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Unveiling the Marvels of Indian Wetlands: Distribution, Ecological Importance, Challenges, and Conservation

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Abstract

Comparable to tropical evergreen forests or coral reefs, wetland ecosystems are among the most dynamic and productive ecosystems on the planet. A region's dynamism may have a substantial impact on its ecological sustainability. Exploring the distribution, range, categorization, ecological functions, biological variety, and dangers to India's wetland diversity is the goal of this article. The management of irrigation water, groundwater, fisheries, non-timber forest products, water supply, recreation, and pollution control through carbon sequestration, flood control, nutrient cycles are just a few of the essential ecological services that wetlands typically provide for sustainable development in many areas. However, the growing anthropogenic activity in and around the wetlands put them under ongoing stress, which is seen as a reduction in area and has a severe impact on their hydrological, ecological, and economic functions. Wetlands are one of the most imperilled ecosystems due to the global decline in their number. India has 75 wetlands that are currently recognised as Ramsar sites, with a total coverage of roughly 1.09 million hectares and an estimated 757.06 thousand wetlands, making up around 4.7% of the total land area. India has the most wetlands in South Asia, and it sustains nearly a fifth of the region's total biodiversity. Unfortunately, between 35–60% of India's wetlands have been lost over the course of the last 40 years, necessitating the creation of new conservation techniques and a rethinking of the laws governing their protection.

Keywords: *Wetlands, Ramsar Sites, Ecological Services, Anthropogenic Activities, Hydrological Functions, Ecosystems, Conservation Strategies*

1. Introduction

Wetlands are distinctive habitats that thrived with diverse and long-persistent biota. Such habitats are considered transitional lands between terrestrial and aquatic ecosystems where the water table is usually at or near the surface or the land is covered by shallow water (Cowardin *et al.*, 1979). Apart from their ecological importance, wetlands are also contributing to the economy of the surrounding area (Manzoor *et al.*, 2021). Wetlands are generally described as 'kidneys of the landscape' because they function as the downstream receivers of water and waste from both natural and anthropogenic sources (Mitsch and Gosselink, 1986). The hydrology of a particular wetland largely assists in determining the development of soil and also describes the various types of flora and fauna communities in the surrounding environment. Wetlands are also known as the nurseries of life as they provide a suitable habitat for the survival of enormous aquatic and terrestrial species. They also act as critical habitats for migratory birds by providing foraging sites, breeding areas, and refuge for the

birds. Wetlands are not only important for their productive environment but also their biodiversity and incredible biosystem it support. Therefore, these water bodies should be conserved and managed sustainably.

For the conservation of wetlands on an international scale, the convention of wetlands of international importance, or the Ramsar convention was held in 1971 and came into force in 1975. A site qualifies to be identified as a Ramsar site only if it contains a representative, rare, or unique type of a natural or near-natural wetland type or has vulnerable, endangered, or critically endangered species present there. There must be a presence of twenty thousand or more water birds, and the wetland must support continuously 1% of the individuals in a population of one species or subspecies of water birds or if it can support threatened ecological communities, or populations of either plant species or animal species or both, which are at a critical stage in their life cycles, or it must be important for maintaining the biological diversity of a particular biogeographic region. The proposed wetland must have a refuge advantage to the water birds during adverse conditions, there must be indigenous fish subspecies, the presence of an important source of food for fishes, spawning ground, nursery, and migration path for the indigenous fish species, there must be possibilities for recreation and eco-tourism, etc. (Convention on Wetlands of International Importance Especially as Waterfowl Habitat. Ramsar, 2 February 1971). Throughout the world, 2435 Ramsar sites with a collective area of 254,685,425 ha have been identified under this convention. Europe leads the list with 1125 Ramsar sites, followed by Africa (420), Asia (374), North America (220), Latin America and the Caribbean (212), and Oceania (84) (Ramsar Secretariat, 2021). India has also become a party to this multination effort for the conservation of wetlands in 1982. India has a significant number of recognized wetlands out of which 75 of them are recognized as Ramsar wetland sites (Ramsar Secretariat, 2021). Figure 1 shows the map of India with 75 Ramsar sites with their respective coordinates and the states where these are located (RAMSAR Wetland sites). The Ramsar site and all other wetlands in India have great ecological and economic significance but have been ignored.

Pertaining to the significance of wetlands, the purpose of this review article is to summarize the status of wetlands in India by depicting their classification and the occupied area. Further, it includes the elucidations concerning ecosystem advantages, services provided, various undergoing threats, and the different approaches and strategies adopted in India for their conservation and management.

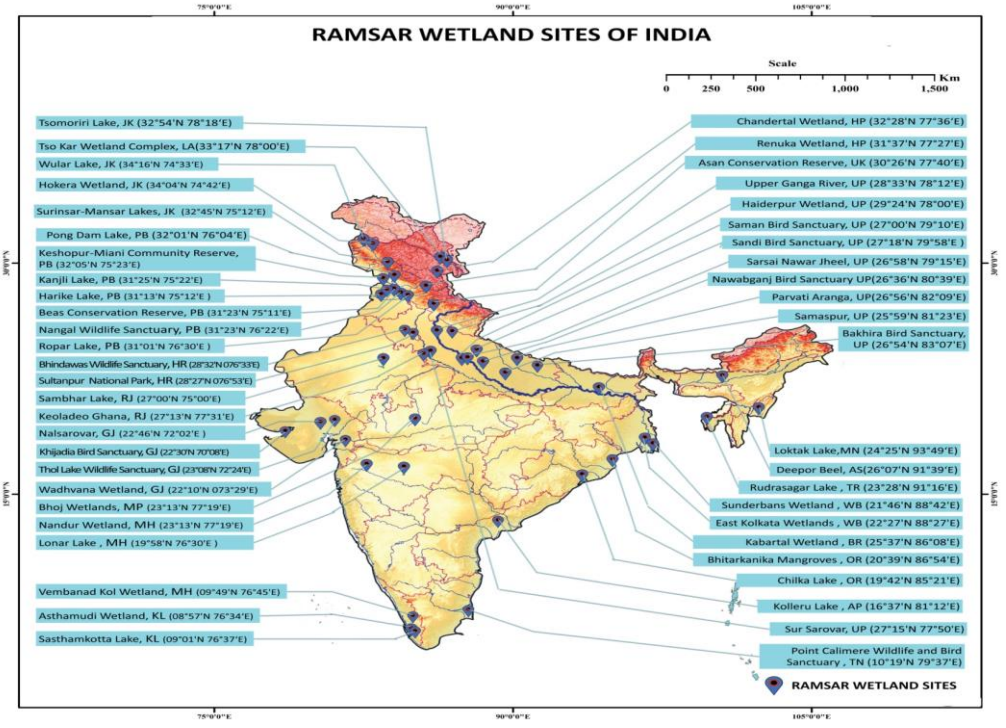

Figure 1: Indian Map showing different 49 RAMSAR Sites of India

(JK-Jammu and Kashmir, LA-Ladakh, PB-Punjab, HR-Haryana, RJ-Rajasthan, GJ-Gujarat, MP-Madhya Pradesh, MH-Maharashtra, KL-Kerala, HP-Himachal Pradesh, UK-Uttrakhand, UP-Uttar Pradesh, MN-Manipur, AS-Assam, TR-Tripura, WB-West Bengal, BR-Bihar, OR-Orissa, AP-Andhra Pradesh, TN-Tamil Nadu, N-North, E-East).

2. Area wise status and types of wetland in India

India, with its varying topography and climatic regimes, supports diverse and unique wetland habitats. The total area under wetlands in India is estimated to be around 153391.93 km^2. This accounts for 4.7% of the total geographical area of the country. The available estimates about the areal extent of wetlands in India vary widely from a lowest of 0.66% geographic area of Mizoram to a highest of 17.56% of the geographical area of Gujarat (fig. 2). In terms of total geographical area, Gujarat is the leading state under wetlands (28538.38 km^2), which is followed by West Bengal (11998.64 km^2). Among union territories in India, Lakshadweep has the highest proportion (around 96%) and Delhi has the least proportion (0.93%) of the geographical area under wetlands (Chandra *et al.*, 2021).

These wetlands are distributed in different geographical regions of India ranging from the Himalayas to the Deccan plateau, Deserts to the coastal region. The first scientific mapping of wetlands of the country was carried out using satellite data from 1992–1993 by Space Applications Centre (SAC), Ahmedabad *(National Wetland Atlas of India: A Review and Some Inferences on JSTOR)*, (Bassi *et al.*, 2014).

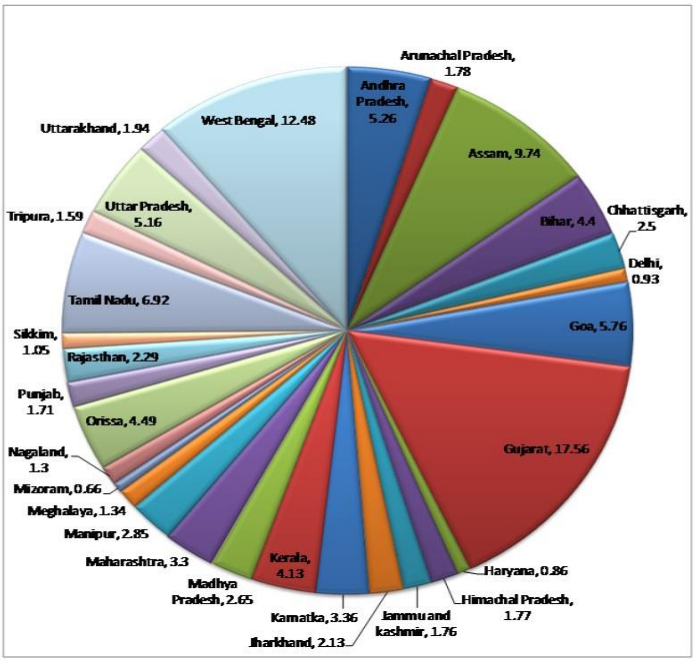

Figure 2: Geographical areal distribution of wetlands of India as per respective states and union territories in percent(Chandra *et al.* 2021).

India has over 757,000 different types of wetlands. The major wetland types are river/stream, intertidal mud flats, reservoirs, tanks, lakes/ponds, and mangrove forests. India has so many different categories of wetlands which includes mangroves (4032.78 km^2) and corals (1062.35 km^2).

Inland wetlands account for over 69%, coastal wetlands about 30% of the geographical area of India, and the Inland natural wetland category has the largest proportion of the areal percentage (about 43.7 %) followed by coastal natural which is 27.7%, after that inland man-made category with 25.6% and the least belongs to a coastal man-made category of wetland which constitutes about 2.8 % of areal extent. Figure 3 shows the area coverage of the different types of wetlands in the form of a pie chart.

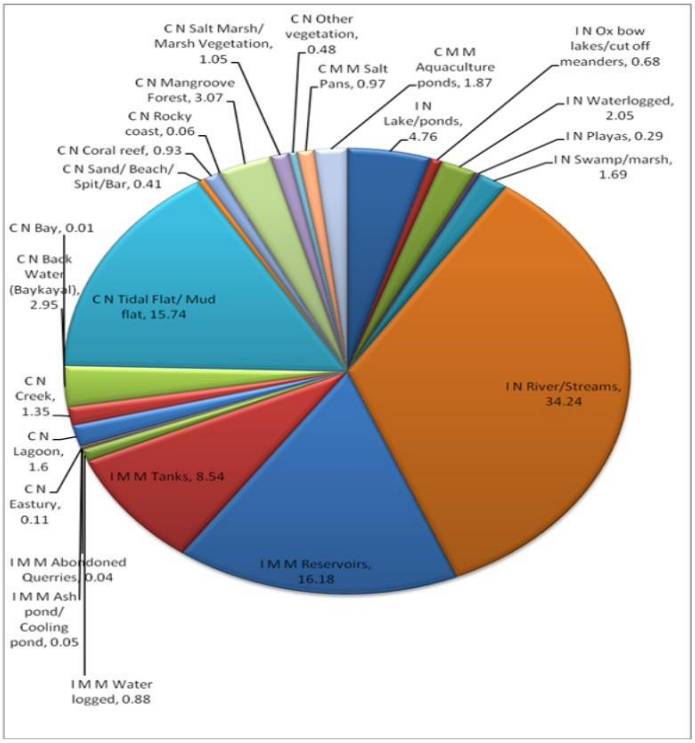

Figure 3: Classification of wetlands of India with their respective type name and geographical percent.

(IN-Inland Natural, IMM-Inland Man-Made, CN-Coastal Natural, CMM-Coastal Man-Made)

3. Overview of India's Ramsar Sites

Wetlands other than their hydrological importance are always a vast site for the habitation of different wildlife. Wetlands are highly productive and biologically diverse systems that provide a home to at least one-third of all threatened and endangered species in India. These are utilized by not only native species but visitor species as well, which increases the overall biodiversity of wetlands. Wetlands are often the favorite feeding and resting station for migratory birds as well as a refuge along flyways for ducks, shorebirds, and waders, which in turn attract large numbers of other visiting wildlife, making them the true hub of biodiversity (Cannicci and Contini, 2009). The overview on the 75 wetlands is obtained from the Ramsar official website. To report the biodiversity of a particular wetland, we have provided the basic web link and cited the papers which are the sources for biodiversity:

Site 1: Asan Conservation Reserve

Location and Geographical Coordinates: Uttarakhand, 30°26'01"N 77°40'58"E

Biodiversity highlights: Putitor mahseer (*Tor putitora*), Ruddy shelduck (*Tadorna ferruginea*), Red-crested pochard (*Netta rufina*).

References : (Asan Conservation Reserve | Ramsar sites Information Service).

Site 2: Ashtamudi Wetland

Location and Geographical Coordinates: Kerala, 08°57'N 76°34'59"E

Biodiversity highlights: *Syzygium travencoricum*, Many species of waterfowls, unique copepod species, penacid and palaemonid prawns, short-neck clam *Paphia malabarica,* edible crabs, black clams.

References : (Ashtamudi Lake | Ramsar sites Information Service ; Arathi *et al.* 2018).

Site 3: Bakhira Wildlife Sanctury

Location and Geographical Coordinates: Uttar Pradesh, 26°54'36"N 83°07'47"E

Biodiversity highlights: Egyptian vulture (*Neophron percnopterus*), the greater spotted eagle (*Aquila clanga*), common pochard (*Aythya ferina*) and swamp francolin (*Francolinus gularis*), the oriental darter (*Anhinga melanogaster*) and woolly-necked stork (*Ciconia episcopus*) .

References: (Bakhira Wildlife Sanctury | Ramsar sites Information Service.)

Site 4: Beas Conservation Reserve

Location and Geographical Coordinates: Punjab, 31°23'41"N 75°11'40"E

Biodiversity highlights: Indus river dolphin (*Platanista gangetica minor*), Endangered masheer (*Tor putitora*) and hog deer (*Axis porcinus*) , vulnerable smooth-coated otter (*Lutrogale perspicillata*).

References : (Beas Conservation Reserve | Ramsar sites Information Service).

Site 5: Bhindawas Wildlife Sanctury

Location and Geographical Coordinates: Haryana, 28°32'01"N 76°33'01"E

Biodiversity highlights: Endangered Egyptian vulture (*Neophron percnopterus*), steppe eagle (*Aquila nipalensis*), Pallas's fish eagle (*Haliaeetus leucoryphus*) and black-bellied tern (*Sterna acuticauda*), greylag goose (*Anser anser*), Indian cormorant (*Phalacrocorax fuscicollis*). Mammals recorded at the site include Nilgai (*Boselaphus tragocamelus*), Common Mongoose (*Herpestes edwardsi*), and Black-naped hare (*Lepus nigricollis*).

References : (Bhindawas Wildlife Sanctury | Ramsar sites Information Service)

Site 6: Bhitarkanika Mangroves

Location and Geographical Coordinates: Orissa, 20°39'N 86°54'E

Biodiversity highlights: Olive Ridley sea turtle, Crocodylus porosus.

References : (Gopi and Pandav, 2007).

Site 7: Bhoj Wetlands

Location and Geographical Coordinates: Madhya Pradesh, 23°13'59"N 77°19'59"E

Biodiversity highlights: Little Grebe (*Podiaps ruficollis*), Large Cormorant (*Phalacrocorax carbo*), Indian Cormorant (*Phalacrocorax fuscicollis*), Bronze-Winged (*Jacana Metapidius*), Large pied wagtail (*Motaciilla maderospaternsis*) .

References : (Avian Diversity of Bhoj Wetland: A Ramsar site of Central India).

Site 8: Chandertal Wetland

Location and Geographical Coordinates: Himachal Pradesh, 32°28'59"N 77°36'E

Biodiversity highlights: Marmot *(Marmota bobak)*, Snow leopard *(Panthera uncia)*, Red Fox *(Vulpes vulpes)*, Goat *(Capara ibex)*, Blue Sheep *(Pseudois nayaur)*, Wild Chukar *(Alectors Chukar)*, Snow Cock *(Tetrogallus spp)*, Golden Eagle *(Aquila chrysaetos)*, Black Winged Stilt *(Himantopus himantopus)*, Brahminy Duck *(Todorna ferruginea)* .

References : (Chandertal Wetland | Ramsar sites Information Service).

Site 9: Chilka Lake

Location and Geographical Coordinates: Orissa, 19°42'N 85°21'E

Biodiversity highlights: The Irrawaddy dolphin (*Orcaella brevirostris*), Bottle neck Dolphins. The Irrawaddy dolphin is flagship species of this wetland.

References : (Chilka lake | Ramsar sites information services).

Site 10: Deepor Beel

Location and Geographical Coordinates: Assam, 26°07'59"N 91°39'E

Biodiversity highlights: Spotbilled pelican (*Pelecanus philippensis*), Lesser adjutant stork (*Leptoptilos javanicus*), Baer's pochard (*Aythya baeri*), Pallas sea eagle (*Haliaeetus leucogaster*), Spot-billed pelican, Greater adjutant stork (*Leptoptilos dubius*), Migratory water fowl, the Siberian crane (*Grus leucogeranus*). These are endangered species of birds. Wild Asian elephants (*Elephas maximus*), the barking deer, Leopard, Jungle cat, Chinese porcupine and Sambar are also found in the beel.

References : (Deepor Beel | Ramsar sites Information Service).

Site 11: East Kolkata Wetlands

Location and Geographical Coordinates: West Bengal, 22°27'N 88°27'E

Biodiversity highlights: Silver carp, Tilapia, Marsh mongoose, Small Indian Mongoose, Palm Civet, Small Indian Civet, Checkered Keel Back (*Fowlea piscator*), Smooth water snake (*Enhydris enhydris*), Buff Striped Keel Back (*Amphiesma stolata*) and Bronze Back Tree Snake (*Tendrelaphis pristis*).

References: (Ghosh, 2004).

Site 12: Haiderpur Wetland

Location and Geographical Coordinates: Uttar Pradesh, 29°24'59"N 78°00'59"E

Biodiversity highlights: It supports about 15 globally threatened species, such as the critically endangered gharial (*Gavialis gangeticus*) and the endangered hog deer (*Axis porcinus*), black-bellied tern (*Sterna acuticauda*), steppe eagle (*Aquila nipalensis*), Indian skimmer (*Rynchops albicollis*) and gold mahseer (*Tor putitora*). The site supports more than 25,000 waterbirds, serves as a breeding site for the near-threatened Indian grassbird (*Graminicola bengalensis*) and provides refuge to the northern subspecies population of the vulnerable swamp deer (*Rucervus duvaucelii*) during its seasonal flood-driven migration. The site also regularly supports more than 1% of the population of greylag goose (*Anser anser*) and bar-headed goose (*Anser indicus*).

References: (Ramsar Secretariat, 2021).

Site 13: Harike Lake

Location and Geographical Coordinates: Punjab, 31°13'N 75°12'E

Biodiversity highlights: Yellow-crowned woodpecker (*Dendrocopos mahrattensis*), Water cock (*Gallicrex cinerea*), Pallas gull (*Ichthyaetus ichthyaetus*), Cotton pygmy goose (*Nettapus coromandelianus*), Tufted duck (*Aythya fuligula*), Sulphur-bellied warbler (*Phylloscopus griseolus*), Horned grebe (*Podiceps auritus*), Black-necked grebe (*Podiceps nigricollis*), Great crested grebe (*Podiceps cristatus*), White-browed fantail (*Rhipidura aureola*), Brown shrike (*Lanius cristatus*), Common woodshrike (*Tephrodornis pondicerianus*), White-tailed stonechat (*Saxicola leucurus*), White-crowned penduline tit (*Remiz coronatus*) ,The Indus Dolphin (*Platanista gangetica minor*), Gharial (*Gavialis gangeticus*).

References: (Harike Pattan Sanctuary Bird Sanctuary), (Harike Lake | Ramsar sites Information Service).

Site 14: Hokera Wetland

Location and Geographical Coordinates: Jammu and Kashmir, 34°04'59"N 74°42'E

Biodiversity highlights: Reed bed of Kashmir is found here only, 68 waterfowl species like Large Egret, Great Crested Grebe, Little Cormorant, Common Shelduck, Tufted Duck and endangered White-eyed Pochard, coming from Siberia, China, Central Asia and Northern Europe.

References : (Hokera Wetland | Ramsar sites Information Service).

Site 15: Kabartal Wetland

Location and Geographical Coordinates: Bihar, 25°37'05"N 86°08'22"E

Biodiversity highlights: Five critically endangered species inhabit this Site, including two waterbirds, The Sociable Lapwing (*Vanellus gregarius*) and Baer's pochard (*Aythya baeri*), Three vultures – the Red-headed Vulture (*Sarcogyps calvus*), White-rumped vulture (*Gyps bengalensis*) and Indian vulture (*Gyps indicus*).

References : (Kabartal Wetland | Ramsar sites Information Service).

Site 16: Kanjli Lake

Location and Geographical Coordinates: Punjab, 31°25'N 75°22'E

Biodiversity highlights: The common fish species of *Catla catla*, *Cythus striatus*, *Cirrhinus mrigala*, *Channa marulius* (Great snakehead), *Labeo calbasu* and *Labeo rohita*, The tortoise is the common reptile found in this wetland, The variousspeciesof goose,Pintail, Mallard Whiteeyedpochard, Wigeon, Tuftedpochard, Commonteal, an d Shoveller,The Indian civet, Mongoose, Indian porcupine, Squirrel and Common Indian hare are also found here.

References : (Kanjli Wetland | Ramsar sites Information Service).

Site 17: Keoladeo Ghana National Park

Location and Geographical Coordinates: Rajasthan, 27°13'N 77°31'59"E

Biodiversity highlights: Siberian crane, Greater spotted eagle, Sambar deer, Rhesus macaque, Hanuman langur, Blackbuck, Small Indian mongoose, Common Indian Gray mongoose, Nilgai, Wild boar , Indian porcupine, Jungle Cat, Leopard cat, Fishing cat, Asian palm civet and Small Indian Civet , Bengal fox Golden Jackals, Striped Hyena, Smooth-Coated Otter. This wetland is also termed as bird-paradise.

References : (Mathur *et al.,* 2009).

Site 18: Keshopur-Miani Community Reserve

Location and Geographical Coordinates: Punjab, 32°05'34"N 75°23'23"E

Biodiversity highlights: Threatened species present include the vulnerable Common Pochard (*Aythya ferina*) and the endangered spotted pond turtle (*Geoclemys hamiltonii*).

References : (Keshopur-Miani Community Reserve | Ramsar sites Information Service).

Site 19: Khijadia Wildlife Sanctuary

Location and Geographical Coordinates: Gujarat, 22°30'52"N 70°08'45"E

Biodiversity highlights: Pallas's fish-eagle (*Haliaeetus leucoryphus*), Indian skimmer (*Rynchops albicollis*), the vulnerable common pochard (*Aythya ferina*), Dalmatian pelican (*Pelecanus crispus*), Greylag goose (*Anser anser*) and common crane (*Grus grus*).

References: (Khijadia Wildlife Sanctuary | Ramsar sites Information Service.)

Site 20: Kolleru Lake

Location and Geographical Coordinates: Andhra Pradesh, 16°37'N 81°12'E

Biodiversity highlights: The critically endangered Spoon-billed Sandpiper, (Kolleru committee report 2010).The lake serves as a foraging ground for resident as well as migratory birds. At present, 6000 Spot-billed Pelicans, 5000 Painted Storks and 5000 Asian Open-bills are estimated to be found in Kolleru.

References : (Kolleru Wildlife Sanctuary| Ramsar sites Information Service).

Site 21: Loktak Lake

Location and Geographical Coordinates: Manipur, 24°25'59"N 93°49'E

Biodiversity highlights: Endangered Sangai (state animal), *Rucervus eldii eldii* or Manipur brow-antlered deer (*Cervus eldi eldi*), Indian python, Sambar, Barking deer, Rhesus monkey, Hoolock gibbon, Stump-tailed macaque, Large Indian civet (*Viverra zibetha*), Wild bear, *Muntiacus muntjak*, Marbled cat and Temminck's Golden Cat.

References : (WWF India - Loktak Lake).

Site 22: Lonar Lake

Location and Geographical Coordinates: Maharashtra, 19°58'33"N 76°30'30"E

Biodiversity highlights: The Site inhabits 160 species of birds including the vulnerable Asian Woollyneck (*Ciconia episcopus*) and Common Pochard (*Aythya ferina*), 46 species of reptiles, and 12 species of mammals including the iconic Grey Wolf (*Canis lupus*).

References : (Lonar Lake | Ramsar sites Information Service).

Site 23: Nalsarovar Bird Sanctuary

Location and Geographical Coordinates: Gujarat,22°46'32"N 72°02'21"E

Biodiversity highlights: Bird species are Rosy pelicans, Flamingoes, White Storks, Brahminy ducks, greater flamingos, Herons, Purple moorhen, Pelicans, Lesser flamingos and four species of bitterns, crakes, grebes. Endangered Wild Ass and Black Buck are present in this wetland.

References : (Nalsarovar | Ramsar sites Information Service).

Site 24: Nandur Madhameshwar

Location and Geographical Coordinates: Maharashtra, 20°01'18"N 74°06'24"E

Biodiversity highlights: Deolali minnow (*Parapsilorhynchus prateri*), Indian vulture (*Gyps indicus*) and white-rumped vulture (*Gyps bengalensis*) are critically endangered species of this ramsar site.

References : (Nandur Madhameshwar | Ramsar sites Information Service).

Site 25: Nangal Wildlife Sanctuary

Location and Geographical Coordinates: Punjab, 31°23'46"N 76°22'16"E

Biodiversity highlights: The endangered Indian pangolin (*Manis crassicaudata*) and Egyptian vulture (*Neophron percnopterus*) and the vulnerable leopard (*Panthera pardus*) are present here

References : (Nangal Wildlife Sanctuary | Ramsar sites Information Service).

Site 26: Nawabganj Bird Sanctuary

Location and Geographical Coordinates: Uttar Pradesh, 26°36'49"N 80°39'17"E

Biodiversity highlights: This site inhabits globally threatened species like Egyptian vulture (*Neophron percnopterus*) and Pallas fish eagle (*Haliaeetus leucoryphus*), in addition to it, vulnerable species like Lesser Adjutant (*Leptoptilos javanicus*) and Woolly-necked Stork (*Ciconia episcopus*), Golden Jackal (*Canis aureus*) and Jungle cat (*Felis chaus*) are found here. This wetland is considered heaven for different bird species as 220 species of resident as well as migratory species of birds are reported from this wetland.

References : (Nawabganj Bird Sanctuary | Ramsar sites Information Service).

Site 27: Parvati Agra Bird Sanctuary

Location and Geographical Coordinates: Uttar Pradesh, 26°56'09"N 82°09'45"E

Biodiversity highlights: The Sanctuary is a refuge for some of India's threatened vulture species: the critically endangered white-rumped vulture (*Gyps bengalensis*) and Indian vulture (*Gyps indicus*), and the endangered Egyptian vulture (*Neophron percnopterus*) have been reported from this site.

References : (Parvati Arga Bird Sanctuary | Ramsar sites Information Service).

Site 28: Point Calimere Wildlife and Bird Sanctuary

Location and Geographical Coordinates: Tamil Nadu, 10°19'N 79°37'59"E

Biodiversity highlights: The vulnerable species Spoonbill Sandpiper (Euryhorhynchus pygmaeus) and Grey Pelican (Pelecanus philippensis) are reported from this Site

References : (Point Calimere Wildlife and Bird Sanctuary | Ramsar sites Information Service).

Site 29: Pong Dam Lake

Location and Geographical Coordinates: Himachal Pradesh, 32°01'N 76°04'59"E

Biodiversity highlights: Egyptian vulture (Nephron percnopterus) and black bellied tern (Sterna acuticauda) are under the category Endangered; Ferruginous duck (Aythya nyroca), Himalayan griffon (Gyps himalayensis), great thick knee (Esacus recurvirostris), river lapwing (Vanellus duvaucelii), river tern (Sterna aurentia) are under the category near threatened; Woolly necked stork (Ciconia nigra) and greater spotted eagle (Clanga clanga) are listed under category Vulnerable according to IUCN status.

References : (Sharief *et al.*, 2018).

Site 30: Renuka Wetland

Location and Geographical Coordinates: Himachal Pradesh, 31°37'N 77°27'E

Biodiversity highlights: There are 103 species of birds present in this site of which 66 are resident and rest are migratory species e.g. Pheasants, Egrets, Crimson-breasted barbet, Mayna, Bulbul, Herons, Mallards and Lapwing. Among ungulates Barking deer, Sambhar, and Ghorals are found in this site.

References : (Renuka Wetland | Ramsar sites Information Service).

Site 31: Ropar Lake

Location and Geographical Coordinates: Punjab, 31°01'N 76°30'E

Biodiversity highlights: The site is an important breeding place for the nationally protected Hog Deer, Sambar, Smooth Indian Otter, several reptiles, and the endangered Indian Pangolin (Manis crassicaudata)

References : (Ropar | Ramsar sites Information Service).

Site 32: Rudrasagar Lake

Location and Geographical Coordinates: Tripura, 23°28'59"N 91°16'E

Biodiversity highlights: The commercially important fish species are reported from this site e.g., *Botia, Notopterus, Chitala, Mystus, Ompok pabda, Labeo bata*, and freshwater scampi. It is an ideal habitat for IUCN Red listed Three-striped Roof Turtle *Kachuga dhongka*

References : (Rudrasagar Lake | Ramsar sites Information Service).

Site 33: Saman Bird Sanctuary

Location and Geographical Coordinates: Uttar Pradesh, 27°00'56"N 79°10'36"E

Biodiversity highlights: About 187 species of birds are reported from this site. The species present there are greylag goose (*Anser anser*), Vulnerable species including sarus crane (*Grus antigone*) and greater spotted eagle (*Aquila clanga*)

References : (Saman Bird Sanctuary | Ramsar sites Information Service).

Site 34: Samaspur Bird Sanctuary

Location and Geographical Coordinates: Uttar Pradesh, 25°59'44"N 81°23'19"E

Biodiversity highlights: The Sanctuary harbours threatened species such as the endangered Egyptian vulture (*Neophron percnopterus*) and Pallas's fish eagle (*Haliaeetus leucoryphus*)

References : (Samaspur Bird Sanctuary | Ramsar sites Information Service).

Site 35: Sambhar Lake

Location and Geographical Coordinates: Rajasthan, 27°00'N 75°00'E

Biodiversity highlights: Bar-headed Geese, Greylag Geese, Pied Avocet, Northern Shoveler, Common Teal, including large numbers of flamingos are reported from this wetland. The IUCN Red List of Threatened Species— Lesser Flamingo and Black-tailed Godwit are also found here

References : (Migratory Birds Retreat from a 'Shrinking' Sambhar Lake: Study | Jaipur News - Times of India).

Site 36: Sandi Bird Sanctuary

Location and Geographical Coordinates: Uttar Pradesh, 27°18'49"N 79°58'19"E

Biodiversity highlights: It harbours over one percent of the South Asian populations of common teal (*Anas crecca*), red-crested pochard (*Netta rufina*) and ferruginous duck (*Aythya nyroca*), while the vulnerable sarus crane (*Grus antigone*) are also reported within the Sanctuary.

References : (Sandi Bird Sanctuary | Ramsar sites Information Service).

Site 37: Sarsai Nawar Jheel

Location and Geographical Coordinates: Uttar Pradesh, 26°58'08"N 79°15'02"E

Biodiversity highlights: The one biggest beneficiary is the vulnerable sarus crane (*Grus antigone*) which is the largest flock in the region. Other threatened species present include the critically endangered white-rumped vulture (*Gyps bengalensis*) and endangered woolly-necked stork (*Ciconia episcopus*).

References : (Sarsai Nawar Jheel | Ramsar sites Information Service).

Site 38: Sasthamkotta Lake

Location and Geographical Coordinates: Kerala, 09°01'59"N 76°37'E

Biodiversity highlights: Some 27 freshwater fish species are present. The water contains no common salts or other minerals and supports no water plants; a larva called "cavaborus" abounds and eliminates bacteria in the water, thus contributing to its exceptional purity.

References : (Sasthamkotta Lake | Ramsar sites Information Service).

Site 39: Sunderbans Wetland

Location and Geographical Coordinates: West Bengal, 21°46'29"N 88°42'51"E

Biodiversity highlights: This site is "Tiger Conservation Landscape" of global importance for Tigers. It also inhabits critically endangered species like Northern River Terrapin (*Batagur baska*), Irrawaddy dolphin (*Orcaella brevirostris*), and vulnerable species like fishing cat (*Prionailurus viverrinus*). Two of the world's four horseshoe crab species are also found here.

References : (Sundarban Wetland | Ramsar sites Information Service).

Site 40: Sultanpur National Park

Location and Geographical Coordinates: Haryana, 28°27'54"N 76°53'31"E

Biodiversity highlights: It supports more than ten globally threatened species including the critically endangered sociable lapwing (*Vanellus gregarius*), the endangered Egyptian vulture (*Neophron*

percnopterus), saker falcon (*Falco cherrug*), Pallas's fish eagle (*Haliaeetus leucoryphus*) and black-bellied tern (*Sterna acuticauda*). Bar-headed goose (*Anser indicus*), greylag goose (*Anser anser*) are also found here.

References : (Sultanpur National Park | Ramsar sites Information Service).

Site 41: Surinsar-Mansar Lakes

Location and Geographical Coordinates: Jammu and Kashmir, 32°45'N 75°12'E

Biodiversity highlights: The twin-sister lake supports CITES and IUCN Red-listed *Aspideretes gangeticus, Lissemys punctata,* and *Mansariella lacustris*. Migratory waterfowls like *Gallinula chloropus, Fulica atra, Aythya fuligula, Podiceps nigricollis* and various Anas species living in this site. Different species of deer like spotted deer, barking deer, mammals like Nilgai, etc. are also found here.

References : (Surinsar-Mansar Lakes | Ramsar sites Information Service).

Site 42: Sur Sarovar

Location and Geographical Coordinates: Uttar Pradesh, 27°15'06"N 77°50'24"E

Biodiversity highlights: Threatened species include the vulnerable Greater spotted eagle (*Clanga clanga*), Sarus crane (*Grus antigone*) and catfish *Wallago attu*. The greylag goose (*Anser anser*) are reported from here.

References : (Sur Sarovar | Ramsar sites Information Service).

Site 43: Tso Kar Wetland Complex

Location and Geographical Coordinates: Ladakh, 33°17'53"N 78°00'42"E

Biodiversity highlights: Endangered saker falcon (*Falco cherrug*) and Asiatic wild dog or dhole (*Cuon alpinus laniger*), and the vulnerable snow leopard (*Panthera uncia*). Breeding areas in India for the black-necked crane (*Grus nigricollis*)

References : (Tso Kar Wetland Complex | Ramsar sites Information Service).

Site 44: Tsomoriri Lake

Location and Geographical Coordinates: Jammu and Kashmir, 32°54'N 78°18'E

Biodiversity highlights: Most endangered cranes, the Black-necked crane (Grus nigricollis), and the only breeding ground for Bar-headed geese in India. The Great Tibetan Sheep or Argali (Ovis ammon hodgsoni) and Tibetan Wild Ass (Equus kiang) are endemic to the Tibetan plateau.

References : (Tsomoriri | Ramsar sites Information Service).

Site 45: Thol Lake Wildlife Sanctuary

Location and Geographical Coordinates: Gujarat, 23°08'29"N 72°24'39"E

Biodiversity highlights: It is habitat to the critically Endangered white-rumped vulture (*Gyps bengalensis*) and sociable lapwing (*Vanellus gregarius*), and the vulnerable sarus crane (*Grus antigone*), common pochard (*Aythya farina*) and lesser white-fronted goose (*Anser erythropus*), glossy ibis (*Plegadis falcinellus*). Blackbuck (*Antilope cervicapra*) is also found here.

References : (Ramsar Convention, 2014) .

Site 46: Upper Ganga River (Brijghat to Narora Stretch)

Location and Geographical Coordinates: Uttar Pradesh, 28°33'N 78°12'E

Biodiversity highlights: Gharial, Ganges River Dolphin, Crocodile, six different species of turtles, otters are present here.

References : (Rhodin et al., 2017 ; Behera et al., 2013; Upper Ganga River | Ramsar sites Information Service).

Site 47: Vembanad Kol Wetland

Location and Geographical Coordinates: Kerala, 09°49'59"N 76°45'E

Biodiversity highlights: Over 90 species of resident birds and 50 species of migratory birds are found in the Kol area. This wetland is also rich in fish species and harbours critically endangered species include *Ompok malabaricus* and Red-tipped halfbeak (*Hyporhampus xanthopetrus*). Other fish species include *Labeo sps*., *Tetradon*, *Puntius sps*., *Wallago attu*, and *Xenentodon cancila*. one exotic fish species *Poecilia reticulate* is also found here.

References : (M.S.B. Kumar, P.K. Gopalakrishnan, 2008).

Site 48: Wadhvana Wetland

Location and Geographical Coordinates: Gujarat, 22°10'19"N 73°29'12"E

Biodiversity highlights: Pallas's fish-eagle (*Haliaeetus leucoryphus*), The vulnerable common Pochard (*Aythya ferina*), near-threatened Dalmatian pelican (*Pelecanus crispus*), Grey-headed fish-eagle (*Icthyophaga ichthyaetus*), ferruginous duck (*Aythya nyroca)*, the red-crested pochard (*Netta rufina*), the vulnerable river tern (*Sterna aurantia*), Sarus crane (*Grus antigone*) and the near-threatened black-necked stork (*Ephippiorhynchus asiaticus*).

References: (Wadhvana Wetland | Ramsar sites Information Service).

Site 49: Wular Lake

Location and Geographical Coordinates: Jammu and Kashmir, 34°16'N 74°33'E

Biodiversity highlights: Wular lake harbors different wildlife species like Common carp (*Cyprinus carpio*), Rosy barb (*Barbus conchonius*), Mosquito fish (*Gambusia affinis*), *Nemacheilus sp.*, *Crossocheilus latius*, and various Snow trout species like Sattar snowtrout (*Schizopyge curvifrons*), *Schizothorax planifrons*, *Schizothorax macropogon*, *Schizothorax longipinus*, Chirruh snowtrout (*Schizopyge esocinus*) and Chush snowtrout (*Schizopyge niger*) .

References : (WWF - Wular Lake).

Site 50: Karikili Bird Sanctuary

Location and Geographical Coordinates: Tamil Nadu, 12°35'56"N 79°50'32"E

Biodiversity highlights: Near-threatened oriental darter , (*Anhinga melanogaster*) and spot-billed pelican (*Pelecanus philippensis*).

References: (Karikili Bitd sanctury| Ramsar sites Information Service).

Site 51: Pallikaranai Marsh Reserve

Location and Geographical Coordinates: Tamil Nadu,12°55'40"N 80°13'13"E

Biodiversity highlights: Russell's viper (*Daboia siamensis*), The glossy ibis (*Plegadis falcinellus*), Grey-headed lapwings (*Vanellus cinereus*) and Pheasant-tailed jacana (*Hydrophasianus chirurgus*).

References: (Pallikaranai Marsh Reserve Forest |Ramsar sites Information Service).

Site 52: Pichavaram Mangrove Forest

Location and Geographical Coordinates: Tamil Nadu, 11°26'17"N 79°47'11"E

Biodiversity highlights: The critically endangered great white-bellied heron (*Ardea insignis*) and spoon-billed sandpiper (*Eurynorhynchus pygmeus*), the endangered spotted greenshank (*Tringa guttifer*) and the vulnerable olive ridley turtle (*Lepidochelys olivacea*).

References: (Pichavaram Mangrove Forest| Ramsar sites Information Service).

Site 53: Pala Wetland

Location and Geographical Coordinates: Mizoram, 22°11'49"N 92°54'07"E

Biodiversity highlights: The endangered Hoolock gibbon (*Hoolock hoolock*) and Phayre's leaf monkey (*Trachypithecus phayrei*)

References: (Pala Wetland| Ramsar sites Information Service).

Site 54: Sakhya Sagar

Location and Geographical Coordinates: Madhya Pradesh, 25°26'03"N 77°42'25"E

Biodiversity highlights: Mugger crocodile (*Crocodylus palustris*)

References : (Sakhya Sagar | Ramsar sites Information Service).

Site 55: Satkosia Gorge

Location and Geographical Coordinates: Odisha, 20°34'20"N 84°49'56"E

Biodiversity highlights: Red-crowned roofed turtle (*Batagur kachuga*), Indian narrow-headed softshell turtle (*Chitra indica*), Tiger (*Panthera tigris*) and black-bellied tern (*Sterna acuticauda*).

References: (Satkosia Gorge | Ramsar sites Information Service).

Site 56: Nanda Lake

Location and Geographical Coordinates: Goa, 15°14'12"N 74°06'26"E

Biodiversity highlights: Black-headed ibis (*Threskiornis melanocephalus*), Common kingfisher (*Alcedo atthis*), Wire-tailed swallow (*Hirundo smithii*), bronze-winged jacana (*Metopidius indicus*), brahminy kite (*Haliastur indus*), intermediate egret (*Ardea intermedia*), little cormorant (*Microcarbo niger*) and lesser whistling duck (*Dendrocygna javanica*).

References: (Nanda Lake | Ramsar sites Information Service).

Site 57: Gulf of Mannar Marine Biosphere Reserve

Location and Geographical Coordinates: Tamil Nadu, 09°06'57"N 78°47'12"E

Biodiversity highlights: The dugong (*Dugong dugon*), Whale shark (*Rhincodon typus*), Green sea turtle (*Chelonia mydas*), Hawksbill turtle (*Eretmochelys imbricata*) and Indo-Pacific humpback dolphin (*Sousa chinensis*).

References : (Gulf of Mannar Marine Biosphere Reserve| Ramsar sites Information Service).

Site 58: Ranganathittu Bird Sanctuary

Location and Geographical Coordinates: Karnataka, 12°24'28"N 76°40'55"E

Biodiversity highlights: Painted stork (*Mycteria leucocephala*), Spot-billed pelican (*Pelecanus philippensis*) and black-headed ibis (*Threskiornis melanocephalus*).

References : (Ranganathittu Bird Sanctuary | Ramsar sites Information Service).

Site 59: Vembannur Wetland Complex

Location and Geographical Coordinates: Tamil Nadu, 08°10'54"N 77°22'34"E

Biodiversity highlights: The Indian river tern (*Sterna aurantia*), the spotted greenshank (*Tringa guttifer*), the garganey (*Anas querquedula*) and the grey pelican (*Pelecanus philippensis*).

References: (Vembannur Wetland Complex | Ramsar sites Information Service).

Site 60: Vellode Bird Sanctuary

Location and Geographical Coordinates: Tamil Nadu, 11°15'06"N 77°39'06"E

Biodiversity highlights: Indian river tern (*Sterna aurantia*), Oriental Darter (*Anhinga melanogaster*) and Painted Stork (*Mycteria leucocephala*).

References : (Vellode Bird Sanctuary | Ramsar sites Information Service).

Site 61: Udhayamarthandapuram Bird Sanctuary

Location and Geographical Coordinates: Tamil Nadu, 10°27'02"N 79°33'16"E

Biodiversity highlights: The Oriental Darter (*Anhinga melanogaster*), Black-headed ibis (*Threskiornis melanocephalus*), Eurasian wigeon (*Anas Penelope*), Northern pintail (*Anas acuta*) and Garganey (*Anas querquedula*).

References : (Udhayamarthandapuram Bird Sanctuary | Ramsar sites Information Service).

Site 62: Vedanthangal Bird Sanctuary

Location and Geographical Coordinates: Tamil Nadu, 12°32'47"N 79°51'21"E

Biodiversity highlights: Black-headed ibis (*Threskiornis melanocephalus*), Eurasian spoonbill (*Platalea leucorodia*), Black-crowned night heron (*Nycticorax nycticorax*) and Painted stork (*Mycteria leucocephala*)

References: (Vedanthangal Bird Sanctuary | Ramsar sites Information Service).

Site 63: Sirpur Lake

Location and Geographical Coordinates: Madhya Pradesh, 22°41'58"N 75°48'44"E

Biodiversity highlights: Common Pochard (*Aythya ferina*), Egyptian Vulture (*Neophron percnopterus*) and Indian river tern (*Sterna aurantia*).

References : (Sirpur Lake | Ramsar sites Information Service).

Site 64: Koonthankulam Bird Sanctuary

Location and Geographical Coordinates: Tamil Nadu, 08°29'44"N 77°45'14"E

Biodiversity highlights: Indian pond heron (*Ardeola grayii*), Eurasian wigeon (*Anas penelope*), spot-billed pelican (*Pelecanus philippensis*), Oriental Darter (*Anhinga melanogaster*) and Northern pintail (*Anas acuta*).

References : (Koonthankulam Bird Sanctuary | Ramsar sites Information Service).

Site 65: Tampara Lake

Location and Geographical Coordinates: Odisha, 19°21'02"N 85°00'04"E

Biodiversity highlights: Vulnerable species such as Common Carp (*Cyprinus carpio*), common pochard (*Aythya ferina*) and River Tern (*Sterna aurantia*).

References: (Tampara Lake | Ramsar sites Information Service).

Site 66: Hirakud Reservoir

Location and Geographical Coordinates: Odisha, 21°36'38"N 83°45'59"E

Biodiversity highlights: The fish species are *Chanda nama, Mystus vitatus, Notopterus notopterus, Colisa fasciatus, Colisa laila, Mastacembelus puncalus, Brachydanio rerio and Botia lohachata, Parambassis lala, Amblypharyngodon mola, Danio devario, Osteobrama cotio, Puntius sophore , Puntius ticto, Rasbora daniconius, Glossogobius giuris, and Notopterus notopterus* etc.

References: (Singh et al., 2015)

Site 67: Ansupa Lake

Location and Geographical Coordinates: Odisha, 20°27'36"N 85°36'11"E

Biodiversity highlights: The Indian skimmer (*Rynchops albicollis*), the black-bellied tern (*Sterna acuticauda*), the wagur (*Clarias magur*), The vulnerable river tern (*Sterna aurantia*) and Helicopter catfish (*Wallago attu*).

References: (Ansupa Lake | Ramsar sites Information Service).

Site 68: Yashwant Sagar

Location and Geographical Coordinates: Madhya Pradesh, 22°48'14"N 75°41'44"E

Biodiversity highlights: The vulnerable Sarus Crane (*Grus antigone*).

References: (Yashwant Sagar | Ramsar sites Information Service).

Site 69: Chitrangudi Bird Sanctuary

Location and Geographical Coordinates: Tamil Nadu, 09°20'28"N 78°28'40"E

Biodiversity highlights: Spot-billed pelican (*Pelecanus philippensis*), Painted stork (*Mycteria leucocephala*), little egret (*Egretta garzetta*) and Grey heron (*Ardea cinerea*).

References : (Chitrangudi Bird Sanctuary | Ramsar sites Information Service).

Site 70: Suchindram Theroor Wetland Complex

Location and Geographical Coordinates: Tamil Nadu, 08°09'03"N 77°27'14"E

Biodiversity highlights: Spot-billed Pelican (*Pelecanus philippensis)*, Darter (*Anhinga melanogaster)*, Northern Pintail (*Anas acuta)*, Common Teal (*Anas crecca)*, Spotbill Duck (*Anas platyrhynchos)*, Garganey (*Anas querquedula)* and Common Coot (*Fulica atra)*

References : (Suchindram Therur Vembanoor-Birdlife Datazone)

Site 71: Vaduvur Bird Sanctuary

Location and Geographical Coordinates: Tamil Nadu, 10°42'10"N 79°18'59"E

Biodiversity highlights: Spot-billed pelican (*Pelecanus philippensis*), black-headed ibis (*Threskiornis melanocephalus*), Eurasian wigeon (*Mareca Penelope*), and northern pintail (*Anas acuta*).

References : (Vaduvur Bird Sanctuary | Ramsar sites Information Service).

Site 72: Kanjirankulam Bird Sanctuary

Location and Geographical Coordinates: Tamil Nadu, 09°21'35"N 78°28'44"E

Biodiversity highlights: Painted stork (*Mycteria leucocephala*), Spot-billed pelican (*Pelecanus philippensis*), Oriental darter (*Anhinga melanogaster*) and oriental white ibis (*Threskiornis melanocephalus*)

References : (Kanjirankulam Bird Sanctuary | Ramsar sites Information Service).

Site 73: Thane Creek

Location and Geographical Coordinates: Maharashtra, 19°06'31"N 72°57'54"E

Biodiversity highlights: Sulawesi fruit bat (*Acerodon celebensis*), Mozambique tilapia (*Oreochromis mossambicus*) and river tern (*Sterna aurantia*), and the endangered great knot (*Calidris tenuirostris*).

References : (Thane Creek | Ramsar sites Information Service).

Site 74: Hygam Wetland Conservation Reserve

Location and Geographical Coordinates: Jammu and Kashmir, 34°14'24"N 74°31'36"E

Biodiversity highlights: Eurasian otter (*Lutra lutra*), Common carp (*Cyprinus carpio*) and Common Pochard (*Aythya ferina*).

References : (Hygam Wetland Conservation Reserve | Ramsar sites Information Service).

Site 75: Shallbugh Wetland Conservation Reserve

Location and Geographical Coordinates: Jammu and Kashmir, 34°09'41"N 74°43'41"E

Biodiversity highlights: Steppe eagle (*Aquila nipalensis*), Pallas's fish-eagle (*Haliaeetus leucoryphus*), black-bellied tern (*Sterna acuticauda*), the vulnerable eastern imperial eagle (*Aquila heliaca*), yellow-eyed pigeon (*Columba eversmanni*) and wood snipe (*Gallinago nemoricola*).

References : (Shallbugh Wetland Conservation Reserve| Ramsar sites Information Service).

Investigating Wetland Dynamics in India

Over the past 20 years, significant progress has been made in wetland studies in India. These studies have utilized various techniques such as remote sensing, geographic information systems (GIS), and field observations to understand the distribution, ecological functions, and conservation needs of wetlands in the country. One key study focused on analyzing the distributional pattern of wetlands in relation to climate. The study used satellite data from Resourcesat-1 AWiFS to map wetlands across India. Two data sets were collected during the pre- and post-monsoon seasons to study hydrological changes. Wetlands were mapped using digital data interpretation and integrated into a comprehensive database with information on bio-geographic zones, river basins, and agro-climatic zones. The research highlighted the potential impact of climate change on wetlands, including alterations in hydrological cycles and changes in the spatial extent and function of wetland ecosystems . It emphasized the importance of understanding these changes to effectively manage and conserve wetlands (Patel *et al.,* 2009).

In the case of East Kolkata Wetlands (EKW), a sustainable conservation and management approach was proposed through an adaptive co-management model. This model integrates environmental, political, physical, economic, and institutional factors to address the various challenges faced by EKW, including population expansion, urbanization, infrastructure development, migration, land conversion, climate change, and pollution. The study emphasized the need for multiple solutions and time-bound target projects to achieve sustainable management of the wetland ecosystems (Roy-Basu *et al.,* 2020).

Another study focused on using diatoms as bioindicators to assess the contamination levels of urban wetlands in central Gujarat. The researchers identified several diatom species that were sensitive to pollution and found that highly contaminated wetlands had pinnate diatom species, while less contaminated areas had more vulnerable species (Singh and Parikh, 2020). This study demonstrated the potential of diatoms as indicators of wetland contamination (Singh *et al.,* 2020).

Research on methane emissions in Indian tropical and subtropical wetlands utilized remote sensing data from MODIS to understand the variability of methane emissions. The study found that temperature and spatial variations significantly influenced wetland characteristics and methane emission rates. Different formulae were used to estimate methane emissions based on observed field measurements and remote-sensing data (Bansal *et al.,* 2018).

The inventory and classification of wetlands in India have also been addressed in studies. One study focused on the classification of wetlands based on factors such as water type, location, salinity, duration of flooding, and dominant flora. This hierarchical classification provided a framework for understanding and managing wetlands based on their unique characteristics (Gopal and Sah, 1995).

Studies on avian diversity in wetlands, such as the Pong Dam Wildlife Sanctuary in Himachal Pradesh, emphasized the importance of biodiversity as an indicator of wetland health. These studies highlighted the direct impact of the physical and chemical characteristics of aquatic environments on the diversity of bird species. Conserving wetlands was identified as crucial for the viability of various animal species (Sharief *et al.,* 2018).

Overall, the studies conducted in India have contributed to a better understanding of wetlands, their distribution, ecological functions, and the challenges they face. Wetlands are at risk from encroachment, deforestation, farming, pollution, climate change, poaching, and other hydrologic activities including canal construction and water source diversions (Gupta *et al.* 2018) The research has emphasized the need for urgent action to conserve and manage wetland ecosystems, including collaborative efforts involving government agencies and local communities (Gajjar *et al.* 2021). The

use of remote sensing, GIS, and other monitoring tools has played a crucial role in assessing and monitoring wetlands for effective conservation (Prasad *et al.*, 2002).

The study conducted in the Sardar Bherry constructed wetland (CW) focused on isolating bacterial strains from the sediment to assess their potential for wastewater treatment and remediation. The researchers found that bacterial isolates closer to the wastewater source were more likely to be pathogenic and caused high fish mortality rates, while isolates further away were non-pathogenic and exhibited inhibitory effects against pathogens. The extracellular proteins extracted from non-pathogenic isolates were effective in inhibiting the growth of pathogenic bacteria, including multidrug-resistant strains. The non-pathogenic isolates also demonstrated the ability to reduce high levels of ammonia in laboratory tests. However, the antibiogram assays revealed a relatively high prevalence of multidrug-resistant or marginally resistant bacteria across all sampling **Site**s, indicating a potential limitation in the CW bioremediation process for addressing antibiotic-resistant strains. Overall, the study provides valuable information on the influence of spatial succession and the potential of bacterial isolates for bioremediation in CWs. These isolates can also be used as wet lab specimens for further comparison with (meta)genomic data from environmental sequencing studies in CW ecosystems (Kumar *et al.*, 2023).

Significance

Wetlands play an important role in maintaining many natural cycles and supporting a wide range of biodiversity. They are also crucial in regulating the global climate, maintaining the global hydrological cycle, protecting ecosystem diversity, and providing enormous socio-economic and environmental values. Wetlands are highly variable and dynamic water bodies in the world and primarily consist of hydric soil which supports many aquatic plants (Gebresllassie et al. 2014). These water bodies give shelter to a huge variety of flora and fauna (Manzoor *et al.*, 2021). They are valuable for humans. Wetlands purify and replenish our water and provide the fish and rice that feed billions. Major services include carbon sequestration, flood control, groundwater recharge, nutrient removal, toxins retention, and biodiversity maintenance (Turner *et al.*, 2000).

Wetlands also act as important pollution sinks as they absorb agricultural runoff and sewage and other waste from urban areas (Gupta et al. 2018). Wetlands can retain pollutants from surface and sub-surface runoff from the catchment and prevent them from entering into streams and rivers acting as the filters for the streams and rivers (Verhoeven *et al.*, 2006).

Wetland as multifold water system

Wetlands either man-made or natural which include tanks, ponds, lakes, and reservoirs are known for contributing to multiple-use water services like water for irrigation, domestic needs, fisheries, and recreational uses, groundwater recharge, flood control, and silt capture. Freshwater lakes and reservoirs are known to supply water to the local population for irrigation and domestic purposes. Lakes such as Carambolim (Goa), Chilka (Orissa), Dal Jheel (Jammu and Kashmir), Deepor Beel (Assam), Khabartal (Bihar), Kolleru (Andhra Pradesh), Loktak (Manipur), Nainital (Uttarakhand), Nal-Sarovar (Gujarat) and Vembanad (Kerala) are known for contributing in recreational, tourism, fisheries, irrigation, and domestic water supply services. These lakes also help in groundwater recharge (Jain *et al.*, 2007). There are 5264 fully constructed reservoirs and 437 dams under construction in India so far which are used for municipal, industrial, hydropower, agricultural, water supply, and flood control (Central Water Commission, 2022).

Wetland as Habitat

Wetlands support huge biodiversity which may include endemic species, endangered, vulnerable, and umbrella species. So, these are the great supporters of biodiversity in India. India has vast floodplain wetland resources. These water bodies give shelter to a huge variety of flora and fauna (Manzoor *et al.*, 2021). Few species of vertebrates and invertebrates depend on wetlands for their entire life cycle while some are related to them only for certain stages of their life. The lakes, rivers, and other freshwater bodies support a large diversity of biota representing almost all taxonomic groups. More than 1200 species of water plants are reported from the wetlands and they provide a valuable source of food, especially for waterfowl (Prasad *et al.*, 2002). The biogeographic region of southern India

(Freshwater ecosystem of Western Ghats) have about 290 species of fish, 77 species of Molluscans, 171 species of Odonates, 608 species of aquatic plants, and 137 species of amphibians. Out of these, almost 53% of freshwater fish, 36% of freshwater Molluscans, and 24% of aquatic plant species are endemic to this biogeographic region of Southern University (Molur *et al.,* 2011). On a similar note, Loktak lake in Manipur, the largest natural water body in North-eastern India, supports a rich biological diversity. The lake is known for its floating mats of vegetation locally called phumdi (Phumdi is a unique ecosystem consisting of a heterogeneous mass of soil, vegetation, and organic matter at various stages of decomposition) and is the only refuge of the endangered Sangai (Manipur brow-antlered deer) Cervus eldi eldi , 75 species of phytoplankton and 120 species of rotifers had been reported from the Loktak lake (Sharma, 2009). Wetlands are important breeding areas for wildlife and provide a refuge for migratory birds. In many such wetland areas of India, like Bharatpur wildlife sanctuary in Rajasthan, Little Rann of Kutch and coastal areas of Saurashtra in Gujarat, and Gharana wetland conservation reserve in Jammu and Kashmir, many migratory species of birds from western and European countries come during winter. All these wetlands acted as the refuge ground for the migratory birds and supply them with food and protection during their stay. Many of the reservoirs such as Govind Sagar Lake formed by diverting river Satluj (Bhakra Dam, Punjab) and Hirakud reservoir (Sambalpur, Orissa) are major tourist attractions.

Ecological values

Wetlands are extremely productive ecosystems that provide innumerable services to society worldwide. Ecosystem goods provided by the wetlands mainly include water for irrigation, fisheries, non-timber forest products, water supply, and recreation. Wetlands in themselves are a unique ecosystem that plays an irreplaceable role in maintaining the global climate, and the global hydrological cycle and safeguarding human welfare. Not only this they are supporting diverse wildlife even though the local human population is too dependent upon it for many purposes like water for domestic use, and irrigation and it also acts as an economic source for the local population (Silvius *et al.*, 2000).

Wetlands play an important role in flood control. They help to control the effect of flooding by absorbing water as they are having hydric soil and it reduces the speed at which flood water flows. The suspended solids and nutrients are also being trapped by the soil of wetlands. Thus, streams flowing into rivers through wetlands will transport fewer suspended solids and nutrients to the rivers. Wetlands are considered to be a natural substitute for conventional flood control investments such as dykes, dams, and embankments (Boyd and Banzhaf, 2007).

Wetlands are essential for various social, cultural, and ecological processes. The human population residing near the wetlands largely depends upon them for economic purposes even the large constructed wetlands are used for culturing different species of fishes, and other freshwater invertebrates like mollusks, arthropods, and vertebrates for economic purposes(Balirwa, 1995).

Pollution Dwindling

Wetlands act as a sink for point and non-point types of contaminants in many agricultural and urban landscapes (Bystrom *et al.,* 2000). In India, wetlands are polluted through agricultural runoff, domestic sewage, untreated discharge of industrial sewage, and waste from urban areas. These wetlands under normal circumstances, preserve pollutants from surface and sub-surface runoff from the catchment and prevent them from entering into main streams and rivers (Mander and Mitsch, 2009). These contaminants in the form of different ways get removed from the water through the process of nitrification, sedimentation, adsorption, and uptake by aquatic plants. This adversely affects the natural wetland water quality and its biodiversity (Verhoeven *et al.,* 2006). The constructed wetlands are a highly recommended and feasible choice for municipal wastewater (Babatunda *et al.,* 2008) and are studied by several scholars in India (Billore *et al.,* 1999; Kaur *et al.,* 2012). The wetland plants like Typha, Phragmites, Eichhornia, Azolla, and Lemna are identified as potent plants for heavy metal removal (Rai, 2008).

Carbon sequestration is one of the important services being provided by swamps and marshes. Wetlands are a vital means of storing carbon dioxide. About 40% of methane emission is lonely done

by wetlands. So, they are reducing the amount of carbon dioxide in the atmosphere intending to reduce global climate change (Lal *et al.* 2015). Wetlands sequester carbon through high rates of organic matter inputs and reduced rates of decomposition (Rechcigl, 2003). In India, coastal wetlands are playing a major role in carbon sequestration. Mangrove wetlands in eastern India, because of their larger size, higher diversity, and being more complicated due to tidal creeks and canal network, it is more important for carbon sinks as compared to their western counterparts. In Toto, mangroves are capable to sequester about 1.5 metric tons of carbon per hectare per year (Kathiresan and Thakur, 2008). On the other hand, it was found that mangroves also emit methane which is one of the primary greenhouse gases, equivalent to around 19% of their carbon sequestration potential. On the same note, coastal wetlands such as the Vembanad Lake were found to be releasing up to 193.2 mg/m2 /h of methane (Verma *et al.,* 2002). Whether wetlands function as greenhouse producers or carbon sequesters is dependent upon their hydrology and bio-geo-chemical processes. As such, there is a need for more research to find out how wetlands can be used and managed as net carbon sinks over time.

Threats to wetlands in India

A lot of work has been done to assess different activities which pose threat to wetlands. Wetlands are very fragile and any type of anthropogenic and natural disturbance can lead to a potential threat to wetlands. In 2014, the NRSCC has monitored 20 Ramsar sites in Asia. They found that the total area of these 20 wetland **Site**s decreased by about 1% between 2001 and 2013, the total water area and the landscape integrity also showed decreasing trends, and the wetland ecosystems had degenerated, which was closely related to insufficient water supply and climate change (NRSCC, 2014).

Natural sources for wetland degradation

There are some natural as well as anthropogenic threats to the water bodies which affect the diversity of the wetland (Daryadel and Talaei, 2014). The natural threats include floods. In the past few years, it has been seen that the flooding of rivers makes the wetlands lose their soil. These wetlands are natural sponges that hold the soil and slowly release surface water which results in much deeper damage to the wetland. It also hinders the physical as well as chemical properties of water affecting their animal biodiversity. Another natural threat is drought. Drought causes the most damage that anything can do. All the plants and vegetation depend on the water as aquatic plants need more water and if the water level decreases it will affect their growth. Droughts mainly occur due to natural causes like less rainfall, climatic changes, substantial drop in river flow, etc. Drought is likely to affect wetlands, including wetland soil microorganisms that drive the soil biogeochemical cycling (Pant *et al.,* 2003). Frequent droughts could reduce the ability of wetlands to serve as sinks for global carbon or could eventually turn them into sources of atmospheric carbon in general and methane in particular.

Subsidence is another natural threat to wetlands. It is the gradual settling or sudden sinking of the earth's surface because of underground material movement, overdraft of groundwater, or oil extraction. In wetland ecosystems subsidence is a major problem. The soil of wetlands is rich in organic matter which is called peat and muck, when subsidence occurs these fertile soils are drained or exposed to air which causes oxidation of organic material (Daryadel and Talaei, 2014). Another main and potential threat to the wetland is soil erosion. Soil erosion is the removal of top fertile layers of soil by water, wind, and other natural phenomenon. Natural processes and anthropogenic influences may fill wetlands with sediment that has great potential in accelerating erosion, prematurely filling wetlands, and degrading wetland functions.

Anthropogenic sources for wetland degradation

There are some anthropogenic potential threats to wetlands which includes wetland drainage and converting them into croplands, due to the increase in population and demand for food, the wetlands have been converted into cropland as there is already the presence of fertile soil beneath (Gupta *et al.,* 2018). Drainage can also negatively affect dry season water flow and supply. Water-level drawdown or drainage of wetlands can produce major changes in soil's physical, chemical, and biological properties. Organic soils in wetlands develop under flooded conditions where organic matter accumulation exceeds its decomposition (Bahilu and Tadesse, 2017).

Another and the most dangerous cause which is harming wetlands is the discharge of effluents from various industries. Urbanization leads to forming of new industries which create large amounts of waste that are dumped in wetlands. Also, the combustion of fossil fuels, mining, and smelting operations leads to anthropogenic sources of pollution (Kara, 2019). There have also been some reports where agricultural waste and pesticide have been found to cause different kinds of damage like altering the growth of aquatic plants, which harm aquatic animals as well. Since the 1950s, wetlands in tropical and subtropical regions have been increasingly degraded or lost, due to their conversion for agricultural use (Gupta *et al.,* 2018). Heavy metal contamination of aquatic environments is a worldwide problem. Heavy metals added to an aquatic system by natural and anthropogenic sources are distributed during their transport between different compartments of aquatic ecosystems, such as water, sediment, and biota (Cochrane *et al.,* 2009). This accumulation of heavy metals leads to bio-magnification, which ultimately depletes human health (Naqash *et al.,* 2020). In present days, another type of anthropogenic threat to wetlands has evolved, Unsustainable Ecotourism. Rare species of animals and plants are getting destroyed or hunted down to use as a tourist attractions. The waste created by the tourists is all shredded in the wetland as well. The impacts of tourism on the ecological functions of wetlands comprise tourism-related constructions for transport and other infrastructure projects; construction, maintenance, and use of tourist facilities; use of water and treatment of wastewater. The tracks which are used by tourist lead to soil erosion. A case study done on Deepor Beel, Guwahati has brought to the fore that tourism has negatively impacted the wetland over the years. Preparing this wetland for eco-tourism has involved adverse anthropogenic activities like filling wetlands for habitation, cutting the sides of wetlands, pollution, fishing and killing of migratory birds, degradation of water quality, sedimentation in the lake surface, and deforestation. As such this wetland is facing threats due to urban encroachment and its illegal uses (Baruah, 2020). All these kinds of activities affect wetlands directly or indirectly. Such damage can be even more extensive when visitors frequently stray off established trails (Battisti *et al.,* 2008).

Overgrazing by animals is another threat to wetlands which leads to the degradation of vegetation in wetlands (Parvaresh, 2011). Wetland fisheries in India comprise capture fishery (natural stock) and culture-based fisheries. Overfishing in wetlands, besides leading to their degradation, may also negatively impact the fish species diversity of the wetlands.

Incidental and intentional introduction of invasive alien species is another emerging issue severely affecting the wetlands. The new species can lead to the extinction of native plants and animals, destroy biodiversity and permanently alter their habitat. The increase in invasive species poses a dramatic threat to the wetland and all other ecosystems. They reproduce rapidly, out-compete native species for food, water, and space, and are one of the main causes of global biodiversity loss. Intentional introductions in aquatic systems are usually brought about through attempts to enhance local fisheries or other food production systems or for the biological control of weeds, other pests, or vectors of disease (Chatterjee *et al.,* 2015 and Moghaddas *et al.,* 2021).

Heavy Metal Pollution in ramsar Sites:

Since the majority of heavy metals have extremely harmful impacts on a variety of creatures, they are seriously threatening aquatic environments. Through the chemical and physical processing of the rocks, the percolation of the soil, and the physiological processes of diverse plants, the heavy metals were transferred into the sediments. Moreover, industrial and agricultural practises may encourage the pollution of soil with heavy metals. Yet, these two processes—natural and man-made—are the main contributors to the contamination of aquatic environments, particularly coastal sediments, with heavy metals. Furthermore to the aquatic ecosystem, the process of adsorption, precipitation, diffusion, chemical reactions, biological activity, etc., extensively deposits heavy metals into the sediments. The wetland pollution with heavy metals is severe issue, The table no.1 showing the different values of heavy metals concentration in different wetlands. These wetlands have been selected for studying heavy metals due to their vulnerability to pollution and their ecological importance. By studying the levels of heavy metals in these wetlands, researchers can assess the impact of human activities and develop strategies for their conservation and sustainable management.

Table 1: The Ramsar sites showing different values of heavy metals concentration present in them

Ramsar Sites	Heavy Metals	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb	References
	Permissible Limits in mg/l	0.05	0.4	0.3		0.02	2.0	3.0	0.003	0.01	
Sunderban wetlands	Value Estimated	81.21 mg/kg	159.29 mg/kg	-	-	45.07 mg/kg	-	93.43 mg/kg	2.56 mg/kg	47.07 mg/kg	A Chowdhury, & S K Maiti, 2016.
Vembanad Kol Wetland	Value Estimated	-	900 mg/kg	46.7 g/kg	-	68 mg/kg	45 mg/kg	95 mg/kg	0.3 mg/kg	20 mg/kg	Hari kumar *et al.*, (2009)
Chilka lake	Value Estimated	-	432.6 mg/kg	290007.1 mg/kg	55.5 mg/kg	29.7 mg/kg	92.7 mg/kg	70.8 mg/kg	4.6 mg/kg	81.4 mg/kg	S Nazneen *et al.*, 2019
Kolleru lake	Value Estimated	12.5 µg/L	55.5 µg/L	9.2 µg/L	-	-	6.9 µg/L	21.3 µg/L	-	-	S.D. Sharma, 2020
Gulf of Mannar Marine Biosphere Reserve	Value Estimated	0.006 ppm	0.061 ppm	-	-	-	0.020 ppm	0.304 ppm	0.003 ppm	0.053 ppm	A Balakrishnan & A Ramu, 2016
Point Calimere Wildlife and Bird Sanctuary	Value Estimated	0.8 mg/kg	-	-	1.8 mg/kg	1.8 mg/kg	0.4 mg/kg	0.3 mg/kg	0.3 mg/kg	2.5 mg/kg	Pamdiyan *et al.*, 2021
Loktak Lake	Value Estimated	282 mg/kg	425 mg/kg	7 mg/kg	34 mg/kg	194 mg/kg	67 mg/kg	117 mg/kg	-	17 mg/kg	Mayanglambam B, Neelam, 2020
Upper Ganga River	Value Estimated	0.03 mg/l	0.1 mg/l	2.49 mg/l	-	-	-	0.49 mg/l	-	0.01 mg/l	S Parsad *et al.*, 2020
Sambhar Lake	Value Estimated	0.03 mg/l	0.0052 g/l	0.07 6g/l	9.1 mg/l		2.1 mg/l	0.62 mg/l	1.48 mg/l	0.4 mg/l	AP Pathak, & MN Cherekar, 2015.
Wular Lake	Value Estimated	-	412 mg/kg	-	6 mg/kg	6 mg/kg	-	27 mg/kg	-	7 mg/kg	J A Sheikh *et. al.*, 2014
Harike Lake	Value Estimated	0.12 ppm	0.02 ppm	-	0.007 ppm	0.01 ppm	0.26 ppm	0.69 ppm	0.01 ppm	0.53 ppm	O S Brraich and S Jangu, 2015
Deepor Beel	Value Estimated	1.80-583.00 µg/L	47.44-956.00 µg/L	49.00 - 2769.00 µg/L	-	-	45.00-980.00 µg/L	-	0.97 - 89.80 µg/L	3.02 - 109.41 µg/L	S Dash *et al.*, 2019
Surinsar Mansar lake	Value Estimated	63 ppm	0.07 ppm	4 ppm	35 ppm	46 ppm	26.40 ppm	67 ppm	-	32.67 ppm	B K Das *et al.*, 2006

Conservational Strategy in India

For the conservation of wetlands, Ramsar Convention (international treaty) is a major step at the global level that acts as a great framework of inter-governmental collaboration for the management of wetlands. It describes that the sustainable conservation and management of all wetlands should be achieved only by the joint efforts shown by local, national, and international cooperation. Besides Ramsar Convention, various steps are now being implemented at national or regional levels to save the wetlands in the country. Management of wetland ecosystems is controlled by the Ministry of Environment, Forest, and Climate Change. Apart from this, the conservation of wetlands in India is directly influenced by a range of policies and legislations.

Several acts have been passed from time to time to conserve the water bodies which directly or indirectly helps in the conservation of wetlands. Some of these are discussed in following table number 2:

No.	Acts	Role played	References
1	The Indian Fisheries Act, 1897	This act highlights the conservation of fish and banned the use of all activities which influence the quality of water and cause the destruction of fish.	(The Indian Fisheries Act, 1897)
2	The Indian Forest Act, 1927	The wetlands were occasionally included under protected areas.	(Forest Conservation Act, 1980 with Amendments Made in 1988)
3	Wildlife Protection Act, 1972	This act protects faunal diversity which can be aquatic by including them under various lists of the law which ultimately leads to the protection of wetlands.	(Wildlife Protection Act, 1972)
4	Water Prevention and Control of Pollution	The act was endorsed to prevent and control water pollution and maintenance	(Water Prevention and control of Pollution Act, 1974)

	Act, 1974	of water integrity. It is being governed by an organization Central pollution control Board.	
5	Forest Conservation Act, 1980	The act was mainly passed to conserve forests. This act also indirectly contributes to the conservation of wetlands by preventing soil erosion and siltation due to deforestation and land use change.	(Forest Conservation Act, 1980 with Amendments Made in 1988)
6	Environment Protection Act, 1986	Environment Protection Act is the more effective and strong measure to tackle the problem of pollution of air, water, and soil thus involved in the conservation of wetlands.	(Environment Prortection Act, 1986)
7	Coastal Zone Regulation Notification, 1991	The act has certain provisions that assist in the preservation of fresh water and marine life. The act also classifies some coastal zones as ecologically sensitive zone and prohibition of human activities around there.	(Coastal zone Regulation Notification, 1991)
8	National Conservation Strategy and Policy Statement on Environment and Development-1992	It also helps in the conservation and management of different ecosystems which includes wetlands too.	(National conservation strategy and policy statement on environment and development government of India Ministry of Environment and Forest 1992).
9	National Policy and Macro level Action Strategy on Biodiversity-1999	It indicates once biodiversity will be conserved, it leads to the conservation of the habitat in which biodiversity resides. Therefore conserve different wetlands which are also the habitat of biodiversity.	(National Policy and Macro level Action Strategy on Biodiversity-1999)
10	The Wetlands Conservation and Management Rules, 2010	These rules prohibit certain activities that are directly or indirectly liable for wetland degradation.	(The Wetlands Conservation and Management Rules, 2010).

Apart from these conservational policies of the government, there are lots of government projects which directly or indirectly help in the conservation and management of wetlands (Project Tiger, Project Crocodile, Project Rhino, etc.). These conservation projects are intended to protect the habitat of the animal and in turn wetlands in those protected areas get conserved. Besides, there are many non-governmental organizations (NGOs) that work for the management and conservation of wetlands in India. The Bombay Natural History Society (BNHS), Centre for Science and Environment, Vindhyan Ecology and Natural History Foundation, Environmentalist Foundation of India, Vanshakti NGO, etc. are such agencies that play an important role in the conservation of wetlands. Wetlands support huge biodiversity and provide several ecological services as well as benefits to humans. Therefore, it is important to work towards their conservation and management. All the efforts as mentioned earlier in the strategies of wetland conservation and different acts and rules passed legislatively should be followed in letters and spirits to protect or conserve wetlands and the ecosystem services they provide (Sarkar and Das, 2016). Therefore, an integrated approach is a unique way in the country for sustainable conservation and management of wetlands.

4. Conclusion

Wetlands are well known to regulate ecological processes that contribute to a healthy environment. The wise use of wetlands is necessary for their conservation to maintain ecological balance which is a very crucial aspect of the ecosystem. These wetlands help to retain water during dry periods, thus keeping the water table high and relatively stable. They are having innumerable advantages as well as they are also under stress. The wetlands of India are huge habitats for a variety of plant and animal life, including some extremely rare and endangered species of birds. Various studies done on Indian

wetlands suggest that India has lost 35-60% of its wetlands over the past 40 years. The conservation of these wetlands requires a coordinated approach both by residents as well as the Government. That means a multi-criterion approach is necessary for their conservation. Geospatial tools like Remote Sensing and Geographic Information Systems (GIS) are now frequently used to assess the condition of the wetlands. The wetland's conservational status can be taken under consideration by the widespread and consistent use of satellite-based remote sensors and low-cost, affordable GIS tools for effective management and monitoring. A well-constructed framework should be adopted which consists of a combination of economic valuation, systems modeling, stakeholder analysis, and multi-criteria evaluation with the help of advanced tools like GIS and Remote sensing which helps in sustainable and welfare-optimizing wetland management and policy development. An intensified cooperation is needed between social and natural scientists and a multidisciplinary approach is a must for the sustainable conservation and management of wetlands.

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Author's contributions

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