Sustainability and Biodiversity Conservation

A review of the biogeography, diversity, and current conservation status of turtles and tortoises of the Indian subcontinent

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Abstract

There are approximately 357 turtles and tortoise species worldwide, of which 33 freshwater turtles (terrapins) and tortoise species are found in the Indian subcontinent (South Asia). According to the IUCN Red List analysis, 85% of South Asian turtle species are threatened; vulnerable (VU), critically endangered (CR), and endangered (EN), while the remaining 15% are at low risk; least concern (LC) or near threatened (NT). This study focuses on the current conservation status and information regarding its biogeography, distribution, and diversity. The authors evaluated existing records of South Asian tortoises and freshwater turtles. This review discusses the checklists and proposes integrating ecological and molecular biology concepts to provide more comprehensive information about biogeography, diversity, and the current conservation status of turtles and tortoises of the Indian subcontinent.

Keywords: Biogeography, Conservation, Diversity, Indian subcontinent, Turtles.

Introduction

Order Chelonia includes sea turtles, tortoises, and terrapins. This order has animals with bones or cartilage consisting of ribs. Chelonia is derived from the Greek word "Khelone" (χελώνη)" meaning interlocking armor or shield (Purkayastha et al., 2015). The terms sea turtle, tortoise, and terrapin are often used interchangeably to refer to their habitats, but usage of these terms varies from country to country (Khan et al., 2015). Turtles are aquatic and semi-marine animals that are mostly carnivorous, although some feed on certain plants. Tortoises are land-dwelling animals that are herbivores. The term terrapin is used for semi-aquatic or freshwater testudines' while marine

testudines are simply known as marine turtles. This group of reptiles is considered contemporary with dinosaurs. The oldest fossils date from the late Triassic (ca. 220 mya). They reached the end of their diversity at the end of the Cretaceous and included two major groups: Cryptodira and Pleurodira. Cryptodira, which provides for about three-fourths of all known species of turtles, is characterized by the ability to bend its neck and retract its head into its shell. Pleurodiran turtles (Side-necked turtles) are often called side-necked turtles because their necks fold sideways along their bodies at the bottom of their shells. There are currently 357 species of freshwater turtles and land tortoises in 14 families (TTWG, 2017). Extant reptiles are divided into two clades: Archosauria and lepidosauria. Until recently, turtles, due to their primitive anapsid skull (without fenestra), were considered as an out-group to all other reptiles, and close to extinct and primitive groups of reptiles. Recent nuclear DNA analysis shows that the anapsid skull is a secondary feature derived from the diapsid skull. Based on their relationships with sauropods and paleo-biogeographic and stratigraphic evaluations, these turtles are of aquatic origin. *Odontochelys* was probably the first turtle that crawled in shallow marine water of eastern Asia, around 220 million years ago. This soft-shelled turtle showed a full set of teeth, a condition subsequently lost (Ramakrishna et al., 2014). The first true sea turtle, *Proganochelys*, appeared about 210 million years ago, and its fossils have been found in Germany and Thailand. These large turtles have a real shell; the ribs and vertebrae combine to form the shell, and the sternum components combine with the ribs and vertebrae fused to dermal bones to form the carapace, and the pectoral girdle components fused with the dermal bones to form the plastron. *Proganochelys* lost teeth on the jaws but retained teeth on the palatines (Karl, 2012). Major groups of turtles appeared and were abundant in the late Triassic. The fossil record shows, that they have remained unchanged for at least 150 million years, but their ancestors are still unknown (TEWG, 2015). All countries in South Asia are developing their economies to keep the development process functioning, it is widely understood that the pressure on natural resources often leads to the loss of biodiversity, which's why Freshwater turtles and tortoises are losing ground as a result of this (Das, 1996; Ramakrishna et al., 2014; Purkayastha et al., 2015). The works of Smith (1931, 1935, 1943) continue to be the authoritative sources for the taxonomy of various herpeto-fauna including the Testudines of the Sub-continent. Biogeographic and conservative analysis of the chelonian fauna, within the sub-continent, has been attempted recently by Safi & Khan (2014); Khan, (2015); Safi et al. (2016, 2020, 2021 & 2024); Khan et al. (2015 & 2016) and Karl et al. (2021) for Pakistan; Ramakrishna

et al. (2014); Purkayastha et al. (2015); Das, (1991,1996, 2008); Das & Sangupta, 2010; Rashid et al, (2000). Turtles are revered for their longevity and fecundity, but they are also used as pets, food, and as ingredients in the pharmacopeia of traditional medicine (Das, 1991). Freshwater turtles play an important role in the health of an aquatic ecosystem since they are scavengers, herbivores, and carnivores, provide dispersal mechanism for plants, clean up water resources by scavenging on dead organic matter, and help to maintain healthy populations of fish, soft-shell turtles are the source of Traditional Chinese Medicine, and their shells are highly effective for purifying blood and cure many diseases As a result, most turtles in South Asia are threatened; many are already listed as Endangered or Critically Endangered (Safi & Khan, 2014; Khan et al., 2016). Approximately half of the world's 357 Chelonia species are endangered. Since turtles face threats from human activities as well as natural climate changes, many factors contribute to their conservation today. Sand mining, river damming, wetland collection and degradation, and intensive fishing are some of the long-term impacts of humans on turtles and the impacts on the environment. Along with the demand for flesh, there exists a market for turtle eggs as well. Although the turtle meat and eggs trade are illegal in most countries, the practice and markets exist. Turtles, terrapins, and tortoises, or chelonians (Order: Testudines), include some of the world's most endangered species. For centuries the larger species have been exploited for their shells, meat, and eggs (Purkayastha et al., 2015; IUCN TFTSG & ATTWG (IUCN/SSC), 2000; TTWG, 2021). The Indus-Gangetic and Brahmaputra basins cover the north, northwest, and northeast of South Asia; these mighty rivers are home to the world's important biodiversity hotspots. The region is home to many aquatic species that help maintain ecological balance and act as a blessing for human civilization. This 'Turtle Priority Area' hosts a total of 22 out of 33 species of freshwater turtles in South Asia. Unfortunately, more than 85% of the animals in the area need urgent conservation interventions. Human-caused threats such as bycatch and deaths due to entanglement, especially in these river systems, are also an urgent concern in this regard. Additionally, the lack of understanding and reliable scientific data on chelonian biodiversity and their habitats has widened the awareness gap among the general masses and hinders a realization of their significance and need for their conservation. Failure to protect critical habitats has also led to unchecked exploitation and extinction of these species, degradation of these species, damaging freshwater habitats, and water quality, and threatening biodiversity on a larger scale (Safi et al., 2024). Furthermore, with the river system being dynamic and the flood changing its course, it is

imperative to document, evaluate, and compare the potential habitats to understand the spatial and temporal variations (Kar et al., 2024).

Biogeography

An understanding of the heterogeneity, or non-randomness, in the distribution of flora and fauna of any area on earth, is one of the main goals in the ecological sciences that constitute the collective science known as Biogeography, which incorporates elements from widely disparate disciplines of natural sciences such as; biology, demography, geography, geology, meteorology, ecology, remote sensing, physical and climate sciences and studies all aspects of the adaptations of an organism to its environment, considering systematically the origins, migrations and associations of living things. Mountain and riverine systems provide ideal ecological laboratories to understand the biogeography of flora and fauna of any area, as they present a large variety of environmental conditions, hosting a great variety of life forms over short distances (Das, 1996). This is particularly true for the South Asian Mountain systems especially the Himalayas and three big riverine systems (Indus, Ganges, and Brahmaputra) of South Asia which harbor some of the world's finest biodiversity hotspots (Figure 3). Biogeography and conservation are linked inexorably by the relationships between habitat area, primary productivity, earth history, and species richness. This linkage for turtles is strong in South Asia, which has a diverse and unique Chelonian fauna, rich in taxa, covering an area of approximately 5.2 million square kilometers, and located at the intersection of three distinct biogeographic regions: Palearctic, Ethiopian, and oriental regions (Figure 1). This region also contains some extreme climates, including the highest mountains such as the Karakoram, Hindu Kush, and the Himalayas, as well as some of the rainiest regions in the world, such as Mawsynram, located in Meghalaya's East Khasi Hills district, India, which is the wettest place in the world, this region receives a lot of rain, with an average annual rainfall of up to 11,871 mm. Its proximity to the Bay of Bengal is important in this rainfall. South Asia includes eight countries: Afghanistan, Pakistan, India, Maldives, Sri Lanka, Bhutan, Nepal, and Bangladesh (Figure 1 & 2). Its major physical features include the Hindu Kush, Karakoram, and Himalayan Mountain ranges, the Indus, the Ganges and the Brahmaputra Rivers, and the Thar Desert. The three major river systems including major ‘hotspots’ of biodiversity, have been sustainable for freshwater biota including freshwater turtles. The main physical and biological characteristics of the physical site are shown in Figures 2 & 3 (Das, 1996).

Figure 1. Map of South Asia showing different countries

Figure 2. Map of South Asia showing the physiographic zones and their boundaries

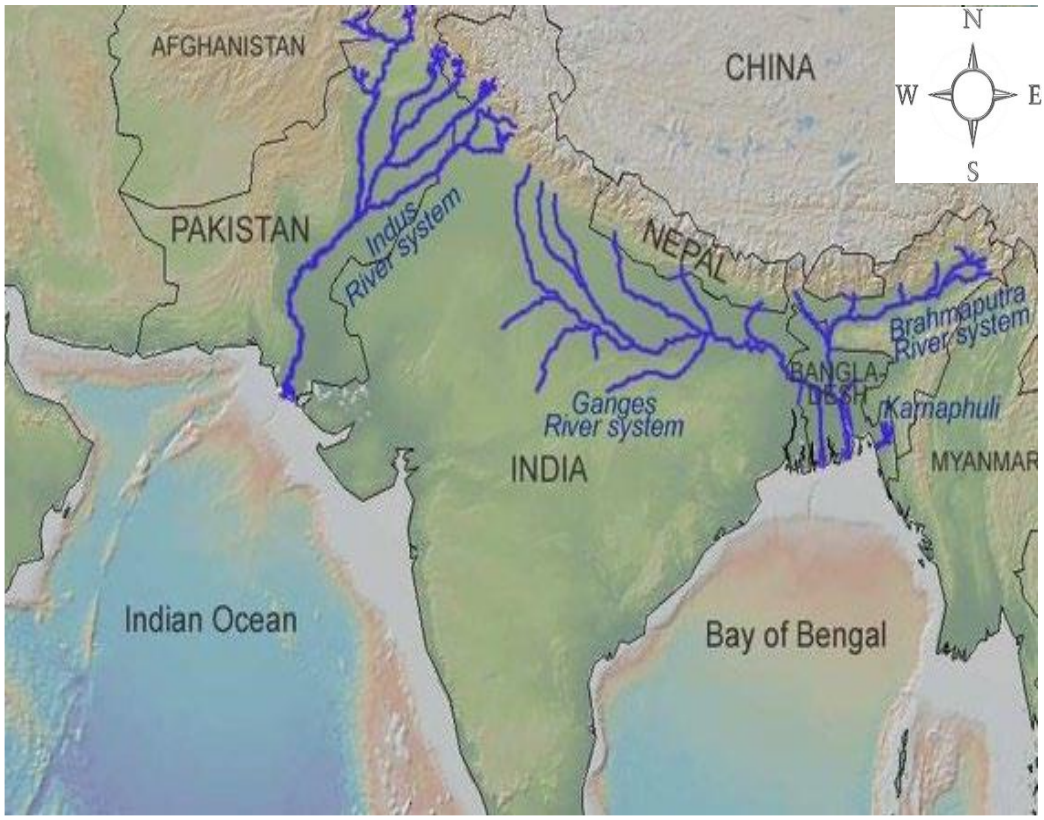

Figure 3. South Asia's geography and river systems (Courtesy: Braulik, 2012)

Diversity

There are currently about 10,120 species of reptiles; two main groups of reptiles, snakes (3,548 species) and lizards (6,199 species), turtles are not diversified by species (357 species only), In South Asia, turtles range in size from small (shell 0.06 m) to larger (shell 2 m). Differences in body size, vary in behavior, ecology, and physiology, indicating their adaptation to different environments (Das, 1996). South Asia is a hotspot of turtle diversity, there are 33 species of turtles and tortoises in South Asia (Afghanistan [3 species], Bangladesh [27 species], Bhutan [6 species], India [30], Maldives [1], Nepal [16], Pakistan [10] and Sri Lanka [3 species]) (Table 1) (Purkayastha et al., 2015).

Land Tortoises (Testudinidae): There are 60 species recognized worldwide, mostly in open areas such as arid, semi-arid, desert, and grassland (Salleh et al., 2022). There are only 4 genera and 5 species in South Asia, and they are adapted to different habitats, including forest habitats and cooler areas in lowland forests (Purkayastha et al., 2015).

Asian Hard-shell Terrapins (Geoemydidae): This is a very diverse family of turtles with 70 species worldwide (Salleh et al., 2022), 10 genera and 19 species of which are in South Asia. (Purkayastha et al., 2015). These are aquatic or semi-freshwater turtles, although some live in cool, wet forests. In recent years DNA sequencing has revealed hidden diversity in this group; for example, *Cyclemys dentata* (Asian leaf terrapin) is now treated as a separate species from *Cyclemys oldhamii* (Oldham's leaf turtle) (Salleh et al., 2022).

Softshell Turtles (Trionychidae): 30 species of soft-shell turtles are found worldwide (Salleh et al. 2022), of which 9 species of 5 genera occur in South Asia (Purkayastha et al., 2015). Softshell turtles lack hard, rigid scales instead; they possess a pliable, leathery carapace. Therefore, they are flatter and less domed than the best-selling terrapins, making it easier for them to burrow into mud or silty substrates and remain undetected. They have long necks and noses that allow them to stay out of water and breathe (Safi et al., 2016).

Diversity of freshwater turtles and tortoises among countries of South Asia (Table 1):

1. **India:** India has 30 species of inland turtles and is the most spacious among all the South Asian countries by turtle species and has all the turtle species of this region except three (*Cyclemys oldhamii* is found in Bangladesh and Nepal, and is also found outside of south Asia in Myanmar, Thailand, Vietnam, and Indonesia globally; The Russian tortoise (*Testudo horsfieldii / Agrionemys horsfieldii*), also commonly known as the Afghan tortoise, the Central Asian tortoise, Horsfield's tortoise, four-clawed tortoise, and the Russian steppe tortoise is a threatened species of tortoise in the family Testudinidae. This species is traditionally placed in *Testudo*. Due to distinctly different morphological characteristics, the monotypic genus *Agrionemys* was proposed in 1966. Today, *Testudo horsfieldii* is being accepted. *Testudo horsfieldii* (Gray, 1844) is the Indigenous land tortoise to Afghanistan, Pakistan, and southern Central Asia among three described sub-species (Karl et al., 2021); and *Lissemys ceylonensis*, which is endemic to Sri Lanka (Badola et al., 2019; Das,1991; 2008; Das & Sangupta, 2010; Ramakrishna et al., 2014; Purkayastha et al., 2015; Yadav et al., 2021; Kar et al., 2024).
2. **Bangladesh**: Bangladesh is smaller in area than Pakistan and Afghanistan but it stands as the second most specious country by terrapin diversity and has 27 species the reason is, that Bangladesh is a riverine country, A total of 58 international rivers flow through

Bangladesh, 55 from India and 3 from Myanmar (Das, 1990; Rashid & Khan 2000; Rashid & Rehman, 2014).

3. **Nepal:** The third terrapin-rich country in this region is Nepal, which has 16 species. It is a hilly country located in the center of the Himalayan range placing the country in the transitional zone between the eastern and western Himalayas. Nepal's rich biodiversity is a reflection of this unique geographic position as well as its altitudinal and climatic variations (Aryal et al., 2010; 2019; Pun et al., 2023).
4. **Pakistan:** Pakistan is the second largest country by area in South Asia but terrapin species are not rich due to physiographic and climatic conditions. All eight species of freshwater turtles are found in the Indus River system. The two land tortoises are also found one is the Russian tortoise (*Testudo horsfieldii*), which is found in Baluchistan and KPK areas adjacent to Afghanistan. The Indian star tortoise (*Geochelone elegans)* is found in Sindh and Punjab areas (Safi & Khan, 2014; Khan, 2015; Khan et al., 2015, 2016; Safi et al., 2015,2021, 2022 , 2024).
5. **Bhutan:** A total of six species, including five hard-shelled freshwater turtles and one tortoise (*Indotestudo elongata*), are recorded from this hilly country (Wangyal et al., 2012; 2020; Phuntsho et al., 2022). No soft-shelled terrapins are found in Bhutan.
6. **Afghanistan:** The complex geography of Afghanistan supports a particularly diversified fauna. The Hindu Kush mountains have been a barrier to a westward dispersal of most elements of the Indian fauna realm. As a result, most of the fauna is typically Palearctic. Only three species, including one Russian tortoise (*Testudo horsfieldii*) also known as the Afghan tortoise are found throughout Afghanistan. Two soft-shell turtles (*Nilssonia gangeticus* and *Lissemys punctata)* are found in the wetlands in the southern parts of the country, especially in the River Kabul.
7. **Sri Lanka:** Sri Lanka has no land connection to other countries of South Asia, it has one species of hard-shelled turtle, *Melanochelys trijuga,* one species of soft-shelled turtle, *Lissemys cylonensis* (which is an endemic species to Sri Lanka), and one tortoise, Indian star tortoise (*Geochelone elegans* (Dilrukshi et al., 2019).
8. **Maldives:** It is a small archipelago country with only one hard-shelled turtle species, *Melanochelys trijuga.*

Table 1. Country-wise checklist of freshwater turtles and tortoises of South Asia

Country	Hard-shelled turtles	Soft-shelled turtles	Land tortoises	Total Species
Afghanistan	-	*Nilssonia gangetica, Lissemys punctatus*	*Testudo horsfieldii*	3
Pakistan	*Hardella thurjii, Geoclemys hamiltonii, Pangshura smithii, Pangshura tectum*	*Chitra indica, Nilssonia gangeticus, Nilssonia hurum, Lissemys punctata*	*Testudo horsfieldii, Geochelone elegans*	10
India	*Pangshura smithii, Pangshura tectum, Pangshura tentoria, Pangshura sylhetensis, Batagur kachuga, Batagur dhongoka, Batagur baska, Cuora mouhotii, Cuora amboinensis, Cyclemys gemeli, Cyclemys dentata Melanochelys tricarinata, Melanochelys trijuga, Vijayachelys silvatica, Morenia petersi, Geoclemys hamiltonii, Heosemys depressa Hardella thurjii,*	*Chitra indica, Nilssonia gangeticus, Nilssonia hurum, Nilssonia nigricans, Lissemys leithii, Lissemys punctata, Pelochelys cantorii, Amyda cartilaginea*	*Indotestudo elongata, Indotestudo travancorica, Manouria emys, Geochelone elegans*	30
Nepal	*Hardella thurjii, Geoclemys hamiltonii, Pangshura smithii, Pangshura tectum, Pangshura tentoria, Batagur kachuga, Batagur dhongoka, Melanochelys trijuga, Melanochelys tricarinata, Morenia petersi, Cyclemys oldhamii*	*Chitra indica, Nilssonia gangeticus, Nilssonia hurum, Lissemys punctata*	*Indotestudo elongata,*	16
Bhutan	*Melanochelys tricarinata, Hardella thurjii, Cuora mouhotii, Cuora amboinensis, Cyclemys gemeli*	-	*Indotestudo elongata,*	6
Bangladesh	*Hardella thurjii, Geoclemys hamiltonii, Pangshura smithii, Pangshura tectum, Pangshura tentoria, Pangshura sylhetensis, Batagur kachuga, Batagur dhongoka, Batagur baska, Cuora mouhotii, Cuora amboinensis, Cyclemys gemeli, Cyclemys oldhamii Cyclemys dentate, Heosemys depressa, Morenia petersi, Melanochelys tricarinata, Melanochelys trijuga*	*Chitra indica, Nilssonia gangeticus, Nilssonia hurum, Nilssonia nigricans, Lissemys punctata, Pelochelys cantorii Amyda cartilaginea*	*Indotestudo elongata, Manouria emys*	27
Sri Lanka	*Melanochelys trijuga*	*Lissemys ceylonensis*	*Geochelone elegans*	3
Maldives	*Melanochelys trijuga*	-	-	1

Current Conservation Status

The Status of the IUCN Red List (Salleh et al. 2022)

The IUCN Red List classifies species into nine categories, with information based on population size, decline rate, geographic range, dispersal, and population rank (Table 2). The importance of applying any measures without extensive information, including suspicion and potential future threats, is emphasized: "so long as these can reasonably be supported". The "Threatened" category includes "Critically Endangered", "Endangered", and "Vulnerable" on its Red List. Table 3 shows that South Asia has 33 turtle species excluding marine turtles, and 85% of these 33 species are threatened; Source: IUCN Red List, June 2024) Tables 2-3 and Figure 4, show that South Asia has 33 turtle species excluding marine turtles, five species of four genera which are land tortoises belonging to family Testudinidae, nine species of five genera are soft-shelled freshwater turtles belong to family Trionychidae, and the other nineteen species of ten genera belong to family Geoemydidae, Asian Hard-shelled freshwater turtles. According to the IUCN Red List, three species of South Asian land tortoises (*Geochelone elegans, testudo horsfieldii,* and *Indotestudo travancorica)* are in Vulnerable (VU) status; these are considered at an increased risk of unnatural (human-caused) extinction. The other two tortoises (*Indotestudo elongate* and *Manouria emys*) are in Critically Endangered (CR) status, which indicates the Points are in a particular and extremely critical state. Three species (*Pelochelys cantorii*, *Nilssonia nigricans,* and *N. leithi*) are in Critically Endangered (CR) status among soft-shelled terrapins, three species (*Nilssonia hurum*, *N. gangeticus,* and *Chitra indica)* are declared as Endangered (EN) species, which means a very high risk of extinction in the wild. The remaining three soft-shelled freshwater turtles (*Lissemys punctata, Lissemys ceylonensi*s, and *Amyda cartilaginea)* are declared Vulnerable (VU). Eight species are declared as Endangered (EN) species, five species are in Critically Endangered (CR) status, and one species, *Pangshura tactum* is in Vulnerable (VU) status. The remaining all other species among hard-shelled freshwater turtles of family Geoemydidae are either least concern (LC), which means, these are unlikely to become extinct soon or Near Threatened (NT) means, close to being at an increased risk of extinction soon (Table 3: Fig. 4). Referring to Figure 4 and Table 3 the IUCN Red List analysis shows that 85 percent of the South Asian turtle species are threatened (VU, CR, and EN), while the remaining 15 percent are at lower risk (least concerned, LC or near threatened, NT).

The CITES Appendices (Salleh et al. 2022)

The Convention's Appendices I, II, and III are lists of species with different levels of protection from over-exploitation.

Appendix I lists the most endangered plants and animals on the CITES list. The Agreement on International Trade in Endangered Species of Wild Fauna and Flora allows international trade in specimens of these species as long as imports are non-commercial (e.g. research studies).

In Appendix II, this is a list of animals that are not currently threatened with death, but are likely to be threatened with death in the future if the illegal trade is not controlled. Trade-in specimens of Appendix-II species will be permitted by the issuance of an export license or re-export permit certificate. No import permit is necessary for these species under CITES (although a permit is needed in some countries with stricter measures than CITES requires).

Appendix III contains a list of species added at the request of a party that already regulates international trade in the species. Specimens of the species in this appendix can be traded around the world only if the proper permits or certificates are shown.

An analysis of Table 4 reveals that CITES has classified South Asian turtles as 9 species in Appendix I, in which five species from hard-shelled turtles; *Kachga baska, Batagur kachuga, Pangshura tectum, Geoclemys hamiltoni,* and *Melanochelys tricarinata,* while all the four species of genus *Nilssonia* among soft-shelled turtles are included in Appendix I. the remaining all 24 species are included in Appendix II.

This region hosts about 10% of the world's freshwater turtles and tortoises. International trade in endangered species is regulated by CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora); Appendix I and Appendix II listing is given to eight and twenty-three turtle species respectively. In this dismal phase of history, these ancient and long-lived groups of vertebrates, steps to stop their decline are urgently needed. In doing so, identification as well as knowledge of their biology are key components, particularly in formulating relevant conservation policies and halting illegal trade (Fig. 5 & 6). This article is designed to assist in the identification of tortoises and tortoises living in South Asia and to provide basic information on their biogeography, distribution, diversity, and conservation.

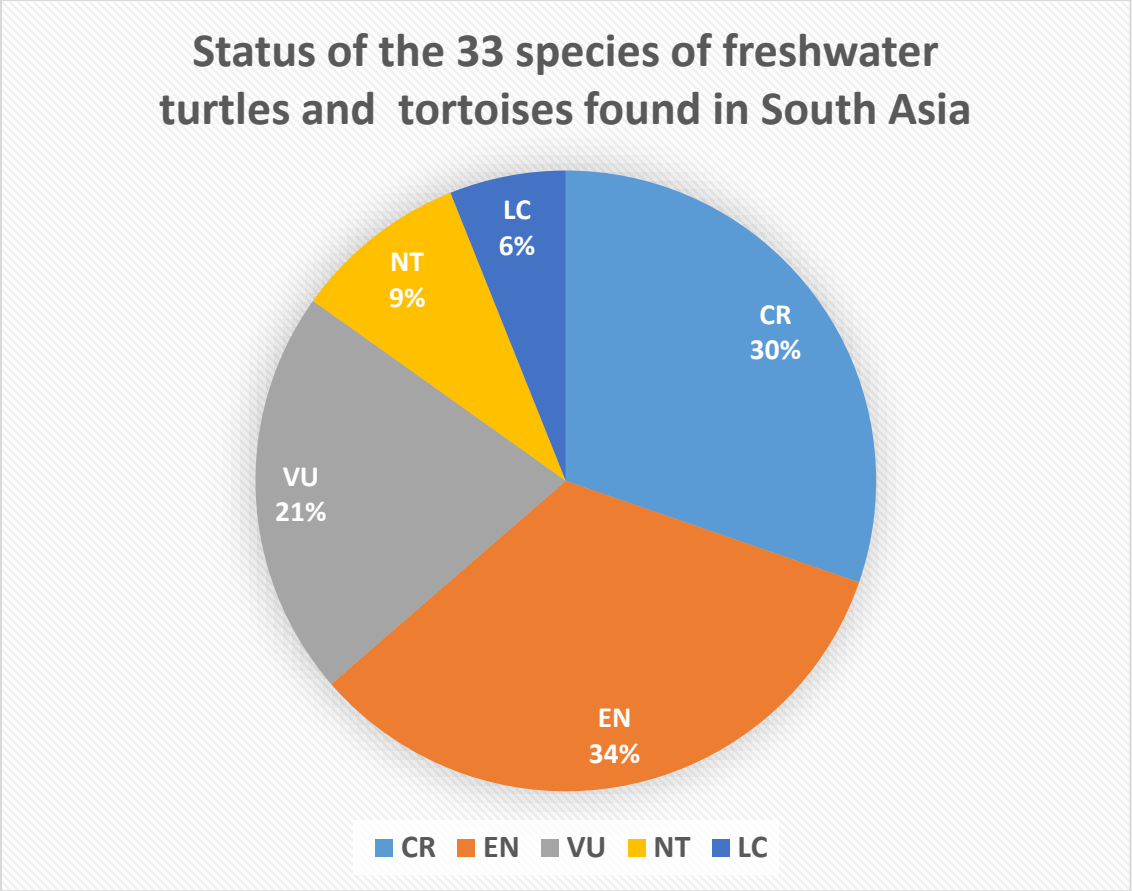

Figure 4. IUCN Status (June 2024); (**CR**: Critically Endangered, **EN**: Endangered, **VU**: Vulnerable, **NT**: Near Threatened, **LC**: Least Concern) of the 33 species of freshwater turtles and land tortoises found in South Asia

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Table 2. The IUCN Red List classifies species into nine groups (Salleh et al. 2022)

Group	Classification	Description
1.	Not evaluated (NE)	Not yet assessed by the IUCN, they indicate species that have not been reviewed enough to be assigned to a category.
2.	Data deficiency (DD)	Offering insufficient information for a proper assessment of conservation status to be made.
3.	Least concern (LC)	It is unlikely to become extinct soon.
4.	Near Threatened (NT)	Close to being at an increased risk of extinction soon.
5.	Vulnerable (VU)	It is considered at an increased risk of unnatural (human-caused) extinction without further human intervention.
6.	Endangered (EN)	A very high risk of extinction in the wild.
7.	Critically endangered (CR)	Points in a particular and extremely critical state.
8.	Extinct in the wild (EW)	Point only lives on in zoos, farms, and places outside of its native range, as surveys have shown.
9.	Extinct (EX)	Beyond a reasonable doubt, the species is no longer extant.

Table 3. Checklist of Turtle Species of South Asia as per IUCN Red List and CITES Appendices

S. No.	Family	Scientific name	Common name	IUCN Status & Version	CITES Appendix	
					I	II
1.	Testudinidae	*Testudo horsfieldii*	Afghan tortoise	VU (2.3)		+
2.	Testudinidae	*Geochelone elegans*	Indian star tortoise	VU (3.1)		+
3.	Testudinidae	*Indotestudo elongata*	Elongated tortoise	CR (3.1)		+
4.	Testudinidae	*Indotestudo travancorica*	Travancore tortoise	VU (2.3)		+
5.	Testudinidae	*Manouria emys*	Asian forest tortoise	CR (3.1)		+
6.	Geoemydidae	*Geoclemys hamiltoni*	Black pond turtle	EN (3.1)	+	
7.	Geoemydidae	*Hardella thurjii*	Brahman river turtle	EN (3.1)		+
8.	Geoemydidae	*Pangshura smithii*	Brown roofed turtle	NT (3.1)		+
9.	Geoemydidae	*Pangshura tectum*	Indian roofed turtle	VU (3.1)	+	
10.	Geoemydidae	*Pangshura tentoria*	Indian tent turtle	LC (3.1)		+
11.	Geoemydidae	*Pangshura sylhetensis*	Sylhet roofed turtle	CR (3.1)		+
12.	Geoemydidae	*Batagur kachuga*	Bengal roofed turtle	CR (3.1)	+	
13.	Geoemydidae	*Batagur dhongoka*	Three-striped roofed turtle	CR (3.1)		+
14.	Geoemydidae	*Batagur baska*	Northern river terrapin	CR (3.1)	+	
15.	Geoemydidae	*Cuora mouhotii*	Keeled box turtle	EN (3.1)		+
16.	Geoemydidae	*Cuora amboinensis*	Amboina box turtle	EN (3.1)		+
17.	Geoemydidae	*Cyclemys gemeli*	Assam leaf turtle	NT (3.1)		+
18.	Geoemydidae	*Heosemys depressa*	Arakan forest turtle	CR (3.1)		+
19.	Geoemydidae	*Morenia petersi*	Indian eyed turtle	EN (3.1)		+
20.	Geoemydidae	*Melanochelys tricarinata*	Three-keeled land turtle	EN (3.1)	+	
21.	Geoemydidae	*Melanochelys trijuga*	Indian black turtle	LC (3.1)		+
22.	Geoemydidae	*Vijayachelys silvatica*	Cochin forest cane turtle	EN (3.1)		+
23.	Geoemydidae	*Cyclemys oldhamii*	Oldham's leaf turtle	EN (3.1)		+
24.	Geoemydidae	*Cyclemys dentata*	Asian leaf turtle	NT (3.1)		+
25.	Trionychidae	*Chitra indica*	Indian narrow-headed softshell turtle	EN (2.3)		+
26.	Trionychidae	*Nilssonia gangetica*	Indian softshell turtle	EN (3.1)	+	
27.	Trionychidae	*Nilssonia hurum*	Indian peacock softshell turtle	EN (3.1)	+	
28.	Trionychidae	*Nilssonia nigricans*	Black softshell turtle	CR (3.1)	+	
29.	Trionichidae	*Nilssonia leithi*	Leith's softshell turtle	CR (3.1)	+	
30.	Trionychidae	*Lissemys punctata*	Indian flap shell turtle	VU (3.1)		+
31.	Trionychidae	*Lissemys ceylonensis*	Sri Lankan flap shell turtle	VU (3.1)		+
32.	Trionychidae	*Amyda cartilaginea*	Asiatic softshell turtle	VU (3.1)		+
33.	Trionychidae	*Pelochelys cantorii*	Asian giant softshell turtle	CR (3.1)		+

Threat Factors

The legislation and laws for the conservation of turtles should be properly implemented. Poaching areas and hotspots should be highlighted. Community-based awareness should be utilized.

Alternate livelihood opportunities should be provided to local people to avoid the turtle trade. Major threats should be detected and resolved. Habitat destruction should be discouraged. Exporting parts of turtles should be checked, and local markets should be monitored to minimize the use of turtles in as pet trade (Safi et al., 2016; Khan et al., 2016). The population trends for all VU, EN, and CR turtle populations are decreasing. This review summarizes the work of other researchers and policymakers for future reference (Table 4). In short, many factors cause threats but the main cause for concern is human activities, particularly eggs and meat consumption, medicines, and illegal trade for pets. Other threats to these South Asian turtles are illegal harvesting, habitat encroachment, pollution, and smuggling to China, Thailand, and Vietnam. These turtles are hunted and smuggled for food, medicine, and decoration. In South Asia, religious beliefs discourage the killing of turtles for food. On the other hand, building dams, taking turtle eggs, removing riparian vegetation, sand mining, and drowning in fishing nets are some of the turtle's most significant problems (Salleh et al., 2022).

Figure 5. Collecting information and noting the data in the fields about *Nilssonia gangetica*

Figure 6. Collecting data, tagging, and fixing Radio-telemetry in freshwater turtles

Table 4. A summary of recommended future research priorities (Salleh et al., 2022)

Topic	Method
Ecosystem effects	Monitor key turtle habitats to generate baseline data. Mesocosm experiments team up with other research disciplines and industries. Create strategies to identify and measure the trophic exchange of plastic, related poisons, and bioaccumulation. Explore the effect of plastics on the cycle of bentho-pelagic coupling.
Impacts on nesting beaches	Record perceptions of experiences with seashore garbage for females and hatchlings. Use oceanographic demonstrating to conjecture how and when key waterfront regions are prone to being affected by plastic contamination.
New sites	The purpose of the examination is to recognize new nesting zones, especially if current nesting locales become unsatisfactory because of improvement or environmental-driven change.
Embryology	Developing and accessing a reliable indicator of hatchling health, comprehending endocrine influences on embryology, and further research into the role of home site selection in hatchling development.
Molecular	There are numerous ways to deal with understanding the spatial biology of turtles, counting hereditary qualities, and natural biomarkers like stable isotopes.
Conservation Management	Designing management strategies with SMART (specific, measurable, achievable, realistic, and time-based) objectives that permit assessment, variation, and the advancement of proof-based preservation will be critical to deciding the board achievement of current and future ventures.
Climate Change	Understanding cumulative impacts or developing conservation responses to climate change.
Threats	Thought of future dangers and their management in decision processes like horizontal planning. GIS should provide new insights into patterns and can greatly aid in understanding the effects of hazards and the sufficiency of relief.
Habitat Restoration	The carrying capacity of territory is a significant consideration in living space reclamation. A few researchers have attempted to explain the general or current-carrying capacities of specific biological systems, though much more work is needed here.
eDNA	Streamlining field techniques for turtle eDNA assortment, further testing primer explicitness through trials of tests containing numerous species' DNA, and creating primers focusing on other turtle networks could extraordinarily improve the recognition rates of uncommon species.
nDNA	Nuclear DNA markers (e.g., microsatellites, SNPs) are expected to confirm and further assess the hereditary portrayal of turtles in the EP as the information from mt-DNA markers just reflects variety among female genealogies.
Microbiology	Harmful microorganisms such as viruses, bacteria, parasites, and fungi have not yet been investigated on turtles through meta-barcoding, which has the potential to spread among or between hosts. Aside from that, future research could look into the impact of the dominant phylum (Proteobacteria) and genus (*Cetobacterium*).

Conclusion

We face serious and urgent challenges to the resilience of turtles in several species. Without intervention, valuable species will be extinct within the next few decades. Re-introduction of new projects should be initiated for these turtle species shortly so that there is adequate time to study and refine the methodologies for conducting research related to turtles for their conservation and current population status. Some of the future research outlined in this review could help researchers

to collaborate to save these turtles for which we are so passionate. This review's benefits may help the readers understand the risks and threats to turtles and set goals for how long we should be able to control these threats, and how should be, we should design new SOPs, strategies, and future planning for practical conservation works. Government, academic, and NGO authorities should initiate studies that include the distribution, population estimates, and economic benefits of these undocumented animals with sufficient information to determine the population.

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