Report on

'Distribution of selected migratory bird species of Tamil Nadu and their conservation challenges'

Tamil Nadu Forest Department
Advanced Institute for Wildlife Conservation
(Research, Training & Education)

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TAMIL NADU FOREST DEPARTMENT

ADVANCED INSTITUTE FOR WILDLIFE CONSERVATION
(RESEARCH, TRAINING & EDUCATION)

Distribution of selected migratory bird species of Tamil Nadu and their conservation challenges

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Table of Contents

Sl.No.	Content	Page No.
	Summary	1
1	Introduction	3
2	Objectives	10
3	Selection of Migratory Bird Species	10
4	Methodology	14
5	Species Identification & Distribution	15
6	Conclusion	52
7	Key Conservation Challenges	53
8	Management Implications	66
9	References	71

Summary

Bird species that travel long distances between breeding and wintering grounds, often covering thousands of miles for suitable habitats and resources, are known as migratory birds. This phenomenon is driven by numerous factors, including seasonal changes in food availability, climate, and breeding conditions. Migratory birds play a crucial role in maintaining ecological balance of various ecosystems, particularly wetland and coastal ecosystems, contributing to pollination, seed dispersal, and pest control. Migratory birds face numerous threats, including habitat loss, degradation, climate change, and light pollution, which can disrupt their natural behaviour, including migration.

The selected migratory bird species in Tamil Nadu are Ruddy Turnstone (*Arenaria interpres*), Eurasian Curlew (*Numenius arquata*), Common Pochard (*Aythya ferina*), Curlew Sandpiper (*Calidris ferruginea*), and Bar-headed Goose (*Anser indicus*)—are chosen based on their conservation status, species diversity, and migratory patterns. The Ruddy Turnstone and Eurasian Curlew are classified as Near Threatened, while the Common Pochard and Curlew Sandpiper are Vulnerable, and the Bar-headed Goose is Least Concern as per the IUCN list. Each species playsa unique role in their ecosystems, from coastal foragers like the Ruddy Turnstone to high-altitude migrants like the Bar-headed Goose. Tamil Nadu is a critical stopover for these species, offering suitable habitats within the Central Asian Flyway, providing key wintering grounds and stopover sites for these long-distance migrants.

The report highlights that certain districts in Tamil Nadu serve as key habitats for migratory birds. The Ruddy Turnstone was mostly sighted in Thiruvallur District in September, with the highest sightings recorded in 2024. The Eurasian Curlew was significantly present in winter (January), peaking in 2024. The Common Pochard was frequently observed in Chengalpattu District in winter (January), with peak abundance in 2020. The Curlew Sandpiper had its highest sightings in Nagapattinam District in October, with an increased presence in 2024. The Bar-headed Goose was notably recorded in Tirunelveli District in winter (January), with the highest number of individuals observed in 2018. These results emphasise the availability of food sources,

suitable habitat conditions for migration, underscoring the role of environmental cues and ecological functions in bird movements.

Migratory birds rely greatly on areas outside protected areas for stopovers and extended stays, indicating a need for enhanced protection of such habitats through effective management and public awareness. Knowledge about these species needs to be enhanced among frontline forest staff, which in turn will increase their capacity to protect them. Understanding the geographical locations and seasonal pattern of migratory species is essential for effective management and conservation. To address this gap, we have collected substantial data on migratory birds from various secondary sources and studied general ecological patterns, analysed the seasonal trends and developed comprehensive distribution maps. This document will benefit forest officials, researchers, bird watchers and others who are interested in studying migratory birds and their conservation strategies. Understanding the dynamics of migratory bird populations is crucial for fostering a sustainable environment that supports both wildlife and human communities.

1. Introduction

Bird migration refers to the movement of birds from breeding to non-breeding sites. This annual phenomenon is driven by various environmental factors, including temperature fluctuations (Alerstam & Högstedt, 1982), food availability, and the need for suitable breeding grounds (Berthold *et al*., 2013). Birds navigate usually in groups or sometimes individually, employing a range of methods such as using the Earth's magnetic field, celestial cues, and landmarks (Higuchi, 2012), indicates that migration enables birds to take advantage of favourable environmental conditions and avoid extreme climates.

Birds are categorized as “far-distance” or “short-distance” migratory species based on their migratory distances. Due to evolutionary factors and metabolic limitations, some birds undertake long migrations, travelling thousands of miles between their breeding grounds and wintering habitats (Alerstam *et al.,* 2003). Short-distance migration is characterized by smaller movements, such as shifts from higher to lower elevations (Danner *et al.,* 2013; Conklin *et al.,* 2013).

Migratory birds can also be classified by their migratory behaviour. Depending on food availability and weather conditions, some species migrate to specific areas regularly, while others migrate opportunistically (Raja *et al.,* 2024; Engel *et al*., 2024).

The Convention on Migratory Species (CMS) is a UN treaty that helps countries work together to protect migratory birds along their routes (CMS, 2024).India’s National Action Plan aims to stop the decline of migratory birds and protect their habitats along the Central Asian Flyway by 2027, focusing on habitat protection, and research. The State of India’s Birds (SoIB) report uses citizen science to track bird populations, showing that many migratory birds are declining and helping set conservation priorities (SoIB, 2023).

Birds utilize migratory flyways, which are essential routes during seasonal migration, providing critical rest and resources along the way. The annual migration of over 800 bird species plays a significant role in global biodiversity by covering vast distances (UNEP-WCMC, 2024). Many species face serious threats from overexploitation

and habitat loss (MoEFCC, 2018; Narwade *et al*., 2021; Schmaljohann *et al.*, 2022; Sharma, 2024).It is estimated that 66-73% of bird species will shift northward or move to higher altitudesby 2070, with 58-59% losing part of their distribution ranges (Deomurari *et al.*, 2023; Faaborg *et al*., 2010).The survival of birds is closely linked to their habitat selection (Cancino, 2024). There is an urgent need to address these pressing issues for enhanced global protection efforts, which include expanding protected areas, combating climate change, and fostering international cooperation (Newton, 2008).

1.1 Types of Migratory Birds

1. **Obligate Migrants:** Birds that migrate annually and spend a significant portion of the year covering long distances during their migration period. For example, the Arctic Tern (*Sterna paradisaea*) migrates from Arctic to Antarctica in exceptional numbers each year (Egevang *et al*., 2010).
2. **Facultative Migrants:** These birds do not migrate every year; instead, they move in response to specific environmental conditions, such as extreme weather or food shortages. The European Robin (*Erithacus rubecula*), a common facultative migrant, only migrates during harsh winter conditions in Europe (Newton, 2012).
3. **Nomadic Migrants:** These birds migrate impulsively in search of food rather than adhering to a specific seasonal schedule. The Gray Teal (*Anas gracilis*), a duck species found in Australia, exemplifies this type of migration, which is driven by changes in water and food availability (Dean, 1997; Roshier *et al.,* 2006).

1.2 Global migratory flyways

Birds migrate across vast distances each year, following specific routes known as flyways. These flyways are not narrow paths; rather, they are broad corridors that birds utilize during their migrations. Birdlife International recognized only four global flyways such as East Asian-Australasian Flyway, African-Eurasian Flyway, Central Asian Flyway, Americas Flyway. Pacific Birds and EAAFP currently recognizes eight global flyways in the terrestrial realm, which are used by both land and water bird species, and

six flyways in the marine realm, which are utilized by seabird species (Boere *et al.,* 2006; Singh *et al*., 2020; Morten *et al*., 2025). The eight terrestrial flyways are listed below:

1. **East Asian-Australasian Flyway (EAAF)**: This flyway stretches from Australia and New Zealand, through Southeast Asia, and reaches upto the Arctic regions of Russia and Alaska.
2. **Central Asian Flyway (CAF)**: Covering a vast region from the Arctic to the Indian Ocean, it spans parts of Eurasia and India.
3. **African-Eurasian Flyway**: This flyway covers a broad area from Greenland, Europe, and western Russia, extending through central and southern Asia, the Arabian Peninsula, and across Africa.
4. **Americas Flyway**: Encompassing North and South America along with the Caribbean, this flyway is divided into four sub-flyways in North America: Atlantic, Mississippi, Central, and Pacific.
5. **East Atlantic Flyway**: Connecting northern North America, Greenland, Iceland, northern Europe, and western Siberia, this flyway links to Western Europe and North Africa.
6. **Black Sea-Mediterranean Flyway**: This flyway spans from northern and western Siberia, across Asia, the Black Sea, and the Mediterranean, reaching northern Africa.
7. **Asian-East African Flyway**: Linking Siberia to East Africa, this flyway covers vast areas of land and ocean.
8. **West Pacific Flyway**: Including New Zealand and the Pacific islands such as Hawaii, it extends to the Arctic regions of North America and Asia.

The West Atlantic Flyway is sometimes considered as the ninth flyway, which connects Western Europe and North Africa (Stroud *et al*., 2006; Colwell, 2010).

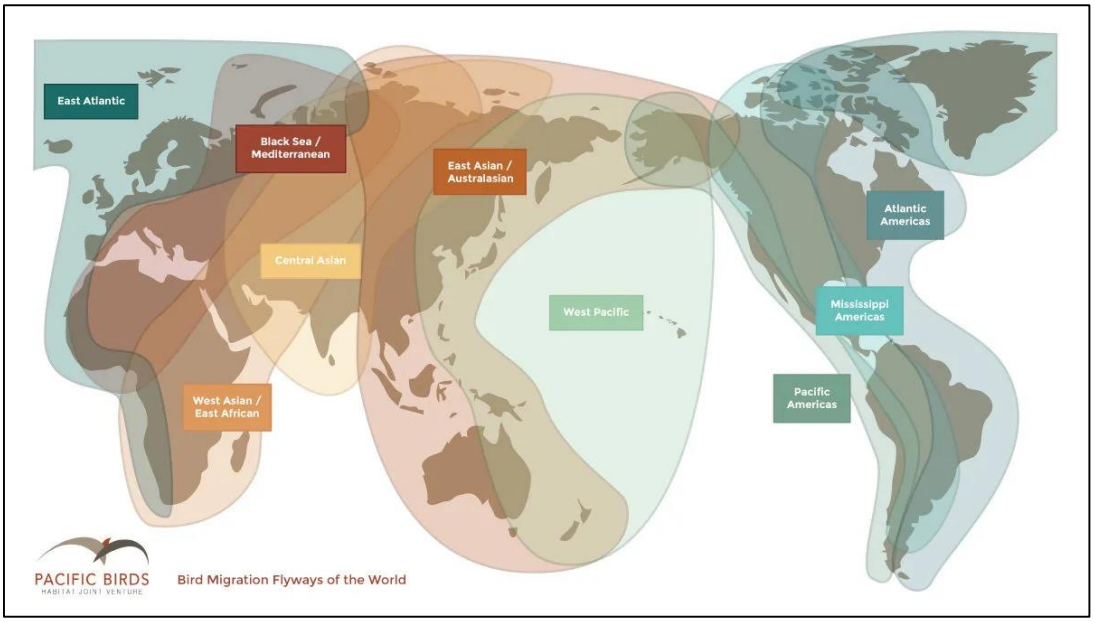


Fig.1: Bird Migration Flyways of the World (Source: Pacific Birds)

1.3 Migratory flyways in India

India is located within three major flyway zones: the Central Asian Flyway (CAF), the East Asian-Australasian Flyway (EAAF), and the Asian-East African Flyway (AEF) (Vaithianathan, 2022; Kumar & Alam, 2023).

1. **Central Asian Flyway (CAF):** The Central Asian Flyway covers a large continental area of Eurasia between the Arctic and Indian Oceans, with India providing critical stopover sites for over 90% of the bird species using this route.
2. **East Asian-Australasian Flyway (EAAF):** The East Asian-Australasian Flyway affects parts of eastern India, connecting Australia and New Zealand with Southeast Asia and the Arctic regions of Russia and Alaska.
3. **Asian-East African Flyway (AEAF):** The Asian-East African Flyway covers parts of western India, linking Siberia with East Africa and supporting various migratory bird species.

370 Migratory Bird Species visit the India subcontinent annually through the Central Asian Flyway (CAF), East Asian-Australasian Flyway (EAAF), and Asian-East African Flyway (AEAF) (CAF National Action Plan 2018 -India). India is represented by 1,358 bird species across 26 orders and 114 families, as documented by

(Maheswaran & Alam, 2024).(Praveen & Jayapal, 2024) indicates that 1,210 are regularly occurring species, 134 vagrants, and 29 historical species newly added.

1.4 Migratory Flyways to Tamil Nadu

Tamil Nadu lies along Central Asia Flyway (CAF), making it a critical hub for migratory species (CMS, 2006; Flack *et al.,* 2022).

1. **Central Asia Flyway**: This flyway brings birds from regions like Central Asia, Mongolia, and Siberia to Tamil Nadu. Wetlands and coastal habitats such as Pulicat Lake, Pallikaranai Marsh, Vedanthangal, Point Calimere, Koonthankulam and other areas, which are crucial for species like the Common Pochard and Bar-headed Goose, which migrate southward in winter (Siddiqui and Balachandran, 2009; Jayakumar *et al.,* 2014; Kumaraguru *et al*., 2021; Galbraith *et al*., 2014; Gandy, 2023 ; Mundkur *et al.,* 2023).

1.5 Migratory Birds outside Protected Areas

While protected areas like bird sanctuaries and national parks are critical for safeguarding migratory bird populations, non-protected areas including farmlands, urban green spaces, and smaller wetlands are also important (Adhikari *et al*., 2022). Only 9% of the 1,451 migratory bird species in the world have adequate protection along their extensive annual migration routes. (Runge *et al*., 2015). These habitats provide crucial resources like food and shelter, allowing birds to breed, rest and replenish during migration.

Agricultural lands, such as rice paddies and grasslands, are especially valuable for waterfowl and waders (Stafford *et al.,* 2010; Sundar, 2011). Urban areas with parks, lakes, and gardens also serve as temporary shelters or stopover sites for migratory birds, offering them food and safe resting places (Vaithianathan, 2022). Protecting these habitats which are outside designated sanctuaries is vital for ensuring a more comprehensive conservation strategy for migratory bird populations
(Schmaljohann *et al.,* 2022).

BirdLife International have identified 314 IBAs/KBAs (Important Bird and Biodiversity Areas/Key Biodiversity Areas) for migratory bird species. Also, 39 localities identified as Important Bird Areas (IBA) in Tamil Nadu (Islam & Rahmani, 2004 & 2008; Rahmani *et al*., 2016). The Tamil Nadu Forest Department (TNFD) is conducting its annual bird survey in two phases during the migratory bird season, which spans from October to April. The first phase, focusing on wetland birds, will cover 1,150 spots across inland and coastal wetlands on March 8-9, 2025 while the second phase will cover terrestrial birds at 900 spots inside and outside protected areas on March 15-16, 2025.

1.6 Importance of migration – Ecological Functions and Reasons for Migration

Migration serves several vital ecological functions for birds and the ecosystems they inhabit:

1. **Energy Efficiency**: Migration allows birds to capitalize on seasonal food availability, which helps them maintain their energy balance and enhances their reproductive success. By moving to areas where food is abundant, birds can optimize their energy use and provide feed to young ones during critical life stages (Alerstam & Lindström, 1990; Sibly *et al*., 2012; McWilliams *et al*., 2021).
2. **Population Maintenance**: By migrating to regions with more favourable climate and habitats, birds can avoid harsh environmental conditions that may adversely affect their survival and reproductive rates. Thus, migration helps to ensure that populations remain stable and healthy (Salewski & Bruderer, 2007; Somveille *et al.*, 2013).
3. **Genetic Diversity**: Long-distance migration facilitates gene flow among bird populations, which is essential for maintaining genetic diversity. This movement between breeding and wintering grounds increases a population's resilience to diseases and environmental changes, ultimately contributing to the long-term survival of species (Barrowclough, 1980; Baker, 2007; Ramos *et al*., 2016).
4. **Ecological Balance**: Migratory birds play a crucial role in maintaining the health of ecosystems. They help regulate insect populations, pollinate plants, and disperse seeds, which are all vital processes for ecosystem stability

(Bauer & Hoye, 2014; Mariyappan *et al*., 2023). Controlling insect outbreaks and supporting plant germination through seed dispersal during feeding, birds contribute significantly to ecological balance and biodiversity (Lopez-Hoffman *et al.*, 2017).

1.7 Reasons for Migration

Major factors that drive bird migration include:

- **Temperature:** Migratory birds seek warmer regions during colder months to avoid freezing temperatures and ensure access to food. Relocating to milder climates, help them conserve energy and better cope with the challenges posed by harsh winter conditions (Heus, 2013; Kumar, 2019).
- **Food Availability:** Birds migrate to areas with abundant food resources, capitalizing on seasonal surpluses. Temperate zones typically provide a rich supply of food during the summer, while tropical regions offer a more consistent food supply throughout the winter. This strategic movement allows birds to optimize foraging opportunities and meet their energy requirements (Hedenström, 2008; Somveille *et al*., 2013; Schmaljohann *et al*., 2022).
- **Breeding Opportunities:** Migration enables birds to access optimal breeding habitats, such as wetlands and forests, which offer essential resources like food, nesting sites, and protection from predators. Moving to these optimal ecosystems, birds can enhance their reproductive success and improve the survival rates of their offspring (Sutherland, 2000; Somveille *et al*., 2015).

2. Objective of the Report

- To prepare a document of some selected migratory bird species of Tamil Nadu focusing on their general ecology, distribution, conservation challenges & management implications.

3. Selection of Migratory Bird Species for Report in Tamil Nadu

List of selected migratory bird species and their conservation status

Sl. No.	Common name	Scientific name	IUCN status	WPA (A), 2022
1	Ruddy Turnstone	*Arenaria interpres*	Near Threatened	Schedule- II
2	Eurasian Curlew	*Numenius arquata*	Near Threatened	Schedule- II
3	Common Pochard	*Aythya ferina*	Vulnerable	Schedule- I
4	Curlew Sandpiper	*Calidris ferruginea*	Vulnerable	Schedule- II
5	Bar-headed Goose	*Anser indicus*	Least Concern	Schedule- II

The above selection of migratory bird species for this report in Tamil Nadu is based on the following key factors:

3.1 Conservation Status

The Ruddy Turnstone is classified as Near Threatened, facing threats from habitat alteration and coastal development. The Eurasian Curlew is also categorized as Near Threatened due to habitat loss and intensive agricultural farming. The Common Pochard and Curlew Sandpiper are listed as Vulnerable, with significant declines linked to wetland degradation and habitat loss along migratory routes. The Bar-headed Goose, however, is categorized as Least Concern, reflecting its stable population despite facing localized threats.

3.2 Species Diversity

These species represent a diverse array of bird families and ecological roles. The Ruddy Turnstone is a small, sturdy shorebird known for its distinctive plumage and stout bill, which are well-suited for foraging in coastal habitats. The Eurasian Curlew is one of the largest wading birds, distinguished by its long, curved bill and greyish-brown feathers. The Common Pochard is a diving duck that feeds on a varied diet of aquatic plants and invertebrates. The Curlew Sandpiper is a smaller wader with a downward curved bill, primarily foraging for invertebrates in mudflats. The Bar-headed Goose is a remarkable high-altitude migrant, equipped with unique physiological adaptations that enable it to traverse the Himalayas.

3.3 Migration Patterns

These species exhibit complex migration patterns. The Ruddy Turnstone migrates from Arctic breeding grounds to coastal areas worldwide, including Europe, Africa, and Southeast Asia. The Eurasian Curlew travels from Northern Europe and Asia to winter in Africa, Southern Europe, and South Asia. The Common Pochard migrates from Northern Europe and Asia to Southern Europe, the Middle East, and Africa. The Curlew Sandpiper undertakes long-distance migrations from Arctic Russia to Africa and Australia, with key stopovers in Southeast Asia. The Bar-headed Goose migrates over the Himalayas from Central Asia to the Indian subcontinent.

Migratory Flyways and visits to Tamil Nadu

Tamil Nadu serves as a critical wintering and stopover region for numerous migratory water birds traversing the Central Asian Flyway (CAF). The state's geographic position at the southern tip of the Indian subcontinent, combined with its diverse and well-protected wetlands makes it indispensable for the survival of many long-distance migrants (Byju *et al*., 2025). The following summarizes the migratory origins, flyways, and wintering patterns of selected five species;

1. Ruddy Turnstone (*Arenaria interpres*)

- **Migratory Origin**: High Arctic regions of northern Eurasia and North America.
- **Migration Flyways**:
    - Passes through Central Asian Flyway, recognized under the (CMS/CAF Action Plan).
- **Arrival in Tamil Nadu**: August to October (peak September).
- **Departure**: March to April.
- **Wintering habitat**: Coastal wetlands.

2. Eurasian Curlew (*Numenius arquata*)

- **Migratory Origin**: Europe and Asia (British Isles to Arctic Russia).
- **Migration Flyways**: Central Asian Flyway.
- **Arrival in Tamil Nadu**: September to November.
- **Departure**: March to April.
- **Wintering habitat**: Mudflats and estuaries.

3. Curlew Sandpiper (*Calidris ferruginea*)

- **Migratory Origin**: Arctic tundra of Siberia (Russia).
- **Migration Flyways**: Central Asian Flyway.
- **Arrival in Tamil Nadu**: August to October.
- **Departure**: March.
- **Wintering habitat**: Coastal marshes.

4. Common Pochard (*Aythya ferina*)

- **Migratory Origin**: Northern and eastern Europe, parts of Asia.
- **Migration Flyway**: Central Asian Flyway.
- **Arrival in Tamil Nadu**: October to November.
- **Departure**: March to April.
- **Wintering habitat**: Inland lakes.

5. Bar-headed Goose (*Anser indicus*)

- **Migratory Origin**: Mongolia, northern China, Tibetan Plateau.
- **Migration Flyway**: Central Asian Flyway
- **Arrival in Tamil Nadu**: October to November
- **Departure**: January to April.
- **Wintering habitat**: Wetlands.

Tamil Nadu also play a crucial role since it comes under entire Central Asian Flyway (CAF), this encompasses overlapping migration routes for different waterbirds across various countries linking their northernmost breeding grounds in Siberia to southernmost non-breeding wintering grounds in west and south Asia, Maldives and the Indian Ocean territory (CMS, 2006; Szabo & Mundkur, 2017; National action plan, 2018; SoIB, 2023; Mundkur *et al*., 2023).

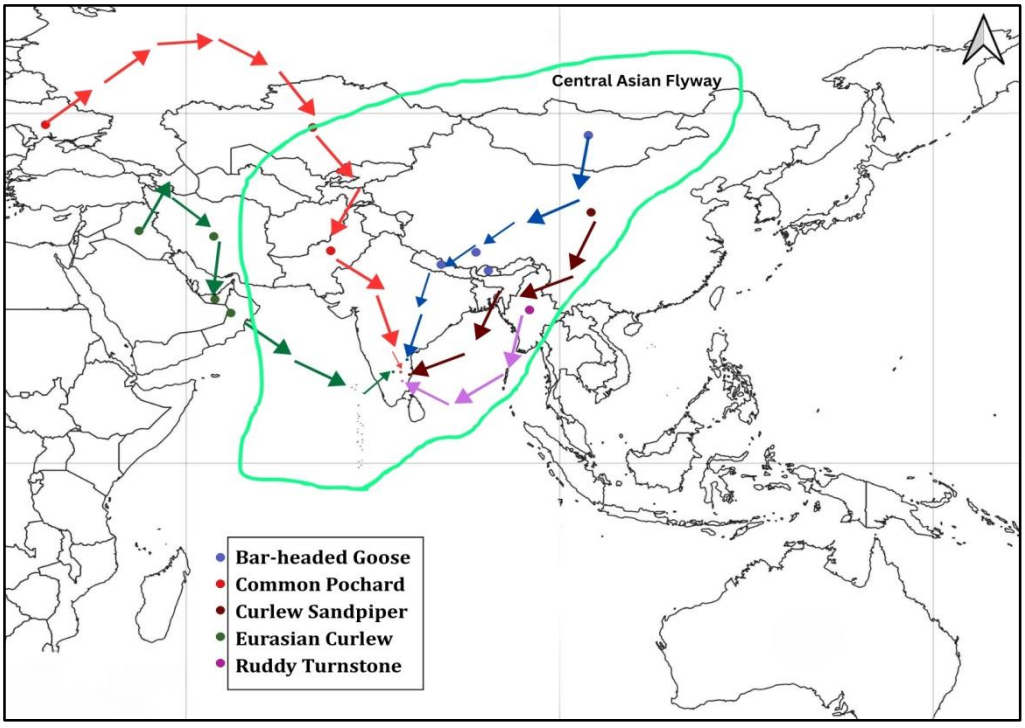


Fig. 2: Illustrated Migratory route map of Ruddy Turnstone,Eurasian Curlew, Common Pochard, Curlew Sandpiper & Bar-headed Goose.

4. Methodology

This report provides the distribution, population trends, and conservation status of five selected migratory bird species such as Ruddy Turnstone, Eurasian Curlew, Common Pochard, Curlew Sandpiper, and Bar-headed Goose in Tamil Nadu over the last 10 years based on secondary data collected from research articles, reputed sources like ebird, IUCN, SoIB database, etc. GIS tool is used for mapping to assess the geographical distribution patterns of each species.

4.1 Data Collection

eBird Observations:

Secondary data were collected from eBird for selected migratory birds of Tamil Nadu, which is the prime data source for this report. eBird is an online platform which maintains a database of bird observations recorded by various researchers, observers or bird watchers. It provides large-scale, real-time data including photographs of observed species. We have collected 10 years data from 2015 to 2025 observed entire Tamil Nadu region which includes time of observations, location of each sightings, and other relevant information for the targeted species.

IUCN Range Maps:

The report also utilizes IUCN range maps to gain a broader understanding of the global and regional distribution of the species. These maps help in defining the geographical boundaries where the species are commonly found, and also essential for identifying suitable habitats and regions at higher risk (Chen *et al.,* 2024).

State of India's Birds (SoIB) 2023 Report:

State of India's Birds (SoIB, 2023) report was utilized for understanding the trends and conservation status of the targeted species in India, also in Tamil Nadu region. The SoIB report was developed based on compiled data from eBird, and provides information on species abundance, specific threats, and other challenges for conservation measures.

4.2 Data Analysis

Mapping and Visualization:

The dataset from eBird contains inherent biases/duplicates due to various factors; therefore, the results were carefully examined and analysed using Microsoft Excel and interpreted accordingly. The data was mapped using QGIS to illustrate the distribution of the selected migratory bird species in Tamil Nadu over the past decade. The bar diagram is used to create the seasonal trends of the bird species. The integration of eBird data with IUCN and QGIS facilitated a deeper analysis of spatiotemporal patterns and relative abundance as per the studies carried out by Rosas-Chavoya *et al*., 2022& Thirumurugan *et al*., 2024.

5. Species Identification & Distribution

5.1. Ruddy Turnstone *(Arenaria interpres)*

- Kingdom: Animalia
- Phylum: Chordata
- Class: Aves
- Order: Charadriiformes
- Family: Scolopacidae
- Genus: Arenaria
- Scientific name: *Arenaria interpres* (Linnaeus, 1758)
- Tamil name: (கோட்டான் / திரகோட்டான்) Kottaan, Tirakottaan

1. Identification Key

1.1 Morphological Characteristics

- **Bird Height:** 21-26 cm
- **Wing Length:** 50-57 cm
- **Weight:** 85-150 g
- **Male Characteristics:** Males have a distinctive black-and-white striped back, orange-red legs, and a black belly.

- **Female Characteristics:** Similar to males but with duller breeding plumage.
- **Plumage Description:** During the breeding season, the plumage is a striking black and white striped back with orange-red legs and a black belly. Non-breeding plumage is greyish-brown with a white belly.
- **Juvenile Plumage:** Pale brown head, pale fringes on upperpart feathers (scaly impression).

2. Behavioural Ecology

- **Social Structure:** Social, forages in small groups, gathers at large roosts.
- **Foraging Habits:** Turns over stones, digs, probes, surface pecks.
- **Geographic Range & Habitat:** Breeds in northern Eurasia and North America; winters on coastlines worldwide, preferring rocky or stony shores.
- **Behaviour:** Diurnal, migratory.
- **Communication and Perception:** Staccato, rattling call; chattering alarm-call.
- **Food Habits:** Carnivorous and scavenging; diet includes invertebrates, insects (breeding), crustaceans, molluscs, worms, carrion, eggs.
- **Predation:** Gulls, foxes, raptors.
- **Ecosystem Roles:** Predator of invertebrates and crustaceans.

3. Reproduction

- **Mating Habits:** Monogamous.
- **Breeding Season:** May-August.
- **Nesting Grounds:** Open tundra with water nearby.
- **Nesting Behaviour:** Nests in shallow scrapes lined with leaves.
- **Egg Laying:** 2-5 eggs.
- **Egg Incubation Period:** 21-24 days.
- **Development of Young:** Precocial; chicks fledge after 19-21 days.
- **Lifespan and Maturity:** Lifespan 9-19 years; reproductively mature at 2 years.

4. Physical Characteristics

- **Overall Description:** Small, stocky wading bird with distinctive plumage.
- **Lifespan/Longevity:** 9-19 years.
- **Top Flying Speed:** 64 km/hr (40 mph).

5. Conservation Status

- **Conservation Status Overview: Near Threatened (IUCN)**
- **Population:** 140,000-500,000 individuals globally
- **Population Trends:** Decreasing.
- **Threats to Survival:** Nest predation, avian influenza, climate change, human disturbances.
- **WPA, 1972 Schedule: Schedule- II**
- **Distribution:** Widespread winter visitor; coastal wetlands

Source: (Nettleship, 2020), (BirdLife International, 2017&2024), (Animalia bio Index) & (R J Ranjit Daniels, B Vinoth, 2023).

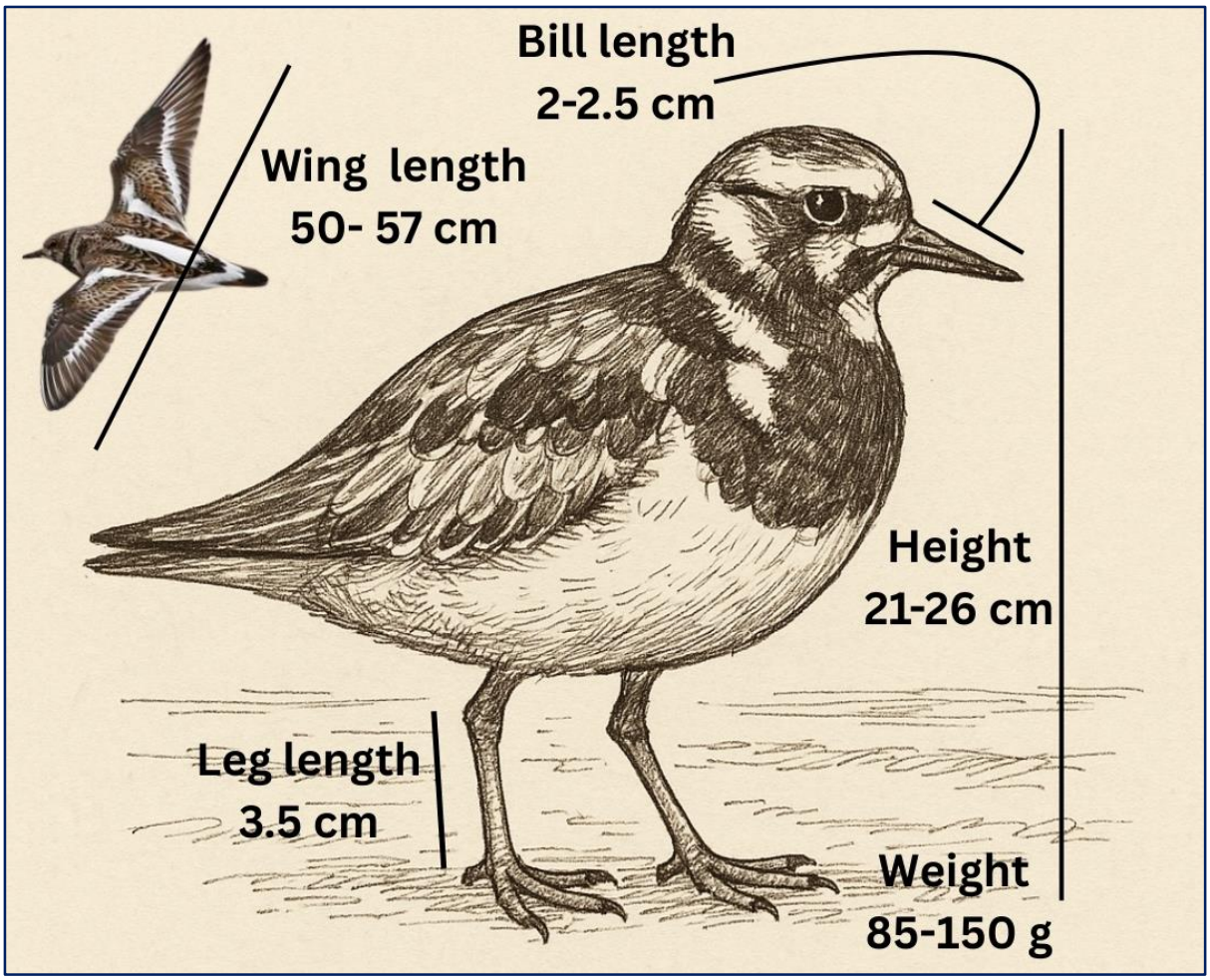


Fig. 3: Illustration of Ruddy Turnstone

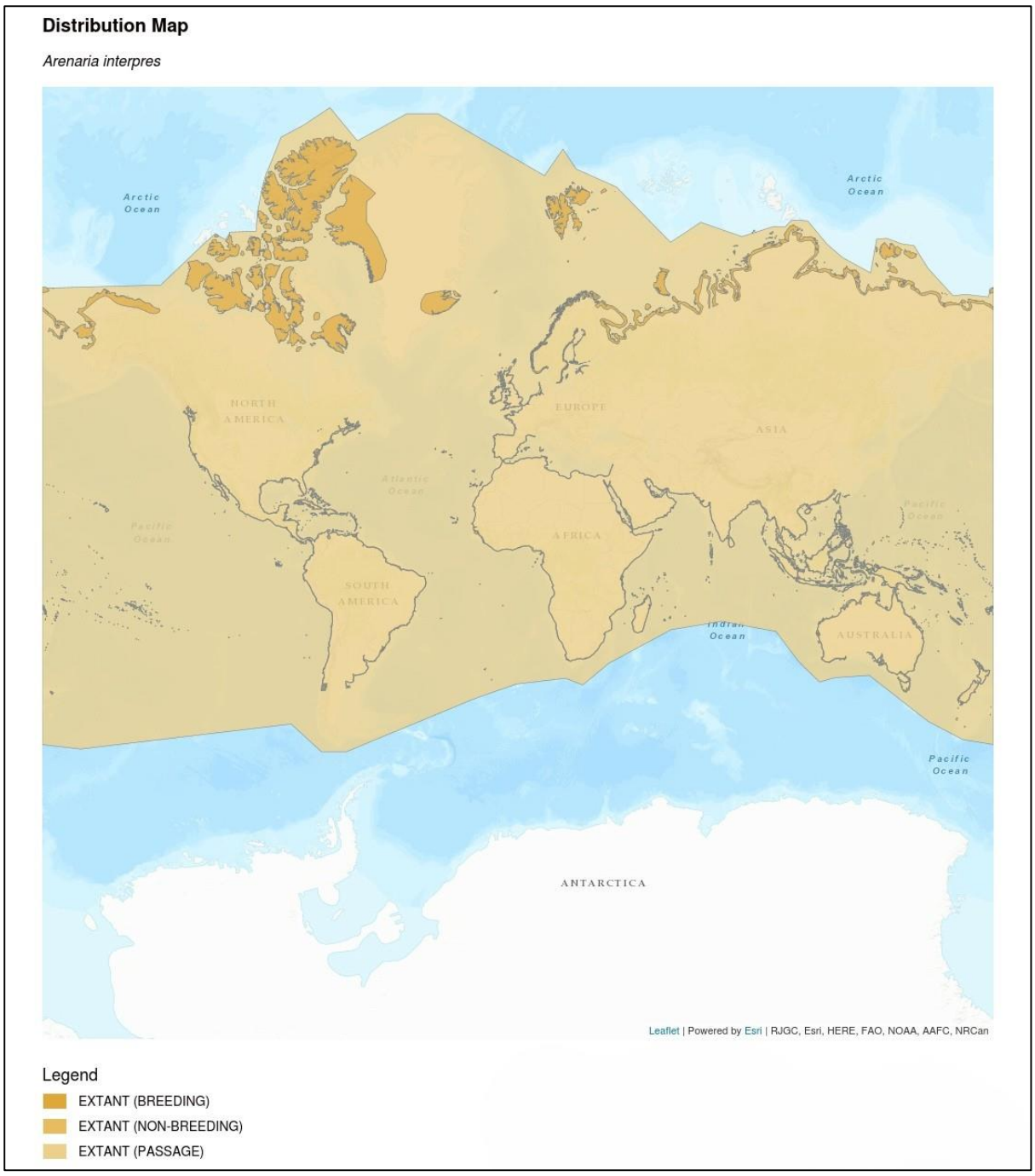


Fig.4: Distribution map adopted from IUCN, (Source: BirdLife International, 2024)

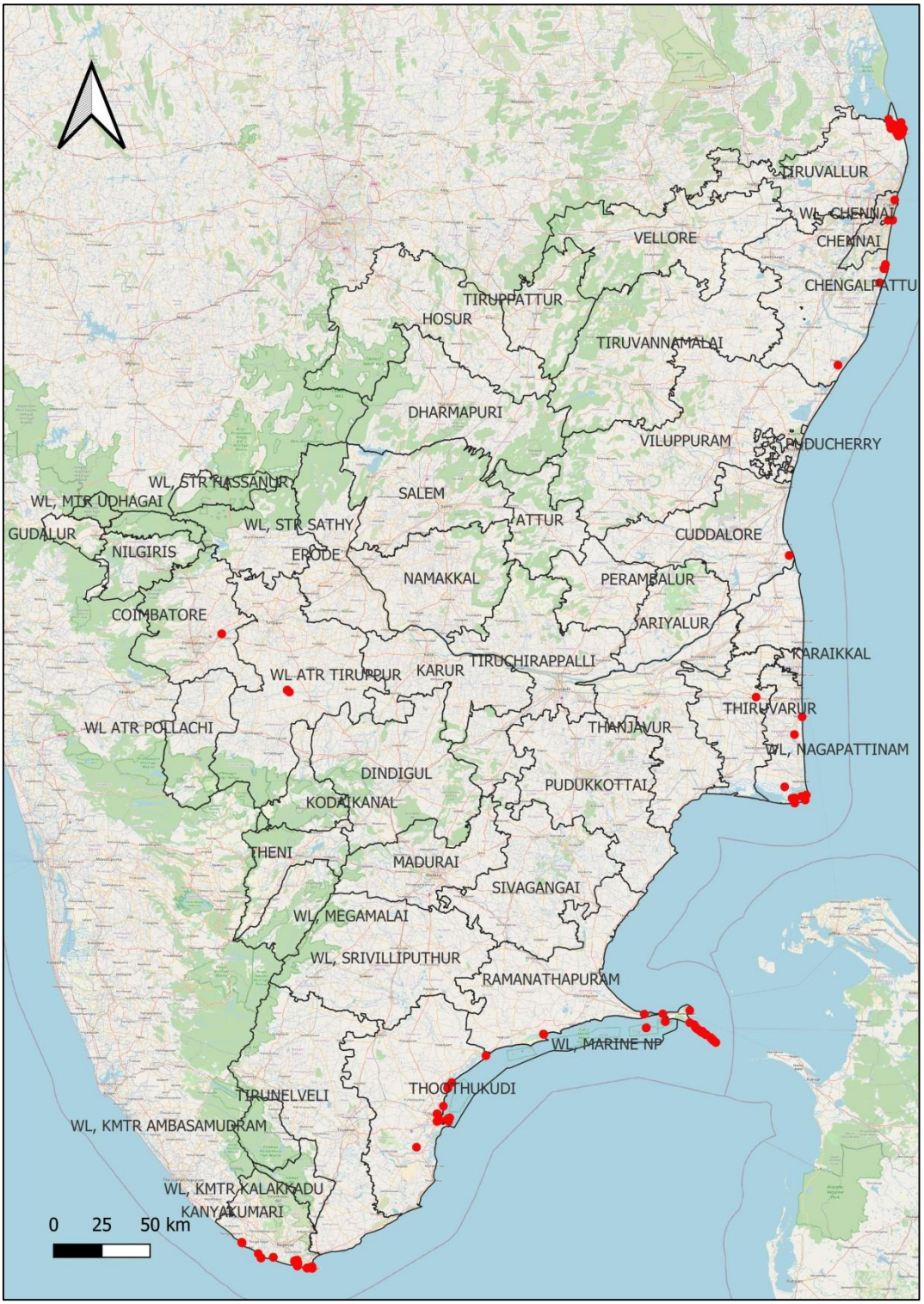


Fig.5: Geographical distribution of Ruddy Turnstone (2015-2025)

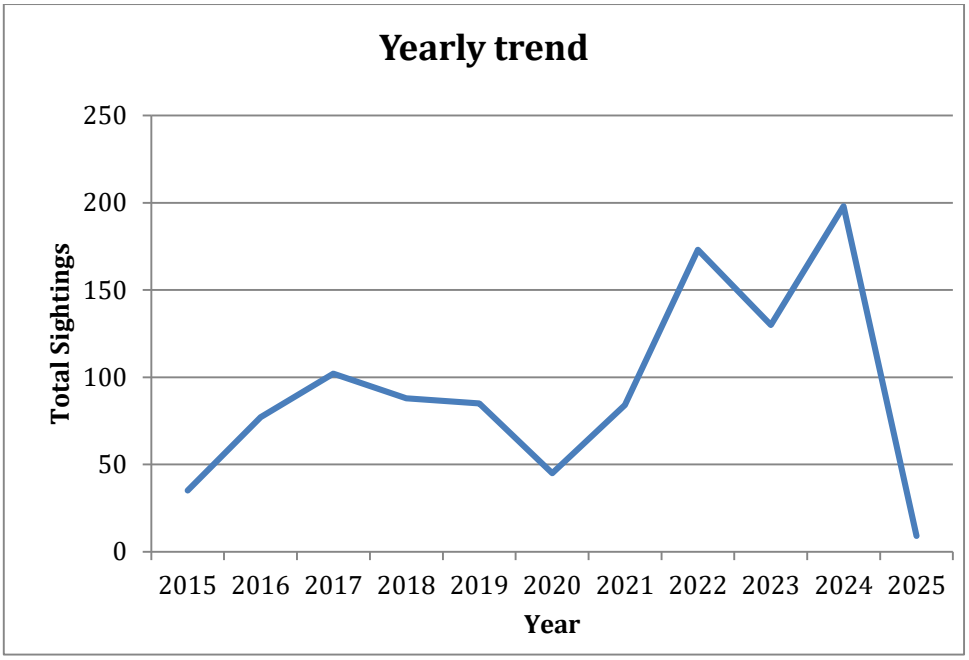


Fig.6: Yearly trend of occurrence of Ruddy Turnstone

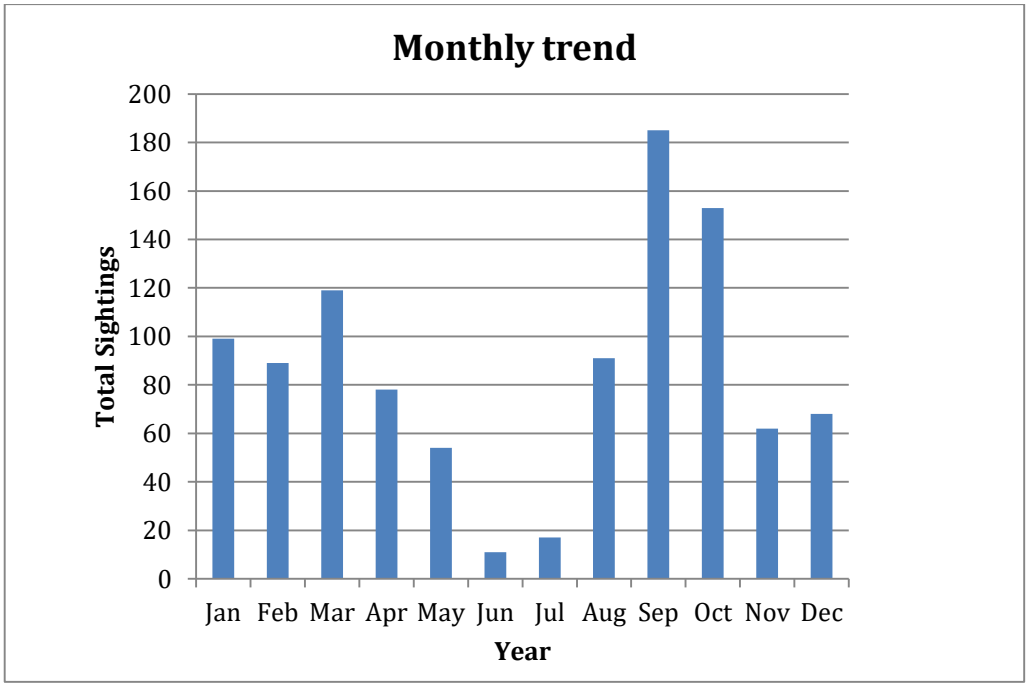


Fig.7: Monthly trend of occurrence of Ruddy Turnstone

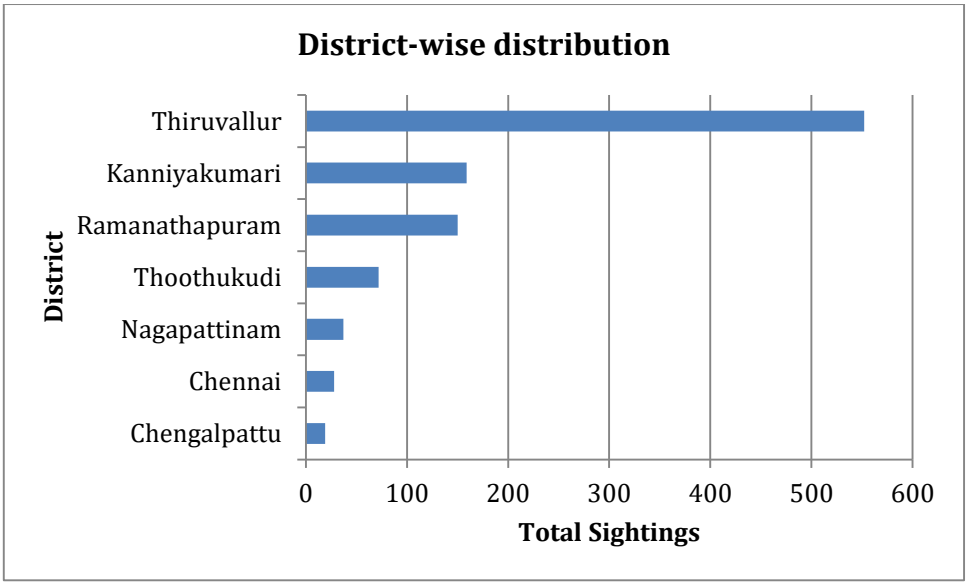


Fig.8: District wise relative abundance of Ruddy Turnstone

Result

The Ruddy Turnstone is the most frequently observed species in Thiruvallur District, with a total of 552 sightings. The highest number of sightings of this species were reported in 2024, with a total of 198 observations. This species was predominantly observed in the month of September with a record of 185 sightings. Such a seasonal peak likely reflects the long duration of migration, and breeding behaviour of the Ruddy Turnstone. The map showing that the Ruddy Turnstone mostly observed in coastal areas in Tamil Nadu, showing the suitable habitat during migration, as the availability of food resources are rich in these areas.

Discussion

The high number of Ruddy Turnstone sightings in Thiruvallur District, particularly during September 2024, aligns with their long-distance migratory behaviour and reliance on coastal stopover habitats rich in food resources. The Ruddy Turnstone (*Arenaria interpres*) displays complex migratory behaviours along the south-eastern coasts of Tamil Nadu, where recent studies have reported population declines during over-summering periods, likely linked to habitat conditions and food availability (Byju *et al*., 2024). These shorebirds undertake long migrations, including non-stop flights up to 7,600 km, requiring critical stopover sites for refuelling (Minton *et al*.,

2011). Their migration follows a narrow path, averaging 39.5 days with flight speeds of 63.4 kph in early stages (Minton *et al*., 2011). Key stopovers, such as coastal areas in Tamil Nadu and South Carolina, are essential for successful migration and breeding (Sanders *et al.,* 2023). Despite strong site fidelity, shifts in wintering locations due to declining food availability have been noted globally (Burton *et al*., 2005). These findings highlight the importance of protecting coastal habitats in Tamil Nadu to ensure the survival and migratory success of the Ruddy Turnstone amid on-going environmental challenges.

5.2 Eurasian Curlew *(Numenius arquata)*

- Kingdom: Animalia
- Phylum: Chordata
- Class: Aves
- Order: Charadriiformes
- Family: Scolopacidae
- Genus: Numenius
- Scientific name: *Numenius arquata* (Linnaeus, 1758)
- Tamil name: (குதிரைகோட்டான்) Kudirai kottaan

1. Identification Key

1.1 Morphological Characteristics

- **Bird Height:** 50-60 cm
- **Wing Length:** 80-100 cm
- **Weight:** 500-1000 g
- **Male Characteristics:** Males have brownish-grey plumage, a long curved bill, and black streaks on their back.
- **Female Characteristics:** Similar to males but with slightly duller breeding plumage.
- **Plumage Description:** The breeding plumage is brownish-grey with black streaks on the back, and non-breeding plumage is greyish-brown with a white belly.

- **Juvenile Plumage:** Similar to adults but with a shorter bill.

2. Behavioural Ecology

- **Social Structure:** Solitary or in small groups.
- **Foraging Habits:** Probes soil for invertebrates.
- **Geographic Range & Habitat:** Europe and Asia; breeds in wet meadows and moors.
- **Behaviour:** Diurnal, migratory.
- **Communication and Perception:** Distinctive, mournful calls.
- **Food Habits:** Earthworms, insects, small invertebrates.
- **Predation:** Foxes, raptors.
- **Ecosystem Roles:** Controls soil invertebrate populations.

3. Reproduction

- **Mating Habits:** Monogamous.
- **Breeding Season:** April-July.
- **Nesting Grounds:** Wet grasslands, meadows, and moors.
- **Nesting Behaviour:** Nests on the ground in dense vegetation.
- **Egg Laying:** 3-5 eggs.
- **Egg Incubation Period:** 26-30 days.
- **Development of Young:** Precocial; chicks fledge after 32-38 days.
- **Lifespan and Maturity:** Lifespan up to 32 years; matures at 2-3 years.

4. Physical Characteristics

- **Overall Description:** Large wader with a long, curved bill.
- **Lifespan/Longevity:** Up to 32 years.
- **Top Flying Speed:** Approx. 50 km/hr (31 mph).

5. Conservation Status

- **Conservation Status Overview: Near Threatened (IUCN)**
- **Population:** 140,000-500,000 individuals globally

- **Population Trends:** Decreasing.
- **Threats to Survival:** Habitat loss, agricultural intensification.
- **WPA, 1972 Schedule: Schedule- II**
- **Distribution:** Widespread winter visitor; coastal wetlands

Source**:** (van Gils *et al*., 2020), (BirdLife International, 2017), (Animalia Bio Index) &(R J Ranjit Daniels, B Vinoth, 2023).

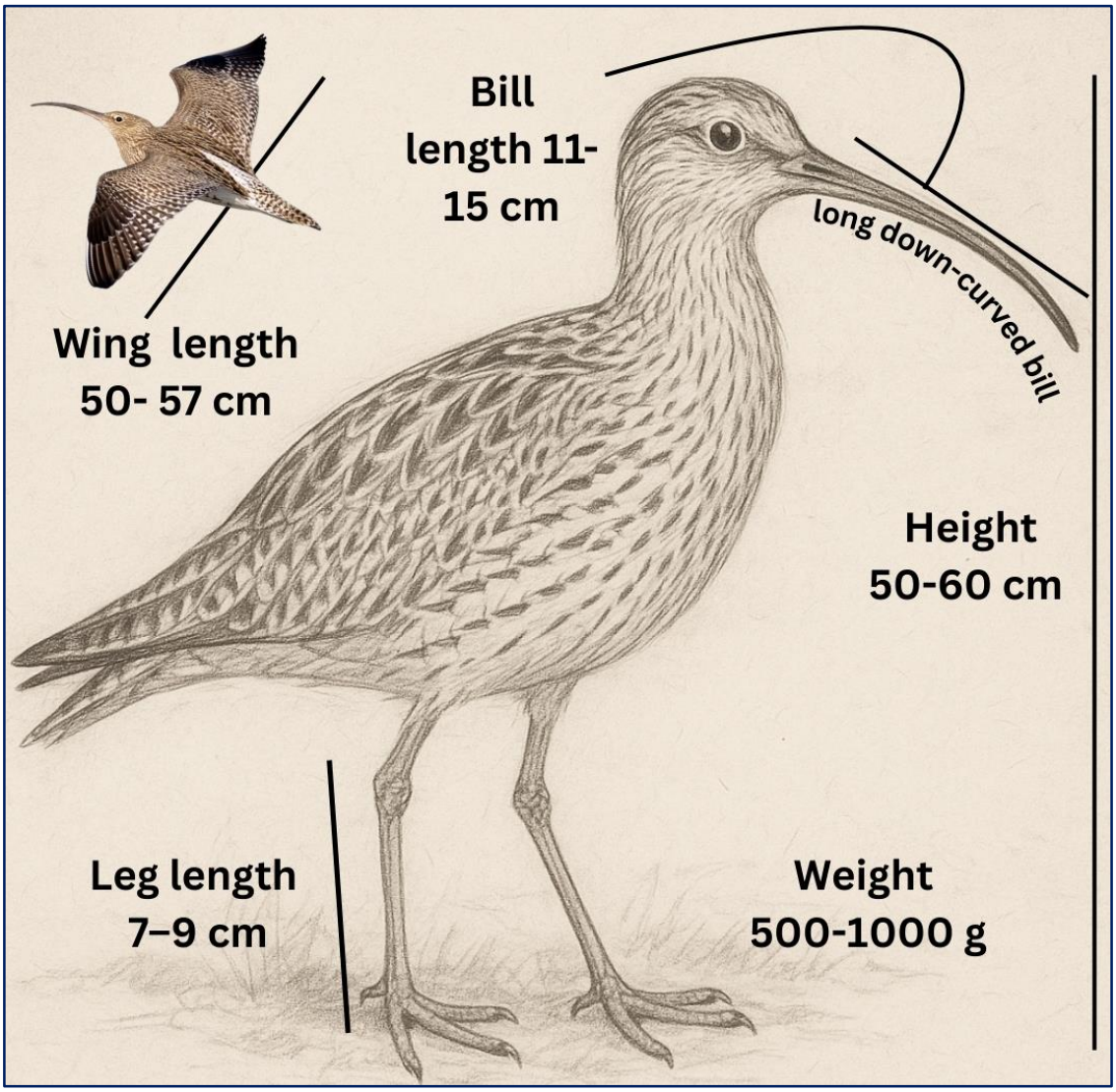


Fig.9: Illustration of Eurasian Curlew

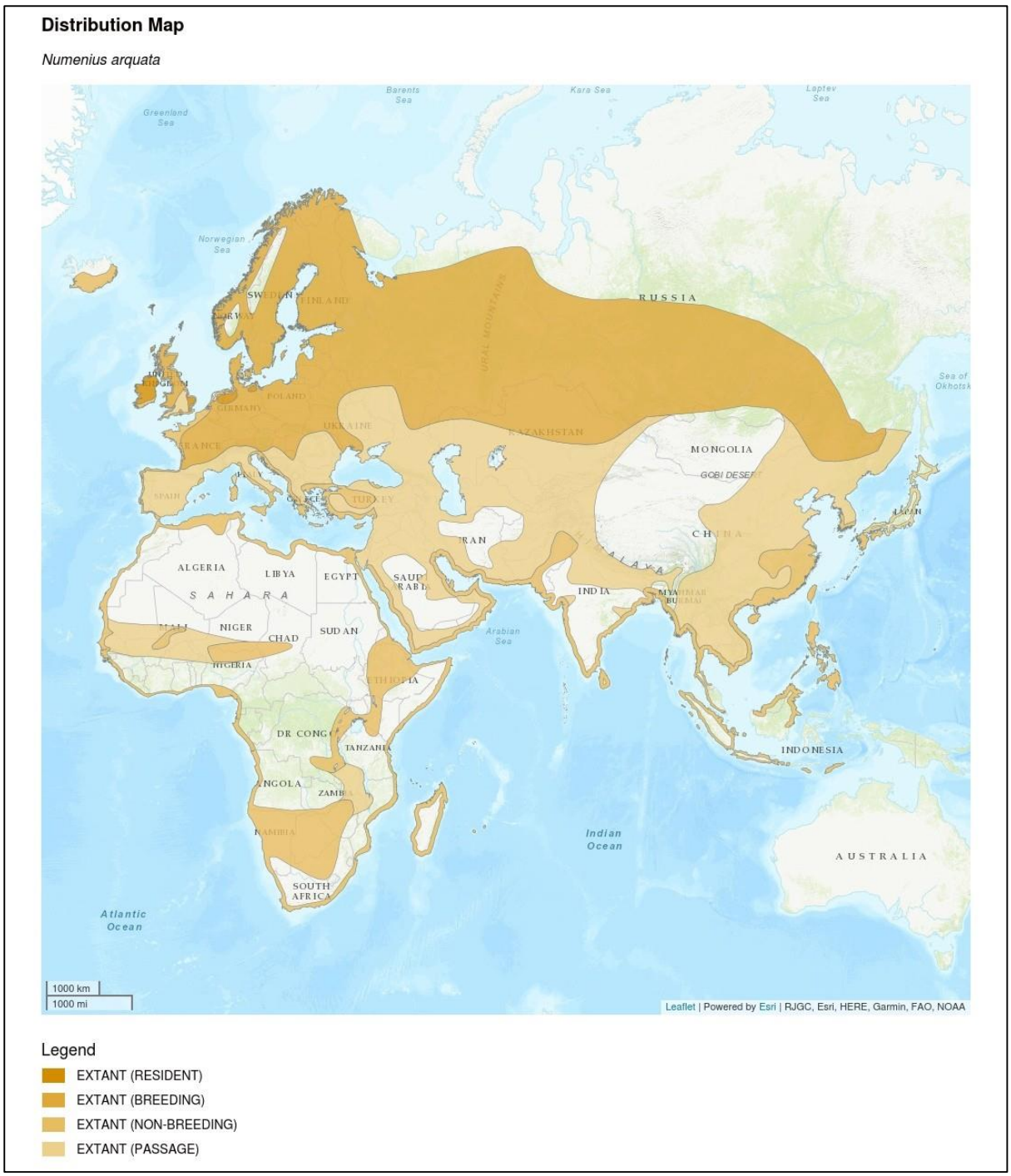


Fig.10: Distribution map adopted from IUCN (Source: BirdLife International. 2017)

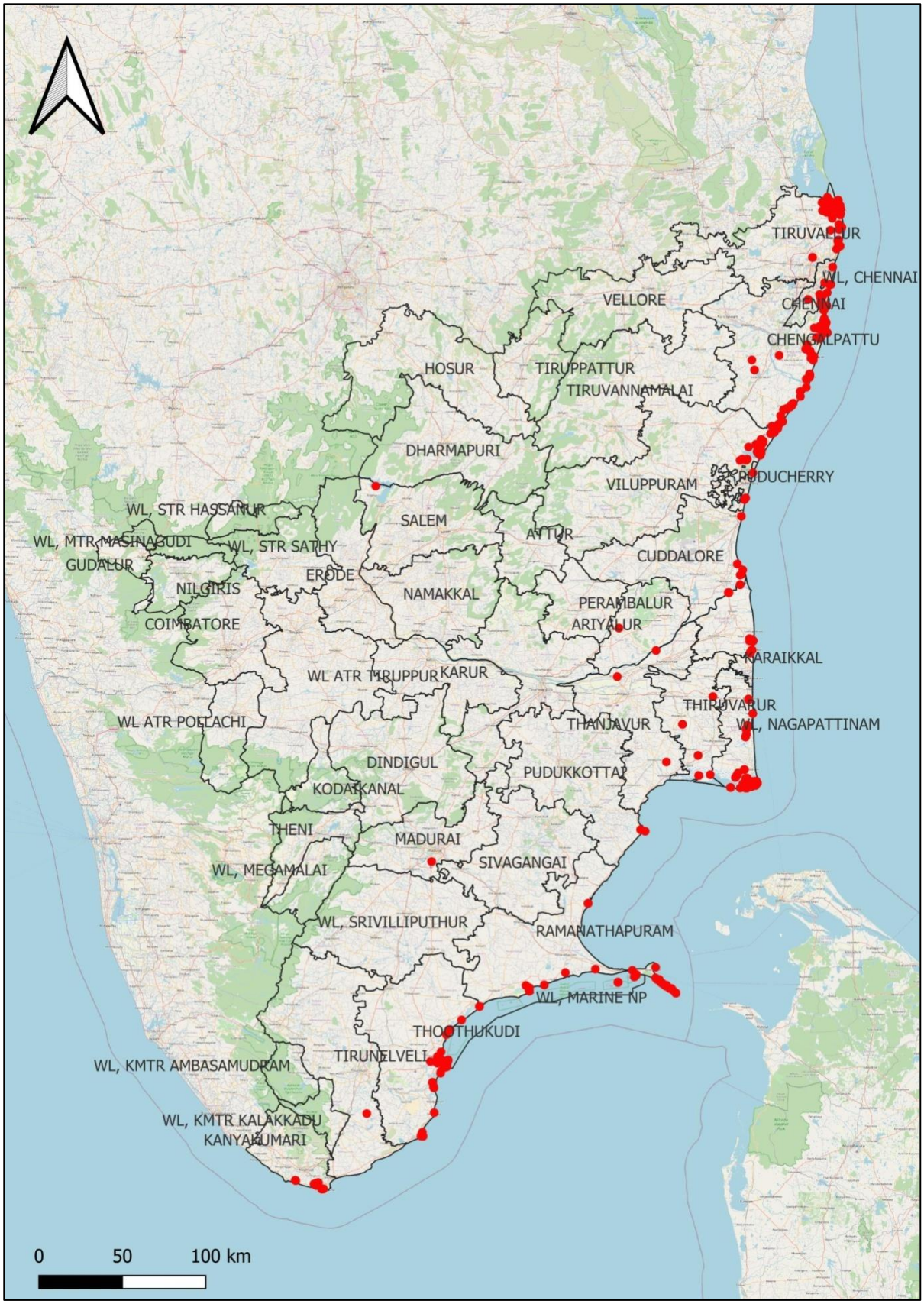


Fig.11: Geographical distribution of Eurasian Curlew (2015-2025)

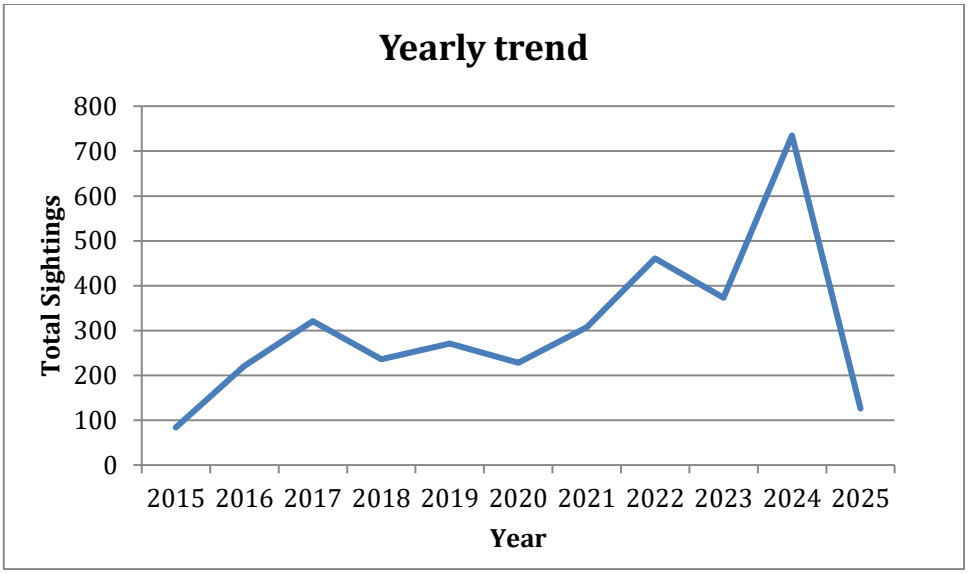


Fig.12: Yearly trend of occurrence of Eurasian Curlew

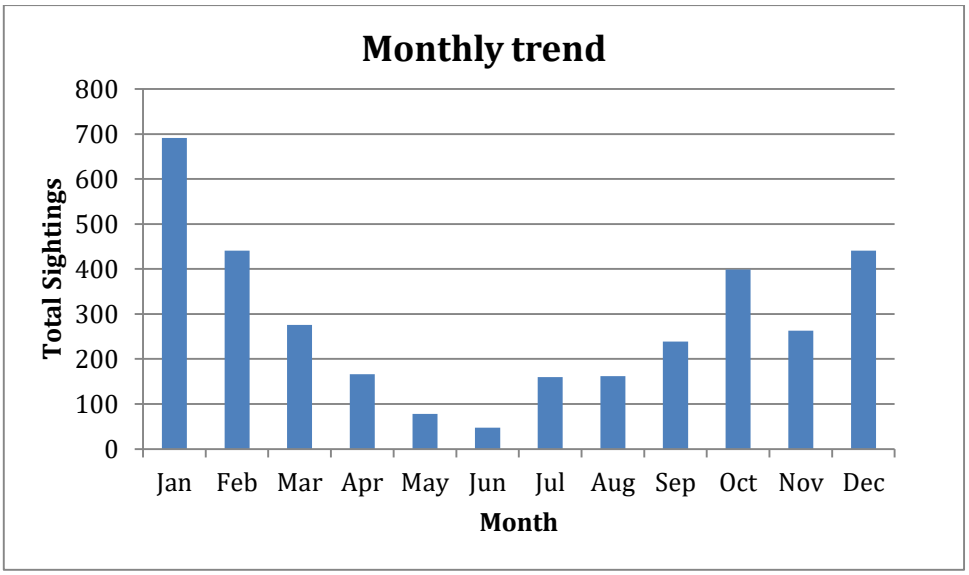


Fig.13: Monthly trend of occurrence of Eurasian Curlew

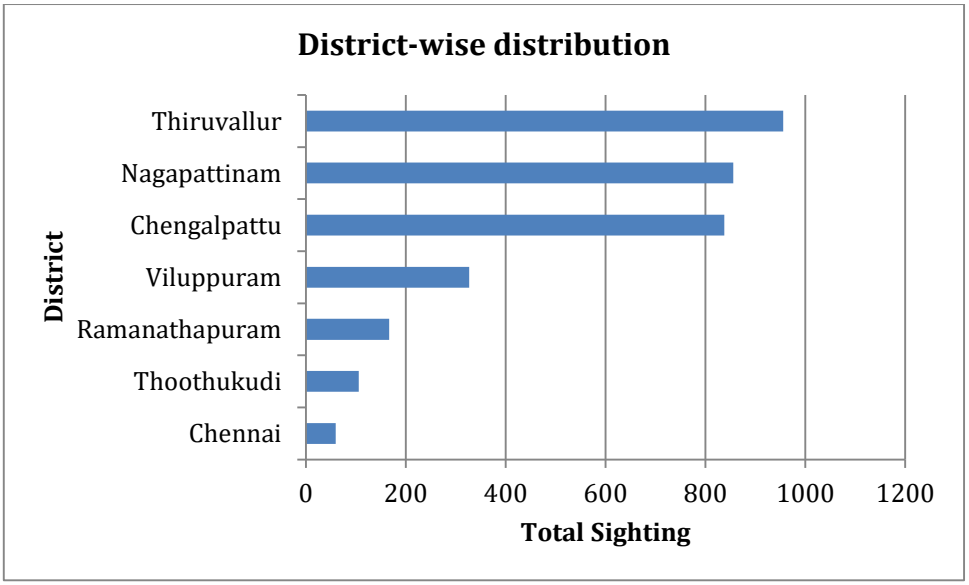


Fig.14: District wise relative abundance of Eurasian Curlew

Result

The Eurasian Curlew is often sighted species in Thiruvallur District, wherein 956 sightings have been recorded during the period of data collection. In 2024, highest count with 735 sightings, indicating a strong presence in that region. Major observations of 691 sightings were recorded during the month of January. It indicates that the peak time of migration of Eurasian Curlew is in January and spending their winter in Northern part of Tamil Nadu region.

Discussion

The high concentration of Eurasian Curlew sightings in January highlights Thiruvallur's significance as a winter refuge along the Central Asian Flyway. The species follows a chain migration strategy, typically making several stopovers en route to wintering sites, which allows for resting and refuelling (Pederson *et al*., 2022). This adaptive migration pattern is shaped by habitat availability and environmental conditions (Sathe & Pawar, 2022). Given the species' global decline and its dependence on wetland habitats, the conservation of critical sites in Tamil Nadu is essential. Protecting these areas will help support not only the Eurasian Curlew but also the broader network of migratory birds reliant on similar habitats (Kumar & Alam, 2023).

5. 3. Common Pochard (*Aythya ferina*)

- Kingdom: Animalia
- Phylum: Chordata
- Class: Aves
- Order: Anseriformes
- Family: Anatidae
- Genus: Aythya
- Scientific name: *Aythya ferina* (Linnaeus, 1758)
- Tamil name:(செங்கிளான்) Sengilaan

1. Identification Key

1.1 Morphological Characteristics

- **Bird Height:** 42-49 cm
- **Wing Length:** 72-82 cm
- **Weight:** 800-1300 g
- **Male Characteristics:** The male has a rufous-chestnut head, blackish breast, grey body with vermiculations, and bright orange-red eyes.
- **Female Characteristics:** The female has a dull brown head, greyish-brown body, and pale grey eyestripe, with a variable pattern on the throat and cheeks.
- **Plumage Description:** Males have a striking rufous-chestnut head and grey body, while females have a dull brown head and greyish-brown body.
- **Juvenile Plumage:** Duller than adult females.

2. Behavioural Ecology

- **Social Structure:** Gregarious, forms large flocks outside breeding season.
- **Foraging Habits:** Dives for food.
- **Geographic Range & Habitat:** Europe, Asia, and Africa; breeds in freshwater wetlands, winters in warmer regions.
- **Behaviour:** Diurnal, migratory.

- **Communication and Perception:** Various calls; visual cues.
- **Food Habits:** Omnivorous, feeding on aquatic plants, insects, and small invertebrates.
- **Predation:** Foxes, raptors, large fish.
- **Ecosystem Roles:** Plays a role in nutrient cycling in wetland ecosystems.

3. **Reproduction**

- **Mating Habits:** Serially Monogamous.
- **Breeding Season:** April-August.
- **Nesting Grounds:** Freshwater wetlands.
- **Nesting Behaviour:** Nests near or over water, often in dense vegetation.
- **Egg Laying:** 6-12 eggs.
- **Egg Incubation Period:** 24-28 days.
- **Development of Young:** Precocial; chicks fledge after 50-55 days.
- **Lifespan and Maturity:** Lifespan up to 13 years; mature at 1-2 years.

4. **Physical Characteristics**

- **Overall Description:** Medium-sized diving duck.
- **Lifespan/Longevity:** Up to 13 years.
- **Top Flying Speed:** Approximately 70 km/hr (43 mph).

5. **Conservation Status**

- **Conservation Status Overview: Vulnerable (IUCN)**
- **Population:** 1,200,000-1,500,000 individuals globally
- **Population Trends:** Decreasing.
- **Threats to Survival:** Habitat loss, pollution, hunting.
- **WPA, 1972 Schedule: Schedule- I**
- **Distribution:** Winter visitor; wetlands

Source: (Carboneras *et al*., 2020), (BirdLife International, 2021), (Animalia Bio Index) & (R J Ranjit Daniels, B Vinoth, 2023).

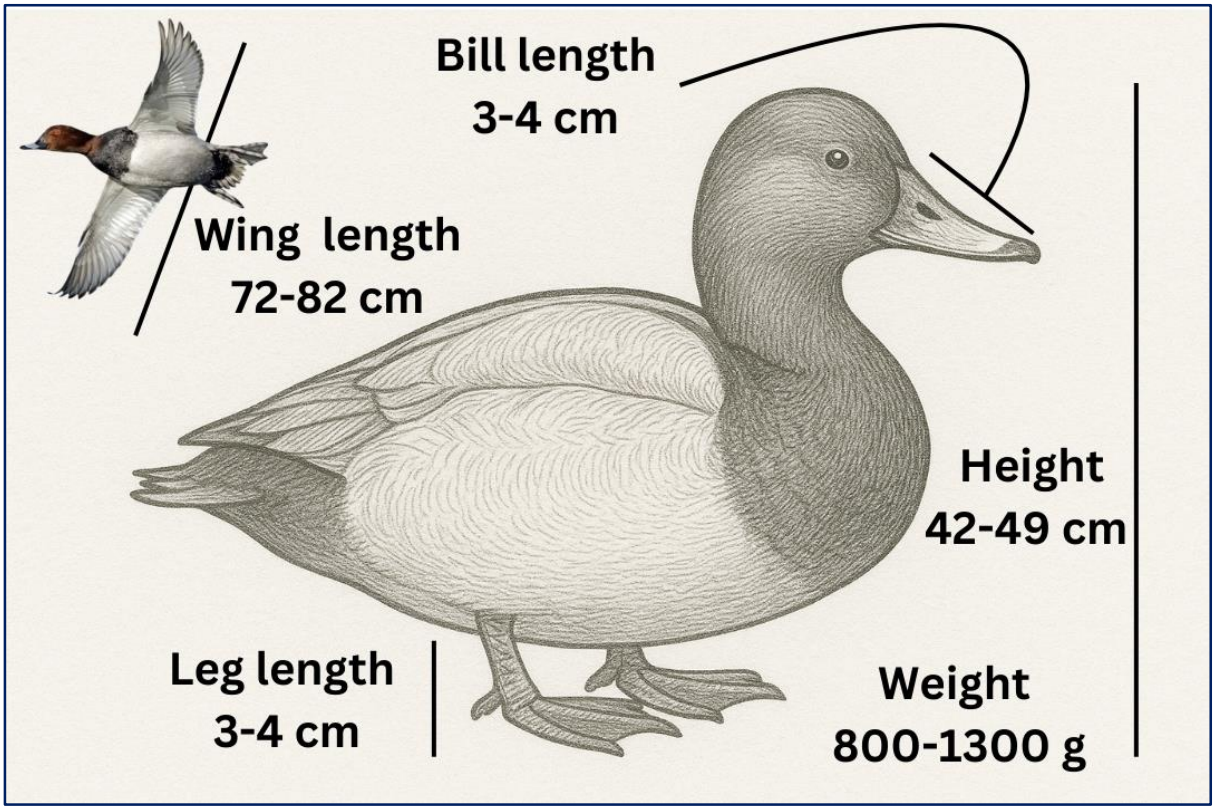


Fig.15: Illustration of Common Pochard

Fig.16: Distribution map adopted from IUCN (Source: BirdLife International. 2021)

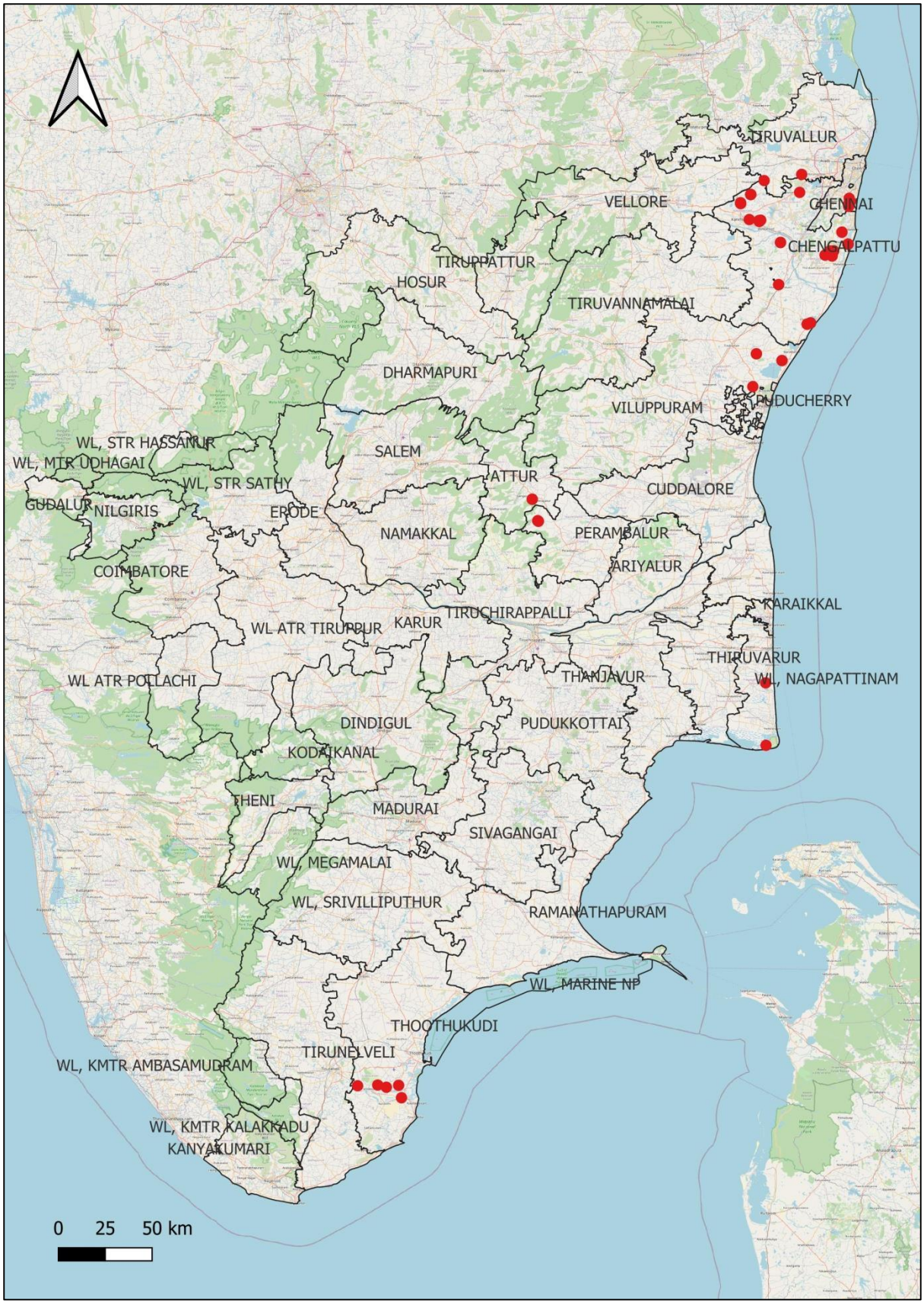


Fig.17: Geographical distribution of Common Pochard (2015-2025)

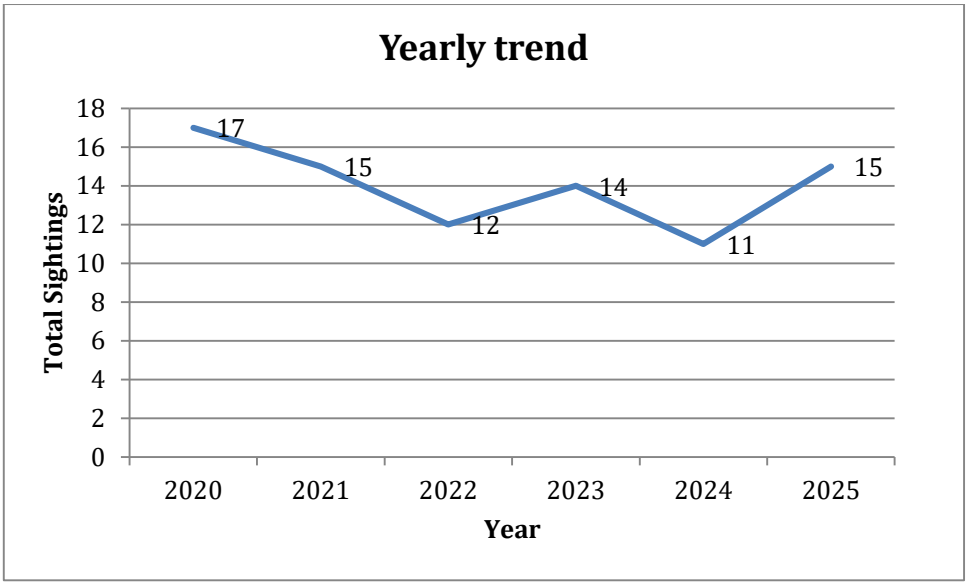


Fig.18: Yearly trend in Occurrence of Common Pochard

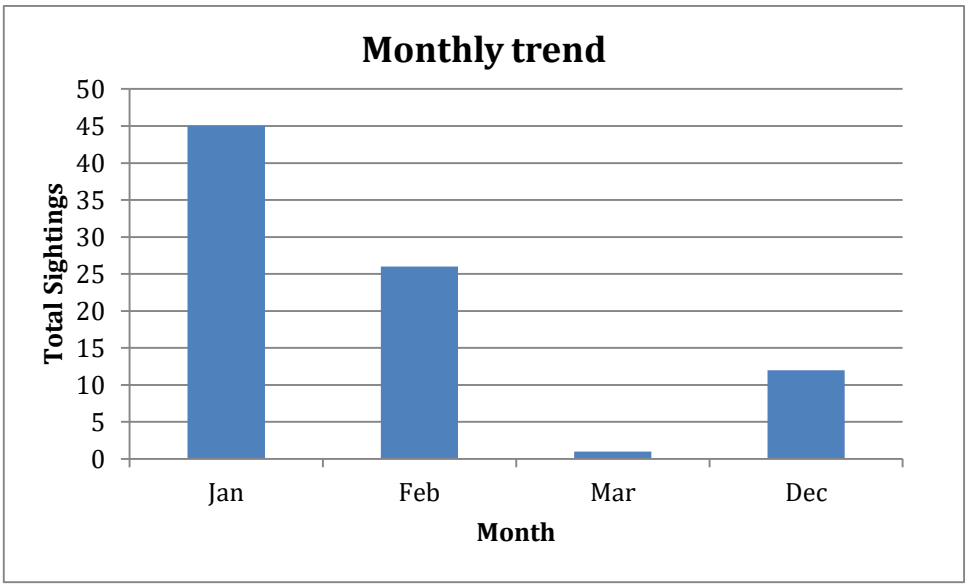


Fig.19: Monthly trend in Occurrence of Common Pochard

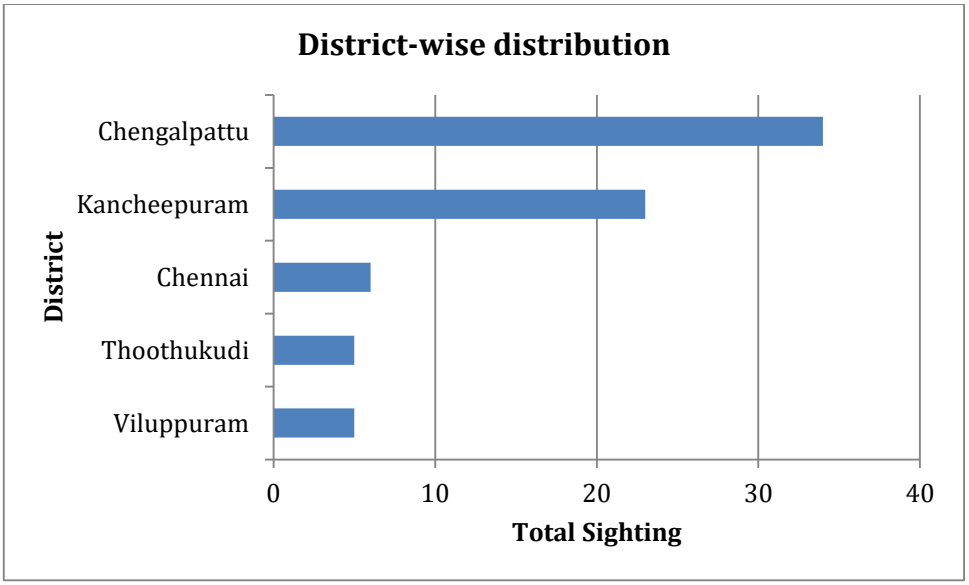


Fig.20: District wise relative abundance of Common Pochard

Result

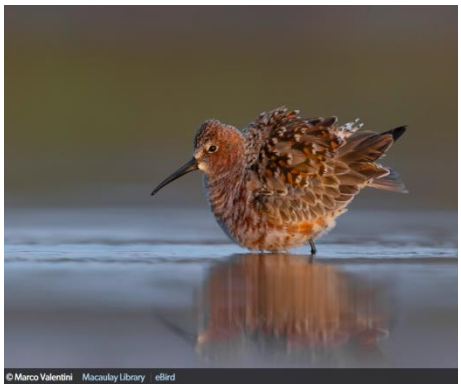
The Common Pochard was mostly observed in Chengalpattu District, wherein a total of 34 sightings were recorded. The highest number of observations were recorded in 2020, with 17 sightings. Highest number of observations found in the month of January, totally 45 sightings. It indicates that the Common Pochard is likely to utilize the wetlands and coastal areas of Chengalpattu Districts during the migration period. As the result shows that the trends of sightings are very stable with 11-17 observations per year and the period of migration is very short.

Discussion

The observed seasonal presence of the Common Pochard in Chengalpattu highlights the district's importance as a migratory habitat. The peak in January and the consistent yet short-term sightings suggest that the species uses this region as a stopover or transient wintering ground. Tamil Nadu's wetland ecosystems—particularly lakes, reservoirs, and fish ponds—offer ideal conditions such as ample food resources and suitable shelter, supporting the needs of this migratory diving duck (Jayakumar *et al*., 2014; Kumar & Srivastav, 2013).

The short migration period aligns with global trends, where habitat use is influenced by water quality and availability of food (Munteanu *et al*., 2022). Given that the Common Pochard is listed as Vulnerable on the IUCN Red List due to declining global populations, the protection of these wetland habitats in Tamil Nadu becomes vital. Conserving such ecosystems will not only aid the Common Pochard but also support a wide diversity of wintering waterfowl species dependent on these habitats.

5.4 Curlew Sandpiper (*Calidris ferruginea*)



- Kingdom: Animalia
- Phylum: Chordata
- Class: Aves
- Order: Charadriiformes
- Family: Scolopacidae
- Genus: Calidris
- Scientific name: *Calidris ferruginea (*Pontoppidan, 1763)
- Tamil name: (வளைமூக்கு உள்ளான்) Valaimooku ullan

1. Identification Key

1.1 Morphological Characteristics

- **Bird Height:** 18-23 cm
- **Wing Length:** 38-45 cm
- **Weight:** 40-70 g
- **Male Characteristics:** During breeding, males have a distinctive rusty-red plumage, a white belly, and black streaks on their back.
- **Female Characteristics:** Females are similar to males but have a duller, more muted breeding plumage.
- **Plumage Description:** The breeding plumage is rusty-red with a white belly and black streaks on the back, while non-breeding plumage is greyish-brown with a white belly.

- **Juvenile Plumage:** Grey-brown upperpart, largely white underparts with some fine streaking on the chest, and a and a face pattern that has a white eyebrow and a dark-brown stripe by the eye.

2. Behavioural Ecology

- **Social Structure:** Gregarious; forms large flocks, especially during migration.
- **Foraging Habits:** Probes mudflats for invertebrates.
- **Geographic Range & Habitat:** Breeds in Arctic tundra; migrates to Africa, Asia, Australia; found in coastal wetlands and mudflats.
- **Behaviour:** Diurnal, migratory.
- **Communication and Perception:** High-pitched calls.
- **Food Habits:** Small invertebrates (crustaceans, molluscs).
- **Predation:** Arctic foxes, gulls, raptors.
- **Ecosystem Roles:** Important component of coastal food webs.

3. Reproduction

- **Mating Habits:** Monogamous.
- **Breeding Season:** June-August.
- **Nesting Grounds:** Arctic tundra.
- **Nesting Behavior:** Nests in shallow depressions on the ground.
- **Egg Laying:** 4 eggs.
- **Egg Incubation Period:** 20-22 days.
- **Development of Young:** Precocial; chicks fledge after 16-18 days.
- **Lifespan and Maturity:** Lifespan up to 10 years; matures at 1-2 years.

4. Physical Characteristics

- **4.1 Overall Description:** Small wader with a curved bill.
- **4.2 Lifespan/Longevity:** Up to 10 years.
- **Top Flying Speed:** Approximately 60 km/hr (37 mph).

5. Conservation Status

- **Conservation Status Overview: Vulnerable (IUCN)**
- **Population:** 1,100,000 - 1,400,000 individuals globally
- **Population Trends:** Decreasing.
- **Threats to Survival:** Habitat loss, climate change.
- **WPA, 1972 Schedule: Schedule- II**
- **Distribution:** Winter Visitor; local in coastal wetlands

Source: (Mlodinow, & Medrano, 2023), (BirdLife International, 2024), (Animalia Bio Index) & (R J Ranjit Daniels, B Vinoth, 2023).

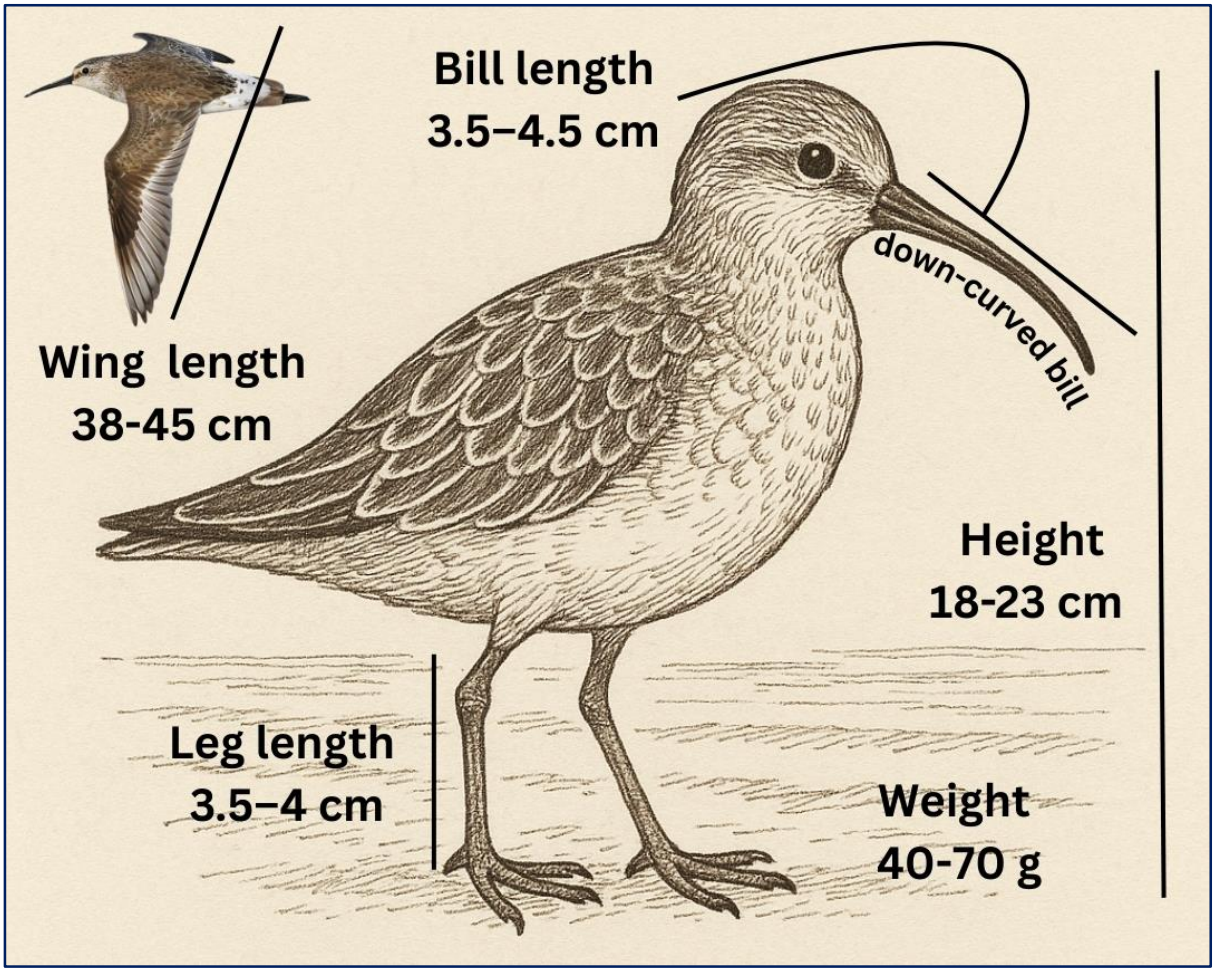


Fig.21: Illustration of Curlew Sandpiper

Fig.22: Distribution map adopted from IUCN, (BirdLife International. 2024)

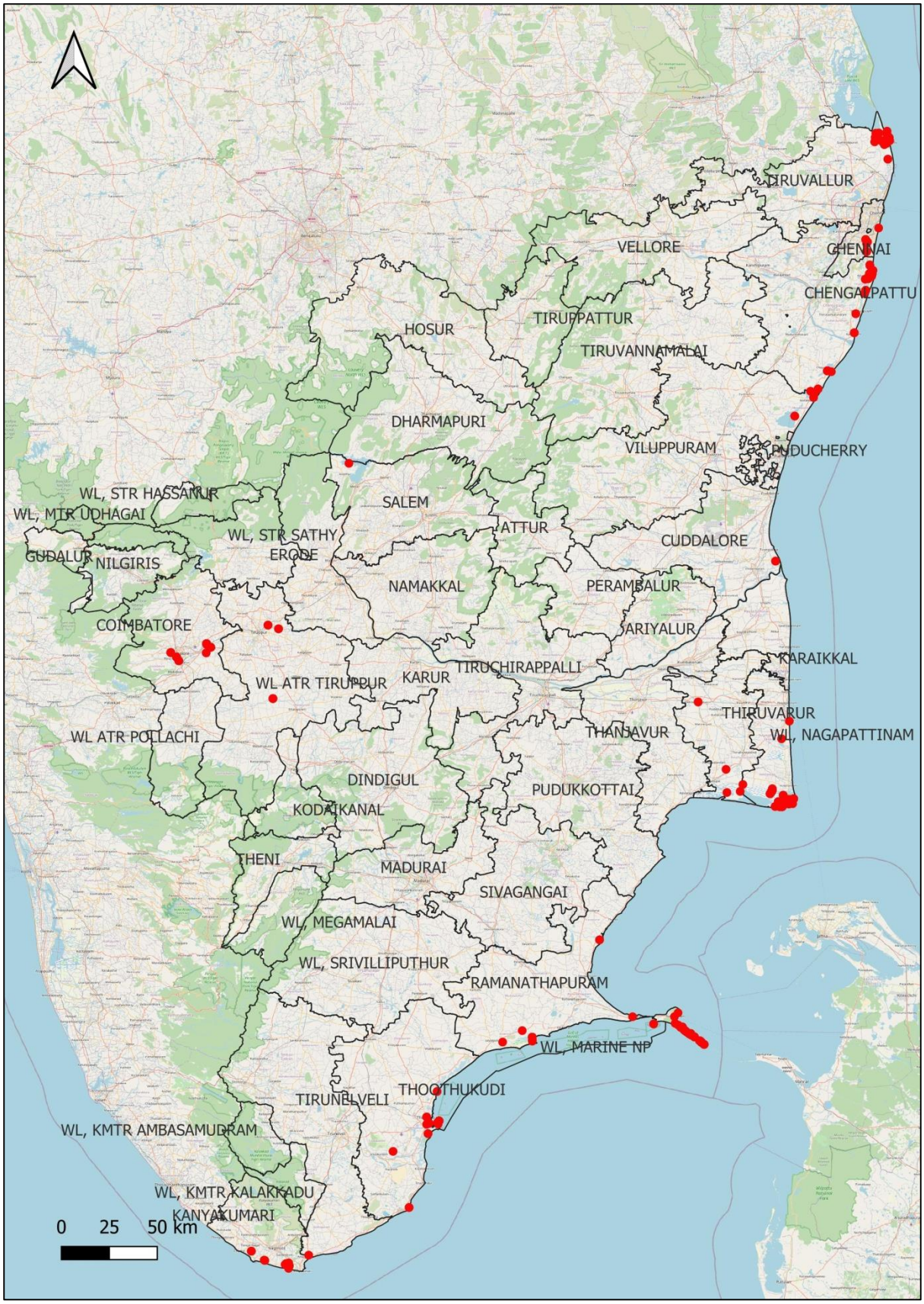


Fig.23: Geographical distribution of Curlew Sandpiper (2015-2025)

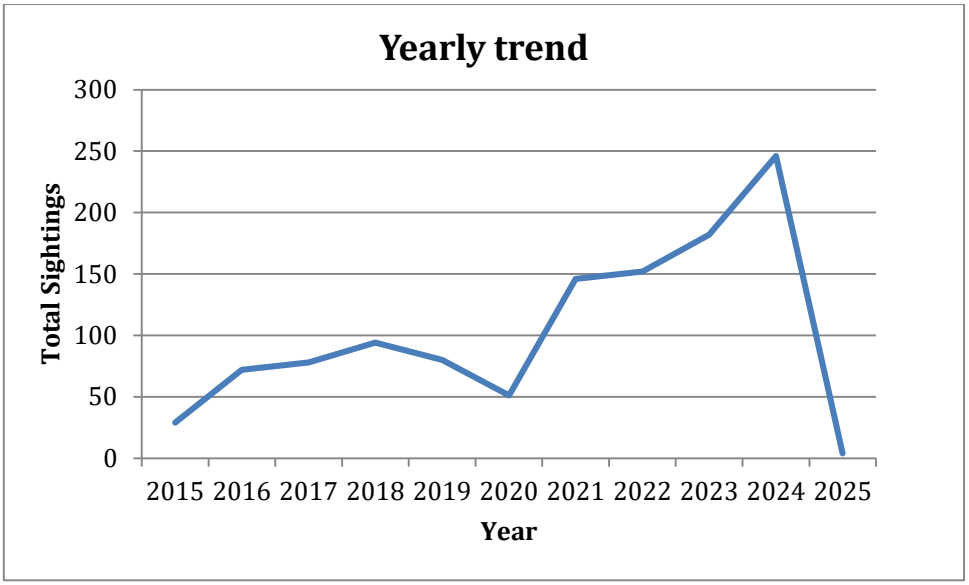


Fig.24: Yearly trend of occurrence of Curlew Sandpiper

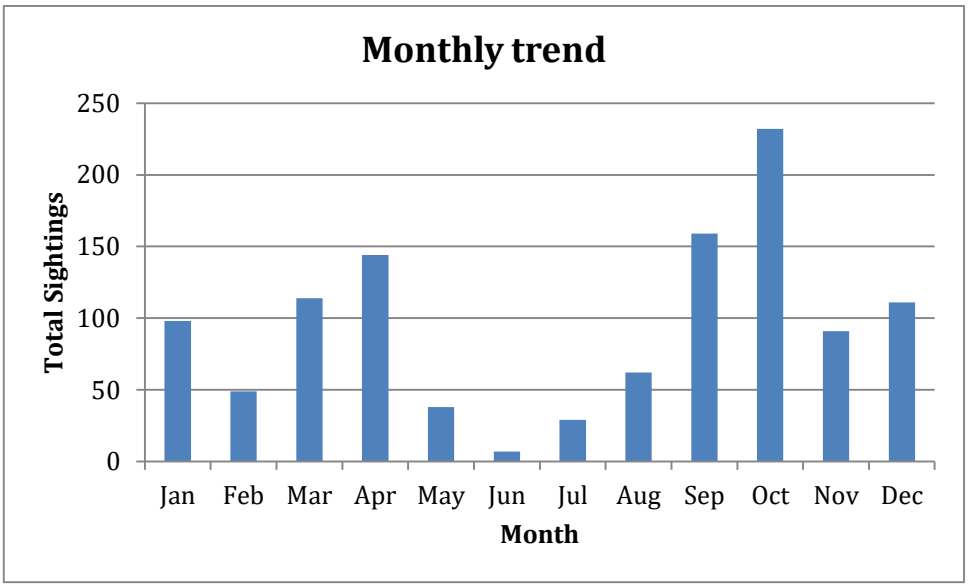


Fig.25: Monthly trend of occurrence of Curlew Sandpiper

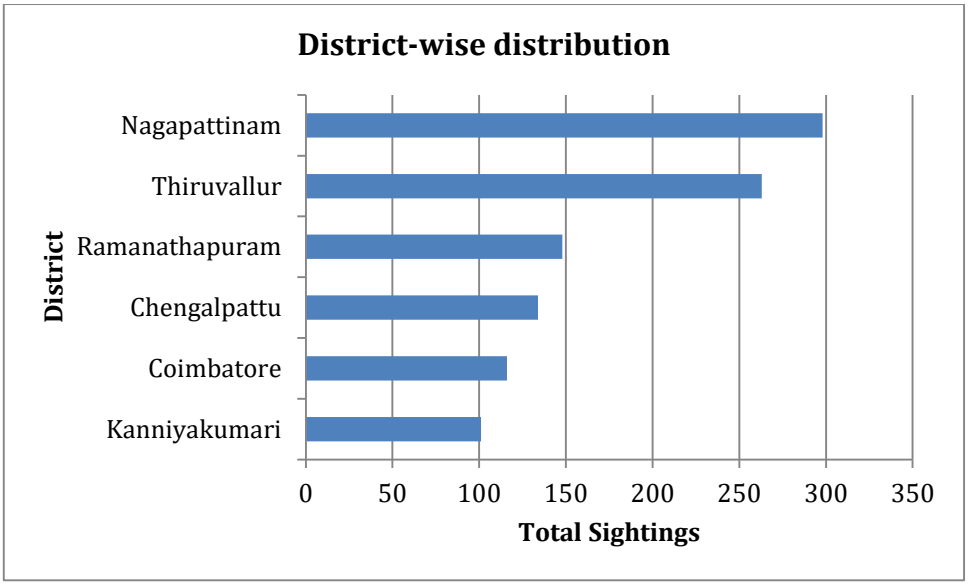


Fig.26: District wise relative abundance of Curlew Sandpiper

Result

The highest number of observations of Curlew Sandpiper from Nagapattinam District, with 298 sightings. The highest number of 246 sightings were recorded in 2024. October month was identified as the peak sightings of this species, with huge number of sightings i.e. 232 observations. The results shows that the Nagapattinam District has large coastal areas and serves as a vital stopover site for the Curlew Sandpiper, and provide suitable habitats during migration.

Discussion

The observation trends indicate that Nagapattinam plays a pivotal role as a migratory stopover for the Curlew Sandpiper (*Calidris ferruginea*), likely due to its rich coastal wetland habitats that provide food and roosting opportunities. This species, a long-distance Arctic migrant, uses the Central Asian Flyway and frequently halts in southern India during its non-breeding season. In some cases, individuals over-summer in Tamil Nadu, bypassing a return to Arctic breeding grounds—an emerging behaviour linked to changing global environmental conditions (Byju *et al.*, 2024).

The significant number of sightings in 2024 and especially in October suggests a peak influx aligned with their southbound migration. Tamil Nadu's wetlands,

particularly those in Nagapattinam, offer essential ecological support to migratory shorebirds, and their conservation is vital for maintaining this function (Byju *et al*., 2023). Studies show low genetic differentiation among populations using different flyways (Wennerberg, 2001), meaning disruptions in any major stopover site, including those in India, could affect global populations.

The Curlew Sandpiper's susceptibility to habitat loss and climate change underscores the urgent need for continued protection and management of coastal and wetland ecosystems in Nagapattinam and beyond. These habitats are critical stopover and wintering sites along the Central Asian Flyway, supporting not only the Curlew Sandpiper but a wide range of migratory shorebirds. Ensuring the ecological integrity of these migratory corridors is essential to sustaining regional and global shorebird populations. These findings highlight the importance of implementing targeted wetland conservation strategies across coastal Tamil Nadu to mitigate environmental pressures and support long-term migratory bird conservation.

5.5. Bar-headed Goose *(Anser indicus)*

- Kingdom: Animalia
- Phylum: Chordata
- Class: Aves
- Order: Anseriformes
- Family: Anatidae
- Genus: Anser
- Scientific name: *Anser indicus* (Latham, 1790)
- Tamil name: (வரித்தலை வாத்து/ நீர் வாத்து) Neer vaathu

1. Identification Key

1.1 Physical Characteristics

- **Bird Height:** 71-76 cm
- **Wing Length:** 140-160 cm
- **Weight:** 2-3.2 kg

- **Male Characteristics:** The male has a white head with black neck stripes and a brownish-grey body.
- **Female Characteristics:** Similar to males but with slightly duller breeding plumage.
- **Plumage Description:** The breeding plumage features a white head, black neck stripes, and a brownish-grey body. Non-breeding plumage is similar but with more brownish-grey on the head and neck.
- **Juvenile Plumage:** Duller plumage.

2. Behavioural Ecology

- **Social Structure:** Gregarious, forms large flocks.
- **Foraging Habits:** Grazes on grasses and aquatic plants.
- **Geographic Range & Habitat:** Breeds in high-altitude lakes in Central Asia; winters in India and Southeast Asia.
- **Behaviour:** Diurnal, migratory.
- **Communication and Perception:** Honking calls.
- **Food Habits:** Herbivorous; grasses and aquatic plants.
- **Predation:** Foxes, eagles.
- **Ecosystem Roles:** Plays a role in seed dispersal and nutrient cycling.

3. Reproduction

- **Mating Habits:** Monogamous.
- **Breeding Season:** May-June.
- **Nesting Grounds:** High-altitude lakes and wetlands.
- **Nesting Behavior:** Nests on the ground near water.
- **Egg Laying:** 3-8 eggs.
- **Egg Incubation Period:** 28-30 days.
- **Development of Young:** Precocial; chicks fledge after 45-50 days.

4. Physical Characteristics

- **Overall Description:** Goose with distinctive head markings.

- **Lifespan/Longevity:** Up to 20 years.
- **Top Flying Speed:** Approximately 80 km/hr (50 mph).

5. Conservation Status

- **Conservation Status Overview: Least Concern (IUCN)**
- **Population:** 50,000-100,000 individuals globally
- **Population Trends:** Stable.
- **Threats to Survival:** Habitat degradation, hunting.
- **WPA, 1972 Schedule: Schedule- II**
- **Distribution:** Winter visitor; wetlands in southern Tamil Nadu

Source: (Carboneras *et al*., 2020); (BirdLife International, 2018), (Animalia Bio Index) &(R J Ranjit Daniels, B Vinoth, 2023).

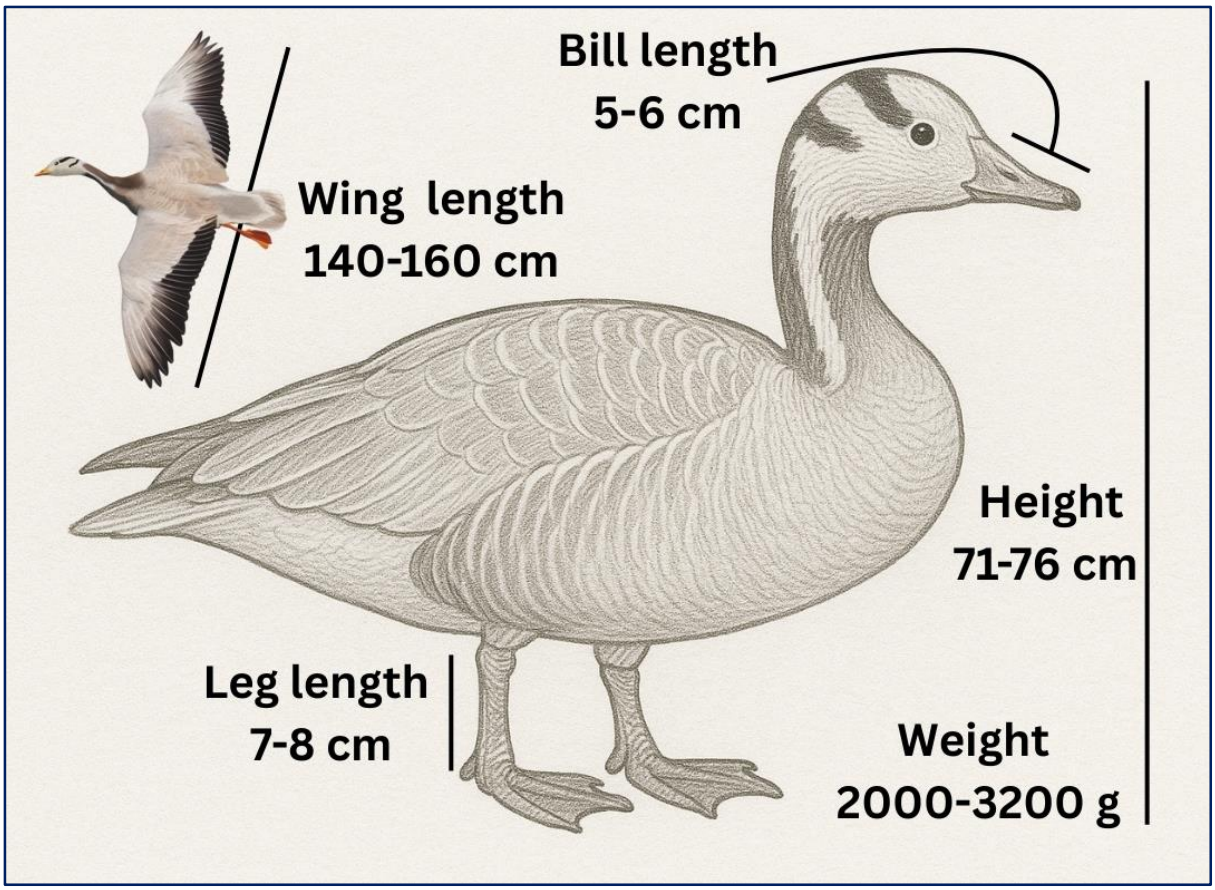


Fig.27: Illustration of Bar-headed goose

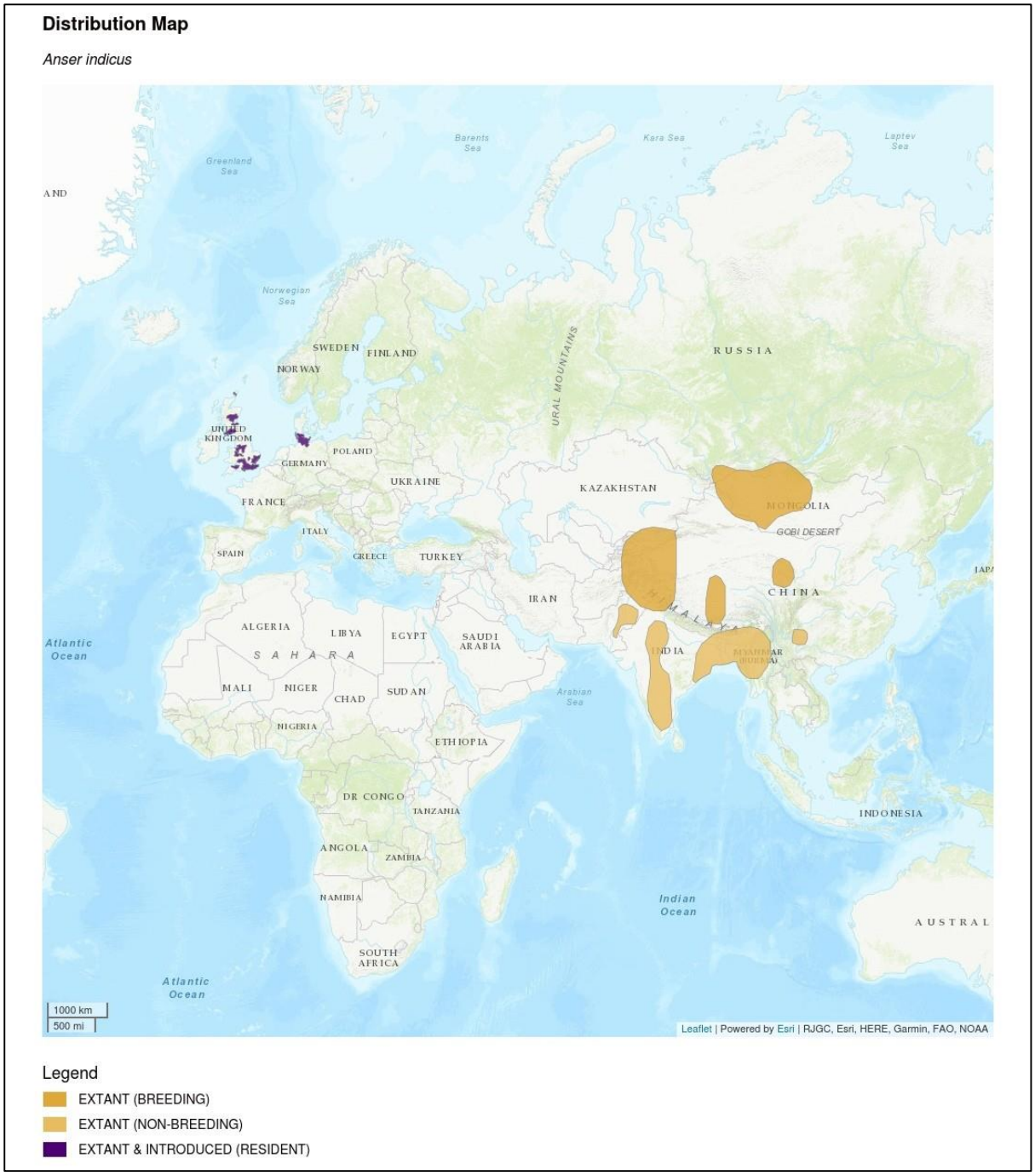


Fig.28: Distribution map adopted from IUCN, BirdLife International. 2018)

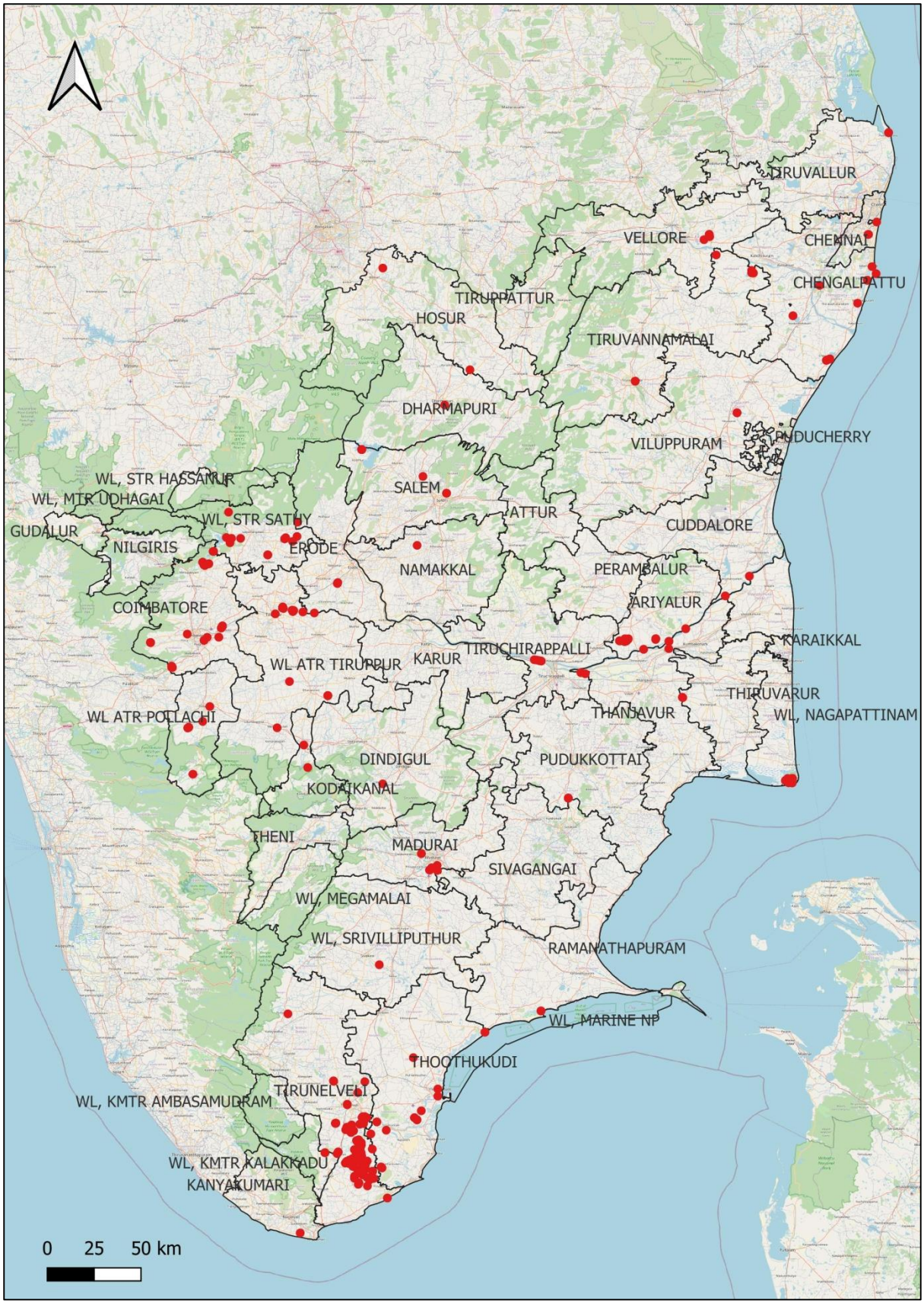


Fig.29: Geographical distribution of Bar-headed Goose (2015-2025)

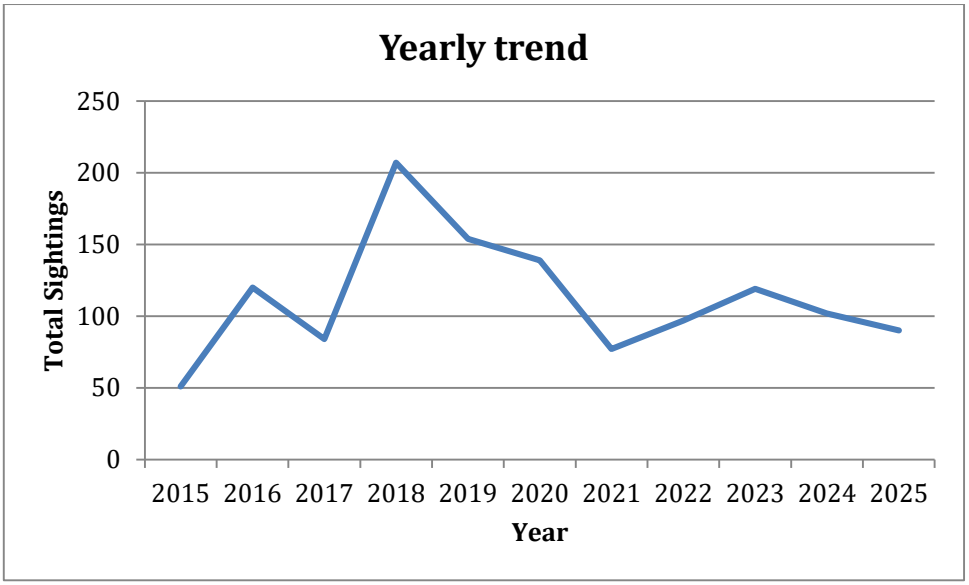


Fig.30: Yearly trend of occurrence of Bar-headed Goose

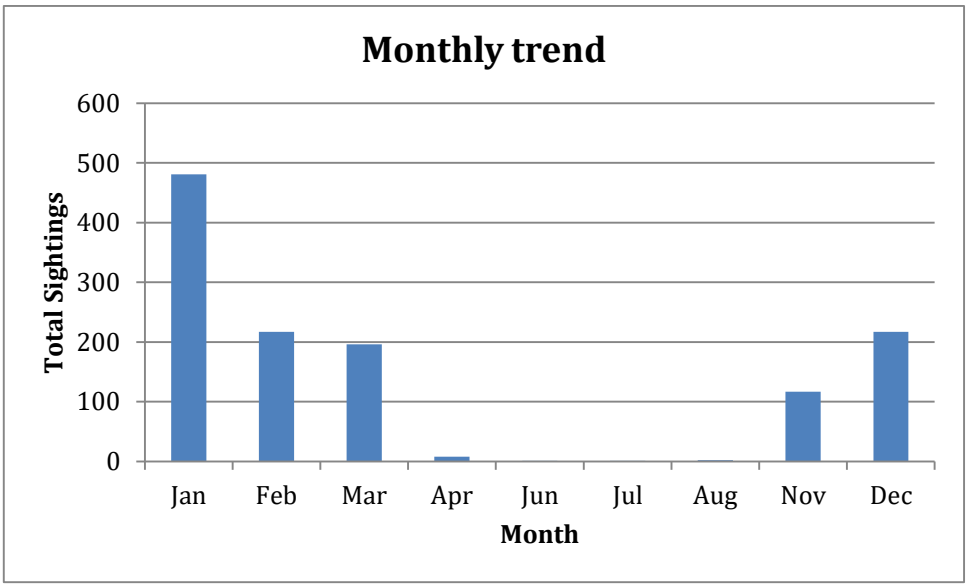


Fig.31: Monthly trend of occurrence of Bar-headed Goose

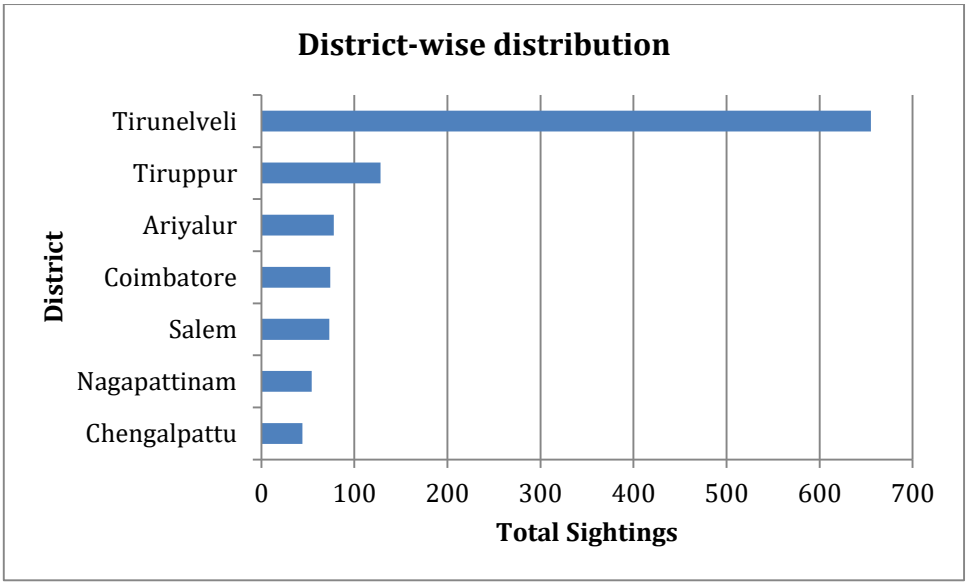


Fig.32: District wise relative abundance of Bar-headed Goose

Result

A total of 655 observations of Bar-headed Goose was sighted in Tirunelveli District, which is highest among other districts of Tamil Nadu..During the last decade, highest number of sightings (207 nos.) were observed in 2018. January month was the most frequent sightings (481 nos.). Since the Bar-headed Goose was observed from November to August, its migration is the most prolonged migration. It indicates that the Bar-headed Goose migrates to the southern regions of Tamil Nadu during migration, likely due to the suitable habitat and availability of food resources.

Discussion

The Bar-headed Goose (*Anser indicus*) demonstrates fascinating migratory behaviour, particularly in Tamil Nadu, where it has been observed during the winter months. Historical records and recent observations indicate a regular winter presence in the region, with migration occurring from October to November, peaking in January to February, and tapering off by March (Santharam, 1997; Kshirsagar *et al*., 2022). These geese are known for their ability to fly at altitudes of up to 9,000 meters, showcasing their remarkable adaptation to high-altitude environments during migration (Scott & Milsom, 2007). In Tamil Nadu, they are spotted in various habitats,

including wetlands and urban areas, with fluctuating populations over the years, as recorded by the Asian Waterfowl Census (Santharam, 1997).

6. Conclusion

This document establishes that migratory bird species are well recorded and frequently traverse the Tamil Nadu region, reflecting the presence of suitable habitats and abundant food sources. It underscores the ecological significance of these rare migratory species within the state.

The findings identify key districts in Tamil Nadu that serve as crucial habitats for different migratory birds. Notably, the Ruddy Turnstone peaked in Thiruvallur in September 2024, the Eurasian Curlew showed a strong wintering presence in Nagapattinam in January 2024, the Common Pochard was most frequently observed in Chengalpattu in January 2020, the Curlew Sandpiper reached its highest numbers in Nagapattinam in October 2024, and the Bar-headed Goose was significantly recorded in Tirunelveli in January 2018.

These seasonal and spatial patterns suggest that migratory birds utilize specific regions at certain times of the year, influenced by food availability and habitat conditions. Ongoing monitoring and conservation efforts are essential to protect these species and their habitats, especially amid environmental changes.

The report highlights the need for continued research and targeted conservation actions, particularly in underreported areas that may lack adequate resources. Integrating ecological knowledge with practical strategies, such as habitat restoration in Chengalpattu for the Common Pochard and focused protection in Tirunelveli for the Bar-headed Goose, will support the long-term survival of these species and the ecological integrity of Tamil Nadu's landscapes.

Effective conservation will require collaboration among researchers, policymakers, and local communities. A cooperative approach to safeguarding wetlands and addressing habitat loss will help preserve the region's biodiversity and the essential ecosystem services provided by migratory birds.

7. Key Conservation Challenges for Migratory Birds

7.1. Habitat Loss and Degradation

a. Urbanization and Infrastructure Development

Urbanization is one of the most significant threats to migratory birds, as cities expand and infrastructure projects alter the natural habitats (Sun *et al*., 2022). Urban areas often replace vital ecosystems with buildings, roads, and other structures, leading to habitat fragmentation. This fragmentation can disrupt migratory routes and reduce the availability of food and nesting sites (Yusuf, 2024). Recent studies have shown that urbanization can alter bird community structures, leading to declines in species that are sensitive to habitat changes (Newton *et al*., 2020) & (Huang *et al*., 2022). Urban areas have more artificial lighting and noise pollution, which can further disorient migratory birds during their journeys. Expanding protected areas will minimize habitat loss (Border *et al*., 2025).

b. Agricultural Expansion

The conversion of forests, wetlands and grasslands into agricultural land is a major driver of habitat loss for migratory birds. Intensive agricultural practices often involve the use of pesticides and fertilizers, which can contaminate nearby habitats and reduce food availability for birds (Johnson *et al.,* 2011); (Byju *et al*., 2023 & 2024). Monoculture farming reduces biodiversity, making it difficult for migratory birds to find the diverse food sources they need during their stopovers (Jacques, P. J., & Jacques, J. R., 2012) & (Altieri, 2009). The loss of natural habitats due to agricultural expansion has been linked to declines in various avian populations, particularly those that rely on specific habitats for roosting, breeding and feeding.

c. Encroachment on Wetlands and Coastal Areas

Wetlands are critical for many migratory bird species, providing essential feeding, breeding grounds and also stopover sites. Developmental and industrial activities have led to significant encroachment on these vital ecosystems. In regions like the East Asia-Australasia Flyway, the loss of wetlands has resulted in dramatic declines

in shorebird populations, as these areas serve as crucial stopover sites during migration (Leibowitz, 2003); (Kirby *et al*., 2008);(Wang *et al*., 2022); (Anand *et al*., 2023) &(Chakraborty, *et al*., 2023). The degradation of coastal areas due to human activities not only reduces habitat availability but also impacts the ecological functions of these environments, further threatening migratory birds.

d. Coastal Erosion

Coastal erosion is a growing concern for migratory birds, particularly in areas where rising sea levels and human activities are accelerating the loss of coastal habitats. Erosion can lead to the loss of nesting sites and feeding grounds, making it increasingly difficult for migratory birds to thrive. Research indicates that coastal erosion is also intensified by climate change, which alters weather patterns and increases the frequency of extreme weather events (Cherian *et al*., 2012);(Balachandran, 2012); (Prasad & Kumar, 2014); (Pang *et al*., 2023) & (George *et al*., 2023). As coastal habitats diminish, migratory birds face increased pressure to find suitable alternatives, which may not always be available.

e. Competition for Resources

As habitats become fragmented and degraded, competition for limited resources intensifies among bird species (Lees *et al*., 2022). This competition can lead to increased stress and lower survival rates for migratory birds, particularlythose already vulnerable due to habitat loss (Guillaumet & Russell, 2022). Species that depend on specific habitats may struggle to compete with more adaptable species that can thrive in altered environments (Powell *et al*., 2021) & (Grether *et al*., 2022). The increased competition for food, nesting sites, and other resources can have cascading effects on bird populations, leading to declines in biodiversity and ecosystem health. Advancing migration studies through integrating new concepts and technologies, researchers can better understand and protect these crucial ecological functions (Robinson *et al.*, 2010).

7.2. Climate Change

a. Mismatched Timing

Mismatched timing refers to the phenomenon where migratory birds arrive at their breeding grounds either too early or too late due to shifts in climate patterns (Visser *et al*., 2004) & (Cox, 2010). This mismatch can disrupt the synchronization between the timing of migration and the availability of food resources, which are essential for breeding (Curley *et al*., 2024). If birds arrive too early, they may find that food sources have not yet emerged, leading to poor reproductive success and lower chick survival rates (Dunn & Winkler, 2010) & (Møller *et al*., 2008). Conversely, if they arrive too late, they may miss the optimal breeding. Research has shown that shifts in breeding dates have occurred in response to climate change, which can have cascading effects on population dynamics (Both *et al*., 2006 & 2010) & Bairlein, (2016).

b. Altered Weather Patterns

Climate change is associated with altered weather patterns, including increased frequency and intensity of extreme weather events such as storms, droughts, and heavy rainfall (Urfi, 2011), (Seneviratne *et al*., 2021); (Li *et al*., 2022); (Leal *et al*., 2023) & (Jamil *et al*., 2024). These changes can significantly impact migratory routes and stopover sites, making it more challenging for birds to find suitable habitats (Schaefer *et al*., 2008). Altered precipitation patterns can affect the availability of wetlands and other stopover habitats, which are essential for refuelling during migration (Charmantier & Gienapp, 2014); (Bhagarathi *et al*., 2024) & (Nagarajan *et al*., 2022). Extreme weather events can lead to habitat destruction, further complicating the migratory process (Warner *et al.,* 2010) & (Deomurari *et al*., 2023). Birds may also face increased energy expenditure due to adverse weather conditions, which can affect their overall health and survival rates (Howard *et al.*, 2018) & (Kassara *et al*., 2025).

c. Loss of Breeding Habitat

The loss of breeding habitat is a major concern as climate change leads to habitat degradation and fragmentation (Sakthivel *et al*., 2019); (Jamil *et al*., 2024) & (Yuan *et al*., 2024). Rising temperatures can negatively impact ecosystems such as wetlands, forests,

and grasslands, which are necessary for many migratory bird species (Londe *et al*., 2024) & (Yang *et al*., 2024). Wetlands dry up due to increased evaporation and altered rainfall patterns, reducing the available nesting sites(Erwin, 2009);(Burkett & Kusler, 2000) & (Nagarajan *et al*., 2022). Habitat fragmentation can isolate populations, making it more difficult for birds to find suitable breeding sites. Habitat loss can result in population declines and reduced genetic diversity, further threatening the survival of migratory bird species (Arunachalam, 2023).

Climate change is a major threat to the migratory birds. Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events disrupt habitats and migration routes (Newson *et al*., 2009); (Knudsen, *et al*., 2011);(Ali & Al Ramahi, 2021);(Seri & Rahman, 2021); (Wang *et al*., 2024) & (Fernando & Gunawardena, 2024). These changes can reduce food availability, affect breeding success, and increase the vulnerability of birds to other stressors such as pollution.

Wetlands play a critical role in supporting migratory bird populations in Tamil Nadu, but they are increasingly threatened by climate-related factors such as sea-level rise, saltwater intrusion, and habitat loss (Thamizoli & Rengalakshmi, 2022); (Roy *et al*., 2023) & (Selvarajhan & Scholz, 2024). Protecting and restoring these vital habitats is essential for ensuring the long-term survival of migratory bird species. Climate change can alter migration patterns, leading birds to new areas where they may face unfamiliar threats (Klaassen *et al*., 2012).

7.3. Collisions with Human Structures

a. Wind Turbines

Wind turbines pose a significant threat to birds, particularly during migration (Erickson *et al*., 2014) & (Loss *et al.,* 2015). Studies estimate that wind turbines cause approximately 140,000 to 328,000 bird fatalities annually in the United States alone (Kumar *et al*., 2012). The threat is intensified by the design and placement of the turbines; taller turbines with larger rotor diameters are associated with higher mortality rates, especially in areas with high bird traffic (Bošnjaković *et al*., 2024) & (Sangroya, *et al*., 2024). As migratory birds navigate through their routes, they may not detect these structures in time to avoid collisions, leading to increased avian mortality.

b. Buildings and Glass Windows

Buildings, particularly those with large glass surfaces, are responsible for an estimated 365 million to 1 billion bird deaths each year in the U.S. (Loss *et al*., 2014). The reflective nature of glass can confuse birds, leading them to collide with windows as they attempt to fly through what appears to be open space(KLEM JR, Daniel, 1979) &(Klem, 2009). This threat is particularly pronounced in urban areas where tall buildings are prevalent, creating a hazardous environment for migratory birds (Barton *et al*., 2017). The high incidence of collisions with glass surfaces represents a critical challenge for avian conservation.

c. Power Lines / Towers

Power lines and towers are another major source of avian mortality, with estimates suggesting that they cause between 5 to 50 million bird deaths annually in the U.S. (Avian Power Line Interaction Committee, 1996). Birds can collide with the lines or electrocuted when they collide, leading to fatalities (Ferrer & Janss, 1999) &(Manville, 2005). The risk of collision is severe in the high rise of power lines and towers that intersect migratory pathways, making these structures a considerable threat to bird populations (Bevanger & Brøseth, 2004); (Bevanger, 2008), (Drewitt & Langston, 2008); (Arun *et al*., 2013) & (Loss *et al*., 2015). The combination of collision and electrocution risks from power infrastructure underscores the urgent need for effective mitigation strategies to protect migratory birds.

d. Collision with Aircraft

Aircraft collision poses a serious threat to migratory birds (Burger & Gochfeld, 1991). Migratory birds navigate through their flyways where they come across numerous aircrafts and it collides unexpectedly due to raising air traffic (Ali, 1979); (Evans Ogden, 1996); (Burger & Gochfeld, 1991) & (Srinidhi & Pramod, 2021). Annually, 70 million dollars is spent in India to repair aircrafts damaged by the vultures (Sodhi,2002). Recent researches with AI and ML have identified a proactive mitigation strategy that leverage advanced predictive models to enhance airport safety and reduce collisions (Pillai *et al*., 2024) & (Deshpande *et al*., 2025).

7.4. Predation and Disturbance

a. Increased Natural Predators and Disturbance

Increased natural predators are threat to migratory birds, particularly in regions where habitat changes have occurred. In Tamil Nadu, the alteration of ecosystems due to urbanization and agricultural practices has led to a shift in predator-prey dynamics (Ramesh, 2010) & (Ramesh *et al.*, 2014). The proliferation of certain predator species, including raptors, can result in higher predation rates on nesting birds and their young ones. Research indicates that the presence of these predators can significantly reduce the reproductive success of vulnerable bird populations, particularly in fragmented habitats where birds may be more exposed to predation (Sergio *et al*., 2008); (Lima, 2009) &(Cresswell, 2011).

The stress induced by the presence of predators can lead to behavioural changes that further impact the survival of migratory birds. (Lima, 1998) discusses how stress from predation risk can alter decision-making processes in birds, affecting their foraging and nesting behaviours. In Tamil Nadu, studies have highlighted the challenges faced by birds in shrimp farms, where predation by both natural predators and disturbances from human activities can lead to significant declines in bird populations (Ramesh *et al*., 2014).

The interaction between migratory birds and their predators can be influenced by human disturbances, such as habitat degradation and increased human presence. These disturbances can increase predation risks, as birds may be forced to alter their behaviours in response to both natural and human-induced threats. The coupling of migratory patterns between predators and prey further complicates these dynamics, as changes in predator populations can directly affect the survival of migratory birds (Furey *et al*., 2018).

7.5 Pollution and Poisoning

Pollution and poisoning are critical issues affecting migratory birds, with various forms of contamination leading to significant health risks and ecological consequences.

These challenges threaten the biodiversity and ecological balance in regions like Tamil Nadu. Key pollution types impacting avian populations in Tamil Nadu are:

a. Oil Spills

Oil spills are catastrophic events that can have devastating effects on bird populations, particularly those inhabiting coastal and marine environments (Chahouri *et al*., 2024). When oil is released into the ocean, it spreads rapidly, forming a slick that coats the feathers of birds. This coating reduces the insulating properties of feathers, making birds more susceptible to hypothermia (Sinduja, *et al*., 2023). Oil can impair the waterproofing of feathers, leading to drowning when birds are unable to maintain buoyancy (Aldrich, 1970)&(Tseng & Ziccardi, 2019). Ingestion of oil during preening can cause internal organ damage and disrupt metabolic processes (Tseng, 1999); (Helm *et al*., 2014);(Down to Earth, 2017) & (Shah & Soni, 2024).

The Ennore oil spill that occurred in January 2017, where a cargo ship collided with a tanker, releasing approximately 1,000 metric tonnes of oil into the sea. This incident had severe consequences for wildlife, particularly migratory birds. The oil spread across the coastal waters and affected nearby marshlands, which serve as critical habitats for various migratory bird species (Han *et al.,* 2018). The spill led to immediate mortality among birds that came into contact with the oil, as well as long-term health issues for those that survived, resulting a drastic decline in bird populations in the affected areas (Leighton, 1993); (Khatai & Ladsaria, 2025); (Harvey, *et al*., 2025) &(Down to Earth, 2017). Cleanup efforts are costly and time-consuming, and the habitat can take years to recover (Biswas *et al*., 2022).

Research has shown that oil spills can have long-lasting effects on bird populations, with studies indicating that some species may take years to recover fully (Kumar *et al*., 2024). The ecological impact extends beyond immediate mortality, as oil spills can disrupt food webs and alter habitat availability, further threatens migratory bird populations. A study published in Down to Earth highlighted that the Ennore oil spill not only affected bird populations but also had broader implications for marine life and local ecosystems, emphasizing the need for stringent regulations and effective response strategies to mitigate such disasters (Down to Earth, 2017).

b. Water & Soil Pollution (Pesticides and Chemical Contaminants)

Water and soil pollution, particularly from pesticides and chemical contaminants, pose severe risks to migratory birds. Pesticides used in agriculture can accumulate in the environment and enter the food chain, leading to toxic exposure for birds that feed on contaminated insects or plants (Muralidharan *et al*., 2012). In Tamil Nadu, agricultural runoff containing pesticides has significantly affected local bird populations. The impact of pesticide contamination is particularly concerning migratory birds that visits the habitats for breeding and feeding during their migratory journeys (Arya *et al*., 2019) &(Kumar *et al*., 2024).

Research indicates that organophosphate pesticides, commonly used in agriculture, have been linked to neurological damage and reproductive issues in birds (Tanabe *et al*., 1998);(Mitra *et al*., 2021)& Kumar *et al*., 2024). These chemicals can disrupt the nervous system, impairing coordination and overall health (Pandiyan *et al.,* 2023). Heavy metals such as lead, mercury, and cadmium have been detected in the feathers of shorebirds in Tamil Nadu, indicating bioaccumulation and potential health risks (Pandiyan *et al*., 2020 & 2023). These contaminants can disrupt the endocrine system, impair reproductive success, and lead to behavioural changes that affect migration patterns (Subramanian & Tanabe, 2007); (Francis *et al*., 2020) & (Mansfield *et al*.,2024). The presence of these toxic substances in the environment underscores the urgent need for better agricultural practices and pollution management strategies to protect avian populations.

Recent incidents in Pulicat have reported that migratory ducks and plovers dying from suspected chemical fertilizer, This highlights the urgent need for better management practices (Batvari & Krishnamurthy, 2017); (Ranjith, 2023) & (Kapoor, 2024). The cumulative effects of pesticide and chemical contamination can lead to population declines and threaten the survival of migratory bird species. (Hooper *et al*. 2017) noted that the long-term exposure to even low levels of these contaminants can have devastating effects on bird physiology and behaviour.

c. Noise Pollution

Noise pollution is an increasingly recognized environmental stressor that can have profound effects on wildlife, including migratory birds. Urbanization, industrial activities, electronics (electromagnetic noise) and transportation networks contribute to elevated noise levels in many habitats, disrupting the natural behaviours of birds (Patricelli & Blickley, 2006);(Morrison, 2014); (Gopinath *et al*., 2021); (Panjwani *et al*., 2022)&(Panda *et al.*, 2022).Migratory birds use vocalizations for communication, especially during mating and territorial disputes (Brumm & Slabbekoorn, 2005). Increased noise levels can cover these vocal signals, making it difficult for birds to find mates and establish territories (Francis *et al*., 2009).

In Tamil Nadu, urban expansion has significantly increased noise levels, particularly in cities like Chennai (Salim & Saravanan, 2024). A study conducted in urban and rural areas of Tamil Nadu found that noise levels in urban settings often exceeded 85 dB, which is considered harmful to both human and wildlife health (Singh *et al*., 2021); (Sinduja, 2023); (Salim & Saravanan, 2024) & (Pradeep & Nagendra, 2024). This urban noise can disrupt the breeding success of local bird populations, particularly species that are sensitive to auditory cues. Research indicates that increased noise levels can lead to stress and altered foraging patterns, ultimately affecting survival rates (Francis *et al*., 2009). The long-term consequences of noise pollution on migratory birds can be severe, as chronic stress from noise exposure can lead to decreased reproductive success, increased mortality rates, and even population declines (Slabbekoorn, &Ripmeester, 2008); (Dutta, 2017) & (Sinduja, 2023). Mitigating noise pollution requires careful urban planning and noise reduction strategies (Wilcox *et al*. 2015).

d. Plastic Waste

Plastic pollution is a growing concern for wildlife, including migratory birds (Aarif *et al*., 2021) & (Raju & Sreeram, 2025). The ingestion of plastic debris can lead to physical blockages, malnutrition, and exposure to toxic chemicals associated with plastics (Cartraud *et al*., 2019). Migratory birds, particularly seabirds and shorebirds are at high risk due to their feeding habits. They often mistake plastic items for food,

leading to severe health issues. In Tamil Nadu, coastal areas have been documented to have high levels of plastic waste (Rajkumar,2015); (Kumar *et al*., 2016) &(Neelavannan *et al*., 2022). The presence of microplastics in the marine environment poses additional risks, as these small particles can be ingested by a wide range of marine organisms, ultimately affecting the entire food web (Karthik *et al*., 2018 & Jeyasanta *et al*., 2023).

Research has shown that plastic pollution can disrupt the reproductive success of birds, as ingested plastics can lead to hormonal imbalances and reduced fertility (Tariq *et al.,* 2022) & (Elias & Corbin, 2025). Plastics can leach harmful chemicals into the bird's system, causing further health complications (Teuten *et al*., 2009). The accumulation of plastics in the digestive tracts of birds can lead to starvation and reduced overall health (Katlam *et al*., 2018); (Roman *et al*. 2022) &(Jayalath & Ratnayake, 2025).

A study conducted in coastal regions of Tamil Nadu found that seabirds frequently ingest plastic debris, which can lead to internal injuries and increased mortality rates (Arun Kumar *et al*., 2019);(Francis *et al*., 2020);(Krishnan *et al*., 2022);(Kannan *et al*., 2023)& Sinduja, 2023). The growing prevalence of plastic waste in coastal habitats underscores the need for effective waste management strategies to protect avian populations. Initiatives such as beach clean-ups, public education on plastic use, and policies aimed at reducing plastic production and consumption are essential for mitigating the impact of plastic pollution on migratory birds.

e. Poisoning

Poisoning from various sources, including lead shot and rodenticides, poses a significant threat to birds. Lead poisoning is particularly prevalent in waterfowl that ingest spent lead pellets while foraging (Yeung *et al*., 2022). Secondary poisoning occurs when birds consume prey that has ingested toxic substances.

In Tamil Nadu, the use of rodenticides and pesticides in agricultural practices has been linked to increased mortality in raptors and scavengers (Muralidharan *et al*., 2012), (Priya *et al*., 2022) & (Kaur & Kler, 2024). A recent study highlights the several species have been found dead due to secondary poisoning from rodenticides (Richards, 2011) & (Kumar *et al*., 2024).

The indiscriminate use of pesticides in agriculture can lead to direct poisoning of non-target bird species, including migratory birds that habitat at agricultural landscapes for foraging. The impact of poisoning extends beyond individual birds, as it can disrupt entire ecosystems and food webs. Conservation efforts must focus on promoting sustainable agricultural practices that minimize the use of harmful chemicals and protect avian populations (Rao, 2003) & (Puthur *et al*., 2020). This alarming trend emphasizes the need for stricter regulations on pesticide use and greater awareness of the impacts of poisoning on bird populations. Implementing integrated pest management strategies and promoting organic farming can help reduce the reliance on harmful chemicals (Karuppuchamy & Venugopal, 2016) & (Paramasivam *et al*., 2022).

f. Light Pollution:

Light pollution poses a significant threat to migratory birds in Tamil Nadu, disrupting their natural navigation during critical migration periods. The bright lights of urban areas can disorient these birds, leading them to fly off course or become trapped in cities. The altered light conditions can affect their feeding and breeding behaviours, further threaten their populations. Tamil Nadu, known for its diverse avian species, is particularly vulnerable as many migratory birds pass through during seasonal migrations (Cabrera-Cruz *et al*., 2018) &(Kumar & Alam, 2023). Efforts to reduce light pollution and minimizing unnecessary illumination, are essential to protect these birds and preserve their migratory routes. By raising awareness about the impact of light pollution, we can help ensure a safer environment for migratory birds in Tamil Nadu.

7.6. Illegal Hunting and Poaching of Migratory Birds

a. Poaching and Hunting

Illegal hunting and poaching of migratory birds pose significant threats to their populations and the ecosystems they inhabit (Velho *et al*., 2012) & (Szabo & Mundkur, 2017). Many migratory birds are targeted for their meat, feathers, or as exotic pets. Poaching often occurs during migration seasons when birds are more vulnerable. This illegal activity is driven by demand in local and international markets, where certain species are prized for their culinary value or as trophies.

The impact of poaching on migratory bird populations leads to decline of the species that are already threatened by habitat loss and climate change. Research indicates that illegal hunting can significantly reduce population sizes and disrupt breeding patterns (Ramachandran *et al*., 2017). Conservation efforts require adequate enforcement of wildlife protection laws and the challenges of monitoring vast migratory routes (UNODC, 2020; UNODC, 2024).

b. Trapping and Trade

Trapping is a common method used in the illegal capture of migratory birds. Various techniques, such as nets, snares, and decoys, are employed to catch birds during their migration (Bateman, 2003). This trap not only targets specific species but can also result in the unintended capture of non-target species, further threatening biodiversity (Alexandar *et al*, 2018);(BirdLife International, 2023); (Umar *et al*., 2018)& (Yadav and Kumar, 2024).

The illegal trade in migratory birds is a lucrative business, often linked to organized crime. Birds are trafficked across borders for sale in markets, where they can fetch high prices. This trade undermines conservation efforts and poses significant challenges to the survival of many migratory species (Dutta, 2023), (Kabir *et al*., 2024) & (UNODC, 2020& 2024).

The illegal trade of migratory bird eggs is a growing concern. Eggs are often collected for consumption or for the pet trade, which can have impact on bird populations. The removal of eggs from nests disrupts breeding success and can lead to population declines (Siriwat & Nijman, 2020) &(Naves & Rothe, 2023).

International agreements, such as the Migratory Bird Treaty Act and the Convention on Migratory Species (CMS), aim to protect migratory birds and their habitats (CMS, 2006). Enforcement remains a critical issue, greater strategies and cooperation of various state and national agencies is needed to combat illegal trapping and trade effectively.

7.7. Invasive alien species

In India, particularly in Tamil Nadu, the introduction of invasive alien fish species and ornamental fish has a greater impact on local ecosystems and migratory bird populations. Species such as the Nile tilapia (*Oreochromis niloticus*) and the African catfish (*Clarias gariepinus*) have been introduced into various freshwater bodies, often outcompeting native fish for resources (Singh & Lakra, 2006), (Knight, 2010), (Sandilyan *et al.,* 2018), (Raghunathan *et al*., 2019) (Sandilyan, 2022) . This competition can lead to a decline in native fish populations, which are crucial food sources for migratory birds. Invasive turtles, such as the red-eared slider (*Trachemys scripta elegans*), further it deepens the situation by preying on native species and thereby it leads to competition for food availability and habitat for migratory birds (Sandilyan *et al.,* 2018, Raghunathan *et al*., 2019 & Joshi *et al*., 2021). The alteration of food webs and the reduction of native prey availability can alter the feeding behaviour of migratory birds, ultimately affecting their survival and reproductive success (Wainright *et al*., 2021). As these invasive species continue to thrive, the ecological balance of water bodies in Tamil Nadu is increasingly threatened, posing significant challenges for conservation efforts aimed at protecting both native aquatic life and the migratory bird populations that depend on these ecosystems for their survival.

7.8 Diseases

World Organisation for Animal Health (WOAH) report warns that major animal diseases like African swine fever (ASF) and High Pathogenicity Avian Influenza (HPAI) are increasingly impacting wildlife, threatening biodiversity and complicating eradication efforts, with over 3,800 outbreaks in 55 countries reported in early 2024. Migratory birds can act as vectors for various diseases, including avian influenza, West Nile virus, and other bacterial and fungal infections, which can spread to other bird species, domestic animals, and even humans. A better understanding of avian migration patterns and infectious diseases of birds would be useful in helping to predict future outbreaks of infections due to emerging zoonotic pathogens (Reed *et al*., 2003).

8. Management Implications for Conservation of Migratory birds

8.1 Habitat restoration and conservation

- Prioritize the restoration of wetlands and critical habitats that support migratory bird populations.
- Implement native vegetation planting to enhance habitat quality and food availability for birds.
- Establish buffer zones around restored areas to minimize human disturbance and protect habitats.
- Engage local communities in restoration efforts to foster stewardship and ensure sustainable practices.
- Focus on the rehabilitation of the wetlands to enhance breeding and foraging opportunities for migratory birds.
- Monitor restored habitats regularly to assess ecological health and adapt management strategies as needed.
- Develop a committee and periodically assess the status of wetlands in their habitat and also in stopover site.

8.2 Threat Minimization and Management

- Develop and implement emergency response plans for oil spills in coastal areas, in line with the National Oil Spill Disaster Contingency Plan.
- Promote use of organic farming / natural farming among farmers to mitigate agro-run off and chemical contamination to the habitat.
- Enforce strict regulations along with Tamil Nadu Pollution Control Board (TNPCB) on industrial discharges to minimize chemical pollution in wetlands and coastal areas.
- Develop and implement strategies to address specific human-bird conflicts.
- Formation of Avian Powerline Committee to identify and assess the high powerline and towers and provide alternatives.
- Restrict permission to construct the high elevation buildings at flyways and the stop oversite to mitigate collisions..

- Periodically monitor and assess control measures for invasive species in the wetland habitat.
- Provide strict regulations and actions against poaching, habitat destruction on the wetland important areas.
- Ensure that all coastal development projects undergo thorough Environmental Impact Assessments (EIA) and follow up on their implementation to mitigate negative impacts on migratory bird habitats.
- Involve local communities, NGOs, and government agencies in discussions about land use and development to ensure that migratory bird conservation is a priority in planning processes.

8.3 Research and Monitoring

- Conduct extensive long-term studies to assess the migratory bird populations and their habitats over time.
- Employ GPS and satellite telemetry to monitor migratory routes and behaviours of migratory species.
- Create a centralized database for tracking and monitoring data to facilitate collaboration among researchers and conservation organizations.
- Involve local communities, NGOs, and government agencies in the research and monitoring process to ensure culturally relevant conservation strategies.
- Regularly analyse monitoring data to refine conservation strategies and respond effectively to emerging threats.

8.4 Integrated Water Management

- Promote sustainable water use practices that support both human needs and ecological health.
- Regulate water levels in wetlands to support the breeding and feeding needs of migratory birds during critical migration periods.
- Encourage rainwater harvesting techniques to enhance water availability in wetlands, especially during dry seasons critical for migratory birds.

- Foster partnerships among government agencies, NGOs, and local communities to ensure integrated and sustainable water management practices.
- Periodically evaluate water management effectiveness and adapt strategies to changing environmental conditions.

8.5 Capacity Building

- Create networks of ornithologists, ecologists, and conservationists, complemented by workshops to enhance skills in migratory bird conservation.
- Encourage collaboration among stakeholders to share experiences and best practices.
- Create platforms for knowledge exchange, such as webinars, and online forums where experts can share research findings, innovative solutions, and conservation strategies.
- Regularly review and update management plans based on monitoring and research findings.
- Build institutional capacity to support effective conservation efforts at all levels.

8.6 International Cooperation

- Partner with organizations like IUCN and Wetlands International to enhance resources and expertise for migratory bird conservation.
- Participate in trans-boundary initiatives to protect migratory bird routes and critical habitats across national borders.
- Work closely with the International agencies and other NGOs to implement effective wetland management practices that support migratory bird conservation.
- Promote the integration of migratory bird conservation into global agenda like the Ramsar Convention and CMS for increased attention and resources.
- Conservation efforts with the UN SDGs, particularly Goal 6 (Water and Sanitation) and Goal 15 (Life on Land), to promote sustainable management of water resources and wetlands.

8.7 Climate Resilience Building

- Formulate targeted strategies to address the impacts of climate change on migratory bird habitats, focusing on challenges such as sea-level rise, extreme weather events, and shifts in food availability.
- Establish robust monitoring systems to track climate-related changes in migratory bird populations and their habitats, enabling timely responses to emerging threats.
- Regularly review and adapt feasible strategies from the policy formulations of the United Nations Framework Convention on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC), the National Ministry of Environment, Forest and Climate Change (MoEFCC).

8.8 Conservation Planning

- Identification and mapping of new protected areas to safeguard critical habitats/ stopover site that is essential for the conservation of both native and migratory bird species.
- Develop strategies to leverage the conservation knowledge of indigenous communities, enhancing habitat management practices.
- Implement preservation and restoration of native tree species within wetland habitats to provide essential shelter and food resources for migratory birds.

8.9 Legal frameworks, Policy support and advocacy

- Enhance collaboration among state enforcement agencies, including the Fisheries Department and Forest Departments, to ensure strict regulations and effective enforcement of laws protecting migratory birds and their habitats.
- Conduct regular surveys in partnership with forest departments to monitor migratory bird populations and their habitats, enabling data-driven conservation strategies.
- Review and align national laws, such as the Wildlife Protection Act, with international agreements like the Convention on Migratory Species (CMS) and the Ramsar Convention to strengthen legal protections for migratory birds.

- Advocate for the designation of Important Bird Areas (IBAs) and Key Biodiversity Areas (KBAs) to secure critical habitats for migratory species and enhance their protection at the policy level.
- Develop clear legal definitions and protections for migratory bird species and their habitats to facilitate effective conservation efforts and enforcement actions.
- Promote the integration of migratory bird conservation priorities into regional and national policy frameworks, including land-use planning and environmental impact assessments, to ensure comprehensive protection measures.

8.10 Community engagement, awareness & outreach

- Encourage farmers to reduce the use of agricultural chemicals through workshops and training sessions, highlighting the benefits for both crop health and migratory bird populations.
- Implement community-led initiatives to protect nesting sites of migratory birds, fostering local stewardship and engagement in conservation efforts.
- Promote community-based conservation practices that integrate local knowledge and create sustainable livelihood opportunities, enhancing support for migratory bird conservation.
- The Forest Department should conduct regular awareness campaigns, particularly before the breeding season of migratory birds, to educate the public on the importance of protecting these species and their habitats.
- Develop outreach programs targeting school and college students, as well as the general public, to instill a sense of responsibility for conservation. Build a network of 'Student Ambassadors' to enlist community support for the conservation of migratory birds and their habitats.
- Create outreach materials in both print and digital formats targeted at diverse audiences to raise awareness about migratory bird conservation.
- Involve the National Cadet Corps and National Green Corps within educational institutions to visit and monitor bird migration sites, fostering hands-on conservation experiences.
- Promote sustainable eco-tourism that supports local communities and conserves wildlife.

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