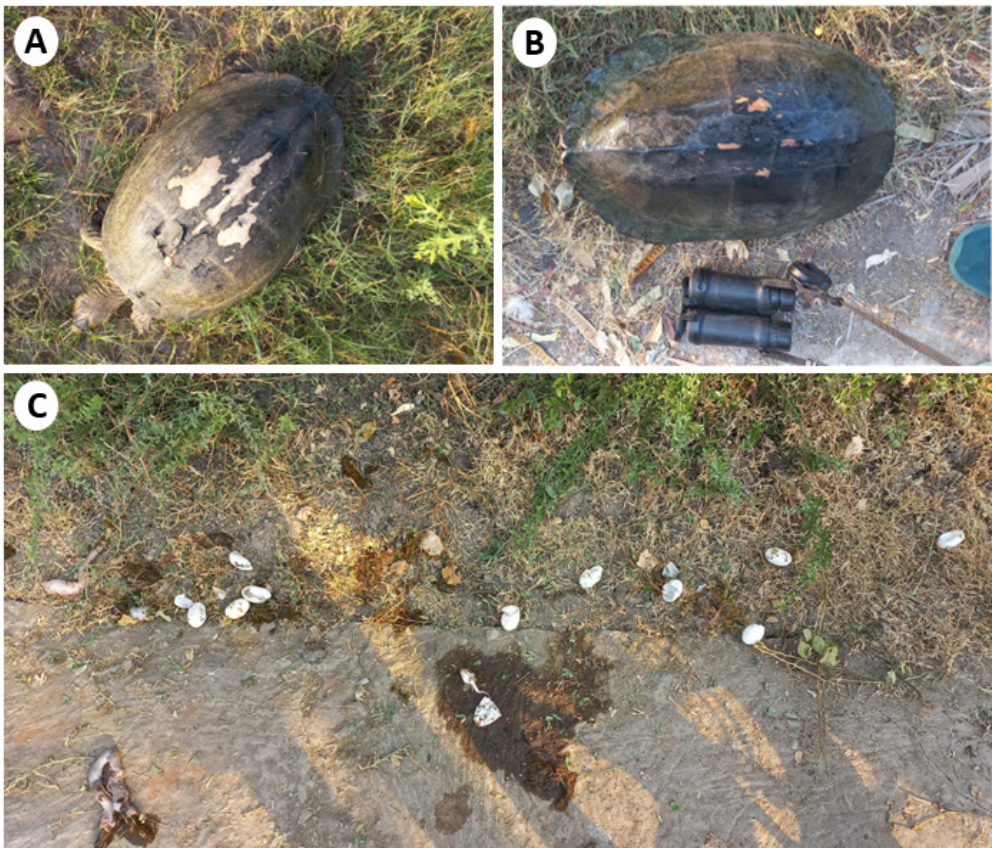

Figure 3. Predation of *Hardella thurjii* by golden jackals at KNP - **A.** & **B.** Drag marks on the carapace of dead turtles, **C.** Eggs/egg shells near the carcasses of *Hardella thurjii*

delay. Each turtle carcass encountered was measured using a tape measure (Freemans), with measurements taken from the carapace and plastron. Features such as footprints, rake marks and drag marks on the carapace, and the presence of eggs were documented.

RESULTS

From August to December 2023, we documented 48 turtle carcasses, with the most deaths occurring in October (n = 28). These fatalities were primarily concentrated on the roads traversing the wetland habitat of D, K and E blocks within the park (Fig. 1). Upon locating live turtles, golden jackals were observed overturning them. They seized the turtles by their hind legs, pulling and dragging them for distances ranging from approximately 5 to 10 metres to a suitable feeding spot. After damaging the hind legs, they commenced feeding from the rear side, predominantly consuming the legs first, before removing the viscera (Fig. 2). Out of the 48 deaths, morphometric measurements and carcass status were collected for 24 individuals (Supplementary Material, Table 1S). Of the observed individuals, 35 were missing one or more limbs and their viscera were visible. The remaining 13 individuals were completely consumed. Except for drag marks (Fig. 3A & B), the carapaces were seen with no damage, injury or discolouration. Seven individuals were observed with egg counts ranging from 5 to 15; however, we could not obtain morphometric measurements and egg counts for three of them.

The morphological features of the carcass confirmed all as females except one during the study. In seven instances, we encountered eggs scattered around the turtle remains, and counted 15 eggshells near one (Fig. 3C). Moreover, on three occasions, Indian grey mongoose *Urva edwardsii* and twice Bengal monitor lizards *Varanus bengalensis* were observed feeding on the internal organs of a turtle carcass, which may have been inaccessible to jackals. Additionally, there was one instance where an Indian flapshell turtle *Lissemys punctata* was observed feeding on a deceased *H. thurjii*.

DISCUSSION

Hardella thurjii displays a unique characteristic within the chelonian community of KNP, as they may wander up to about 1 km in search of suitable nesting sites (Vijaya & Manna, 1982). Females typically commence egg-laying activities between September and November, coinciding with the post-monsoon period (Singh et al., 2022). In KNP, *H. thurjii* use trails and roads to reach other parts of the wetland during the breeding season, which co-incides with the time when golden jackal predation occurs. The number of deaths from September to November was highest during our five months of study, co-inciding with the egg-laying season (Chaudhuri, 1912; Singh et al., 2022).

In contrast to *H. thurjii*, golden jackals are widely present in all habitats in KNP, with an estimated density of 14.84 individuals/km^2 (Singh et al., 2016). From August to December 2023, an increase in the movements of golden

jackal was observed within blocks D, K and E blocks of the park (Fig. 1). This was recorded in the camera traps deployed to study the pythons. The local guides and staff also confirmed increased jackal movement in the D, K and E blocks (Fig. 1) (the same blocks with the most *H. thurjii* fatalities) during the period. Numerous studies have documented the predation of turtles and tortoises by various predators across different regions. For instance, predation of turtles by jackals and foxes during the turtle breeding season has been observed at Akyatan Beach, Turkey (Brown & Macdonald, 1995). However, these observations did not identify specific predation on adult or gravid females. In the Goksu Delta, Turkey, jackals have been identified as a significant predator of loggerhead turtles *Caretta caretta* and green sea turtles *Chelonia mydas*, preying on nests, hatchlings, adult females and gravid females, thus posing a substantial threat to these populations (Akcinar et al., 2006). Additionally, reports from Sariska Tiger Reserve, Rajasthan, document instances of golden jackals feeding on reptiles, although predation on turtles was not specifically mentioned (Mukherjee et al., 2004). In KNP, predation on the turtle species *H. thurjii* by eagles, vultures and jackals has been reported previously , although the intensity of such predation has never been quantified (Das & Bhupathy, 2009).

The exceptionally high population density of jackals in KNP is supported by an abundance of prey species (Singh et al., 2016). During the breeding and egg-laying season of *H. thurjii*, the heightened movement of these turtles offers jackals an easily accessible secondary prey, necessitating less energy expenditure than hunting their primary prey. In the present study, 48 instances of turtle predation were documented, characterised by limb removal and consumption of the viscera, indicative of a specialised predation strategy by golden jackals. Previous golden jackal scat analyses in KNP did not reveal any reptile remains (Sankar, 1988; Singh et al., 2016). However, recent discussions with local guides and forest department personnel suggest a perceived increase in jackal predation on turtles over the past two to three years, although they were uncertain about the species involved.

The predation on *H. thurjii*, particularly gravid females, raises concerns regarding potential demographic impacts on this endangered species in KNP. The concentration of *H. thurjii* carcasses in specific areas, particularly the trails and paths used by turtles during their breeding period, highlights potential predation hotspots, possibly jeopardising the adult female population of this Endangered turtle species, which requires further investigation. Understanding the ramifications of jackal predation on the turtle population is crucial for effective conservation strategies. Further research is essential to explore the drivers behind this predation, and its possible conservation implications. There is a risk that species, such as the Endangered *H. thurjii*, may face local extinction if multiple predators indirectly contribute to their decline (DeCesare et al., 2010). According to Sinclair et al. (1998) and DeCesare et al. (2010), endangered species with below average fitness often become secondary prey, but the establishment of spatial refuges could mitigate depensatory predation and extirpation, thereby supporting conservation efforts. Even if the predation is mitigated, it may still take the *H. thurjii* population a long time to recover as has been the case with other examples of mass predation, for example a snapping turtle *Chelydra serpentina* population in Canada predated by river otters *Lontra canadensis* failed to produce any signs of recovery, even after 23 years (Keevil et al., 2018). Evidence suggests that turtles recover extremely slowly from such catastrophic events (Brooks et al., 1991; Mullin et al., 2020).

Continued depensatory predation on *H. thurjii* in the park may necessitate 'symptomatic' management strategies (Lessard et al., 2005; Sinclair & Byrom, 2006) to minimise these interactions. These 'symptomatic' management strategies require detailed research and may include (i) actively monitoring the movement of jackals during the turtle breeding season, especially in the hotspots (Fig. 1), (ii) installing necessary barricades, (iii) actively checking for injured turtles, and (iv) providing primary and urgent care for injured turtles. As a last resort, translocating jackals to other regions of the park could also be considered. Predation on gravid females, hatchlings and nests by jackals, foxes, armadillos, raptors and humans has in the past been mitigated using similar 'symptomatic' strategies during the breeding seasons of multiple turtle species. These include the loggerhead turtle *C. caretta*, green turtle *C. mydas*, leatherback turtle *Dermochelys coriacea*, and Kemp's ridley turtle *Lepidochelys kempii* at the Hobe Sound National Wildlife Refuge in Florida, USA (Engeman et al., 2003; 2005; 2012), the Blanding's turtle *Emydoidea blandingii* in South Carolina, USA (Beaudry et al., 2010), and the olive ridley turtle *Lepidochelys olivacea* in Orissa, India (Chattopadhyay et al., 2018). However, in the case of eastern long-necked turtles *Chelodina longicollis*, mitigation involved only headstarting, in which eggs were collected from the nest, incubated, and hatchlings raised until ready to be reintroduced into the wild (Spencer et al., 2017). Headstarting could be used if symptomatic management is ineffective in controlling jackal predation (Spencer et al., 2017). In conclusion, to mitigate the predation pressure on *H. thurjii* by golden jackals in KNP and ensure the future viability of this Endangered species, urgent research into their population dynamics and biology is essential.

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