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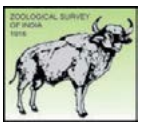

# The Diversity and Distribution of The Order Charadriiformes Along The Kerala Coast and Selected Islands of Lakshadweep, India

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## Abstract

The birds belonging to the order Charadriiformes are widely distributed along the coastal regions and coastal waters of Kerala and Lakshadweep. Most species in this region are migratory and use the coastal habitats and coastal waters as their feeding grounds or stopover sites. In this study, we documented the diversity and distribution of Charadriiformes along the Kerala coast and Lakshadweep, and recorded 47 species of birds. Among this, 22 species were recorded from both the Kerala coast and the Lakshadweep islands. The abundance and distribution of the Charadriiformes have been examined, and the results show the distribution pattern between the mainland and the islands. On the Kerala coast, the population of three gull species and three sand plover species and in Lakshadweep islands, the population of three tern species and brown noddy determines the Charadriiformes abundance. The breeding colonies of *Anous stolidus* and *Onychoprion fuscatus* were observed during the study from the Pashi Pitti, Lakshadweep archipelago. While the distribution and diversity of birds will be used to measure the ecosystem's health, the results obtained from the current study will provide insight into coastal management and conservation of the avian fauna.

**Keywords:** Seabirds, Shorebirds, Laridae, Breeding, Bird sanctuary

## Introduction

Charadriiformes are one of the widely distributed non-passerines, which consist of the alliance of the shorebird and seabird families (Brooke and Birkhead, 1991). This order consists of 15 Families with three suborders: Alcae, Charadrii, and Lari. (McCain, 2015). Charadriiformes have a wide range of habitat preferences, including coastal, freshwater wetlands, and agricultural fields (Gokulakrishnan *et al.,* 2014). Most of the Charadriiformes are long distance migrants, and the species migrate along the Central Asian, South Asian Flyways, East Asian-Australian and Western Pacific Flyways use the Indian subcontinent as their primary wintering grounds and stopover sites (Aarif *et al*., 2020; Rashia *et al.,* 2022). Many avian species are considered sentinel of the aquatic ecosystems and show rapid changes to ecological responses and climate change (Thompson and Ollason, 2001; Piersma and Lindstrom 2004; Frederiksen *et al*., 2006). So, these are considered as monitors and indicators of the ecosystem and ecological evaluations (Furness and Camphuysen, 1997; Canterbury *et al.,* 2000; Mallory *et al.,* 2010). In the Indian scenario, the studies on avian diversity are limited to seasonal monitoring, and detailed studies are limited. According to Gourley *et al.* (2010), studies on the abundance and distribution of birds are crucial in managing ecosystems and conserving Charadriiformes. The present study aims to assess the diversity, abundance and distribution of the birds belonging to the order Charadriiformes across the Kerala coast and the Lakshadweep to study the distribution among the mainland and islands.

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## Materials and Methods

*Study Area*

In Kerala, the surveys for the assessment of birds were conducted along the coastal line around the 570 km stretch, which is part of 9 districts of Kerala. In Kerala, the surveys undertaken mainly in the coastal stretch with sandy beaches are seen, and the pelagic surveys were conducted from Vizhinjam, , Azheekal (Kollam), Kochi, Ponnani, and Neeleshwaram. The survey excluded areas where the seashore is absent and the coastal regions with granite or tetrapod walls. Lakshadweep archipelago (8°–12°13" N 71°–74°E) consists of 27 islands 12 atolls, and 3 reefs from about 220–440 km from the west coast of Kerala. The present study was conducted along seven of ten inhabited islands, excluding Chethlat, Kiltan and Amini, and seven uninhabited islands of the Lakshadweep archipelago.

*Survey method*

The survey was conducted during 2021 – 2022 along Kerala and Lakshadweep. The single day pelagic surveys in Kerala were carried out from September to April in Kerala coast from 5 stations and coastline surveys were conducted from 25 sites (Figure 1). The surveys in the Lakshadweep islands were carried out from January to March (Figure 2). The team visited the Pitti islands and Perumal Par in March.2022. Direct observation of the birds was followed. Point count methods were employed to get the total count and species identification. In the point count or point transact method, we count the birds from fixed locations for a fixed time (Buckland *et al.,* 2001). The survey was conducted during the day, from 0700 to 1100 h, when the birds were active. We employed the line transect method for the opportunistic pelagic surveys, where the vessel moves offshore in a prefixed route and counts the birds (Gregory *et al.,* 2004). In the present study, for the pelagic surveys three-member team is constituted for counting birds. The pelagic survey was carried out from 0500 to 1830 h. The direct observation was done using binoculars (Olympus 10x50 DPI), and the photo documentation was carried out using a DSLR camera (Nikon d500 with Nikkor 200-500mm f 5.6 lens, Nikon d5200 with Nikkor 70-300mm f 3.6: 4 ED lens, and GoPro Hero 9). The species were identified using field guides (Hayman *et al*., 2011; Rasmussen and Anderton, 2012; Vinicombe *et al*., 2014). During the survey, the team maintained the distance between the bird flocks to minimise the disturbance.

*Statistical Analysis*

The Dominance index, Shannon diversity index, Margalef index and Fisher alpha index were assessed and the Whittaker beta diversity index was calculated to compare the diversity across Kerala and Lakshadweep using PAST 4.3 software (Hammer *et al.,* 2001).

## Results and Discussion

Charadriiformes are considered a diverse order in the non-passerine group (Lovette, 2016). According to the checklist of the birds of India and Kerala, 120 species of Charadriiformes were recorded from India and 91 species from the state of Kerala (Praveen, 2015; Praveen *et al.,* 2016; Chandran and Praveen, 2019). In the present study, in total 47 species belonging to Charadriiformes were recorded from the Kerala coast (44 species) and seven inhabited and seven uninhabited islands of Lakshadweep islands (25 species) (Table 1; Figure 3). These species were distributed into eight families and 26 genera. According to the recent checklists, 38 species from the order Charadriiformes were reported from the Lakshadweep islands (Aju *et al.,* 2021). The reports of Mathew *et al.* (1991) and Kurup and Zacharias (1994) also recorded 35 species, and the expeditions conducted by Pande *et al.* (2007) reported 20 species of Charadriiformes.

Out of 47 species reported, 22 species were common to both the Kerala coast and Lakshadweep islands and 22 species were recorded only from the Kerala coast. Three species, *Sternula albifrons, Anous tenuirostris* and *Anous stolidus* were recorded only from the Lakshadweep islands. Three species, *Haematopus ostralegus*, *Numenius arquata* and *Limosa lapponica*, listed as Near Threatened by IUCN, were also documented from the study areas.

Considering family-wise composition, Scolopacidae and Laridae shared the highest number of species (Figure 4). During the survey, species belonging to the Haematopodidae Dromadidae and Stercorariidae was represented only from Kerala. In the case of the abundance of species in Kerala, four species from *Laridae* (*Chroicocephalus brunnicephalus, Chroicocephalus ridibundus*, *Larus fuscus* and *Chlidonias hybrida,)* three species from *Charadriidae* (*Charadrius mongolus Charadrius leschenaultia,* and *Charadrius alexandrines*) and one species from Scolopacidae (*Calidris alba*) contributes the highest count. Considering the population of charadriiforms in Lakshadweep islands, five species from Laridae (*Anous stolidus, Onychoprion fuscatus,*

*Sternula albifrons Thalasseus bengalensis* and *Thalasseus bergii*) contributes the highest numbers. Compared to the checklists, the number of species is comparatively less primarily because the species entries of the checklists are either made by the observers or updated lists based on the compilation of historical records and earlier works, and no seasonal-wise data is available. (KovaČiĆ *et al*., 2020) In Charadriiformes, many species are long distant migrants and in between the migration from breeding sites to foraging sites, these species use the coastal regions as its halting stations (stopover sites) for a short period of time (Butler *et al*., 2001). It will also affect the estimation of species diversity and distribution.

Regarding the breeding population, the nesting colonies of three species, Sooty Terns *Onychoprion fuscatus*, Brown Noddies *Anous stolidus*, and Greater Crested Terns *Thalasseus bergii* have been reported on the Lakshadweep islands (Hume, 1876; Betts, 1939; Kurup and Zacharias, 1994; Mathew *et al.,* 1996). During the present survey, the breeding colonies the Sooty Tern *Onychoprion fuscatus* and Brown Noddy *Anous stolidus* were observed from the Pitti islands, and 167 eggs were counted from the Pitti islet. The number of eggs counted was comparatively less than the previous records of Pande *et al*., (2007) and Mondreti *et al.,* (2018). According to Pande *et al.* (2007), the islet Pitti and Cheriyapani are considered as the breeding grounds for the tern species and Kurup and Zacharias (1994) observed the breeding activities of terns from Suheli island.

The biodiversity can be expressed by the number of species, relative abundance, variability and complementarity between the habitats (Whittaker, 1972). For assessing the status of the avian diversity of the Kerala coast and Lakshadweep islands, various diversity indices were calculated (Table 2). From the results, the Shannon diversity index (2.66), Fisher alpha index (6.99), and Margalef index (5.22) values were highest in Kerala compared to Lakshadweep. In the case of dominance index along the Kerala coast it was estimated as 0.099 but the dominance index value of Lakshadweep was 0.185 and this could be due to the high abundance of species such as *Anous stolidus, Onychoprion fuscatus, Sternula albifrons*. For beta diversity, the Whittaker beta diversity index was calculated and observed at a value of 0.362 between the Kerala coast and the Lakshadweep islands. The overall diversity indices value of the Charadriiformes of the Kerala coast was higher when compared to that of the Lakshadweep islands.

The species abundance and distribution of birds in a location were influenced by migrant species, especially the birds which use the sites as a halting station (stopover site). Their site selection may be influenced by local habitat structure, community patterns, food availability and other ecological parameters., (Cunningham *et al.,* 2016; Taft *et al.,* 2006; Fairbairn *et al.,* 2001). This may reflex in the changes in distribution and abundance estimation of the Charadriiformes across the location and during the survey. According to Rashiba *et al.* (2022) the distribution of Charadriiformes, especially the shorebirds, depends on the distinctive ecological and biotic and abiotic factors along the Indian coast.

The west coast of India has been considered an important wintering ground and stopover site for Charadriiformes, and most of the migratory species in the region show a population decline (Aarif *et al.,* 2018; Hua *et al.,* 2015; Balachandran *et al.,* 2012). So, the documentation of the diversity and distribution of these groups will give an insight into the health of the local ecosystem, and the documentation will be instrumental in coastal and island management and the conservation of the avian fauna.

**Table 1:** List of sea/shore birds (Order: Charadriiformes) recorded from Kerala coast and Lakshadweep islands during the present study.

| Family | Species | Common Name | Kerala | Lakshadweep |
|---|---|---|---|---|
| Haematopodidae | *Haematopus ostralegus* Linnaeus, 1758 | Eurasian Oystercatcher | + | - |
| Recurvirostridae | *Himantopus himantopus* (Linnaeus, 1758) | Black-winged Stilt | + | + |
| Charadriidae | *Pluvialis squatarola* (Linnaeus, 1758) | Grey Plover | + | + |
| | *Pluvialis fulva* (Gmelin, JF, 1789) | Pacific Golden Plover | + | + |
| | *Charadrius alexandrinus* Linnaeus, 1758 | Kentish Plover | + | - |
| | *Charadrius mongolus* Pallas, 1776 | Lesser Sand Plover | + | + |
| | *Charadrius leschenaultii* Lesson, 1826 | Greater Sand Plover | + | + |
| Scolopacidae | *Numenius phaeopus* (Linnaeus, 1758) | Whimbrel | + | + |
| | *Numenius arquata* (Linnaeus, 1758) | Eurasian Curlew | + | + |
| | *Limosa lapponica* (Linnaeus, 1758) | Bar-tailed Godwit | + | + |
| | *Arenaria interpres* (Linnaeus, 1758) | Ruddy Turnstone | + | + |
| | *Calidris temminckii* (Leisler, 1812) | Temminck's Stint | + | - |
| | *Calidris subminuta* (Middendorff, 1853) | Long-toed Stint | + | - |
| | *Calidris alba* (Pallas, 1764) | Sanderling | + | + |
| | *Calidris alpina* (Linnaeus, 1758) | Dunlin | + | + |
| | *Calidris minuta* (Leisler, 1812) | Little Stint | + | + |
| | *Gallinago stenura* (Bonaparte, 1831) | Pintail Snipe | + | + |
| | *Xenus cinereus* (Güldenstädt, 1775) | Terek Sandpiper | + | - |
| | *Actitis hypoleucos* (Linnaeus, 1758) | Common Sandpiper | + | + |
| | *Tringa ochropus* Linnaeus, 1758 | Green Sandpiper | + | - |
| | *Tringa nebularia* (Gunnerus, 1767) | Common Greenshank | + | + |
| | *Tringa totanus* (Linnaeus, 1758) | Common Redshank | + | + |
| | *Tringa glareola* Linnaeus, 1758 | Wood Sandpiper | + | - |
| | *Tringa stagnatilis* (Bechstein, 1803) | Marsh Sandpiper | + | - |
| Dromadidae | *Dromas ardeola* Paykull, 1805 | Crab-plover | + | - |
| Glareolidae | *Glareola maldivaru*m Forster, JR, 1795 | Oriental Pranticole | + | + |
| Stercorariidae | *Stercorarius longicaudus* Vieillot, 1819 | Long-tailed Skua (va-grant) | + | - |
| | *Stercorarius parasiticus* (Linnaeus, 1758) | Arctic Skua | + | - |
| | *Stercorarius pomarinus* (Temminck, 1815) | Pomarine Skua | + | - |

| Family | Species | Common Name | Kerala | Lakshadweep |
|---|---|---|---|---|
| Laridae | *Anous stolidus* (Linnaeus, 1758) | Brown Noddy | - | + |
| | *Anous tenuirostris* (Temminck, 1823) | Lesser Noddy | - | + |
| | *Chroicocephalus genei* (Brème, 1839) | Slender-billed Gull | + | - |
| | *Chroicocephalus brunnicephalus* (Jerdon, 1840) | Brown-headed Gull | + | - |
| | *Chroicocephalus ridibundus* (Linnaeus, 1766) | Black-headed Gull | + | - |
| | *Ichthyaetus ichthyaetus* (Pallas, 1773) | Pallas's Gull | + | - |
| | *Larus fuscus* Linnaeus, 1758 | Lesser Black-backed Gull | + | - |
| | *Onychoprion fuscatus* (Linnaeus, 1766) | Sooty Tern | + | + |
| | *Onychoprion anaethetus* (Scopoli, 1786) | Bridled Tern | + | - |
| | *Sternula albifrons* (Pallas, 1764) | Little Tern | - | + |
| | *Gelochelidon nilotica* (Gmelin, JF, 1789) | Gull-billed Tern | + | - |
| | *Hydroprogne caspia* (Pallas, 1770) | Caspian Tern | + | -- |
| | *Chlidonias hybrida* (Pallas, 1811) | Whiskered Tern | + | + |
| | *Sterna hirundo* Linnaeus, 1758 | Common Tern | + | + |
| | *Sterna repressa* Hartert, 1916 | White-cheeked Tern | + | - |
| | *Thalasseus bengalensis* (Lesson, 1831) | Lesser Crested Tern | + | + |
| | *Thalasseus sandvicensis* (Latham, 1787) | Sandwich Tern | + | - |
| | *Thalasseus bergi*i (Lichtenstein, MHK, 1823) | Greater Crested Tern | + | + |

+ - Presence of the species. 0 – Absence of the species

**Table 2:** Diversity indices of Charadriiformes along Kerala coast and Lakshadweep

| | Kerala coast | Lakshadweep |
|---|---|---|
| Taxa_S | 44 | 25 |
| Dominance_D | 0.09962 | 0.1855 |
| Shannon_H | 2.66 | 2.055 |
| Margalef | 5.222 | 2.824 |
| Fisher_alpha | 6.993 | 3.442 |
| Whittaker beta diversity | 0.362 | |

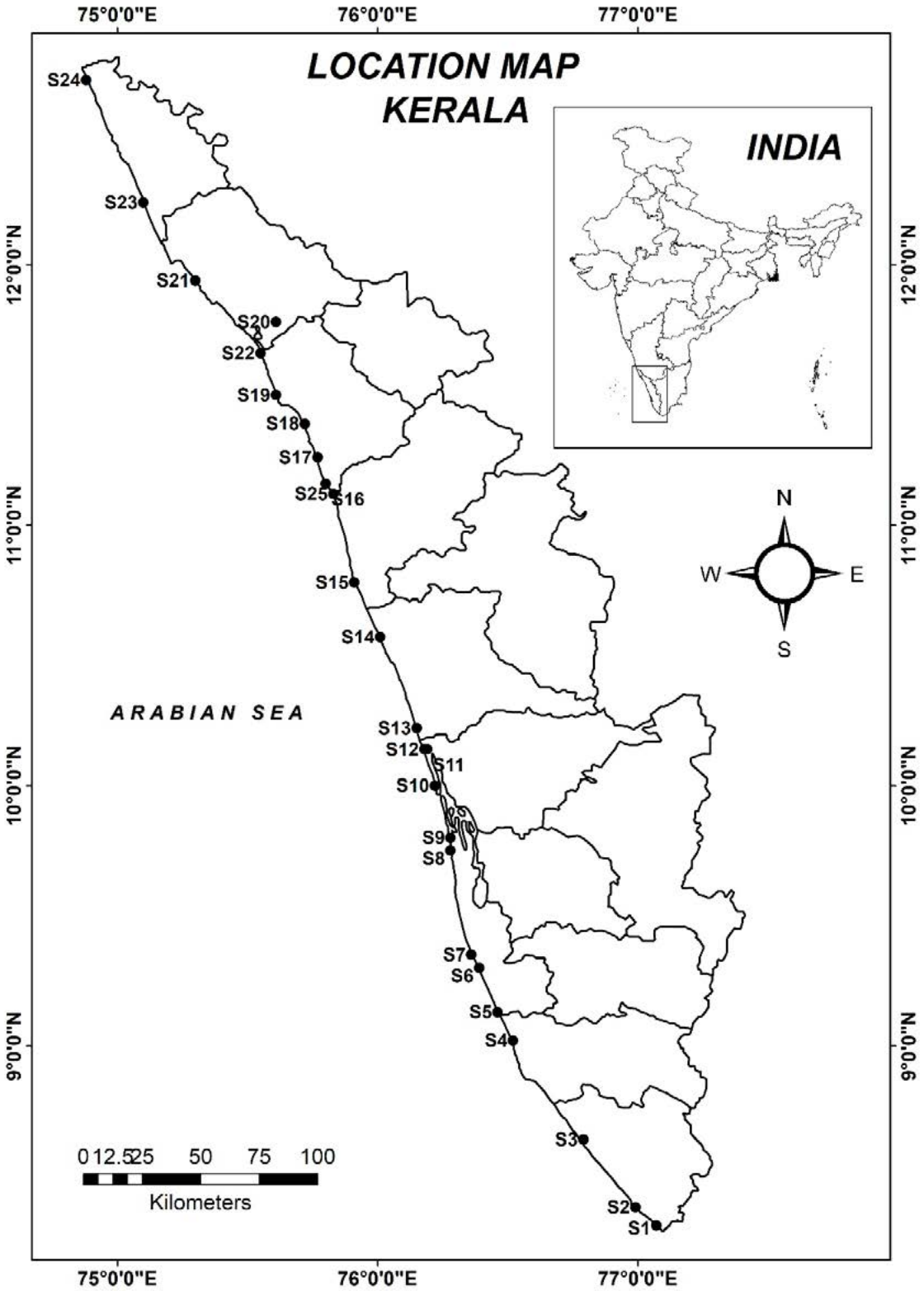


Figure 1: Location map showing the study areas in Kerala with coastline survey locations

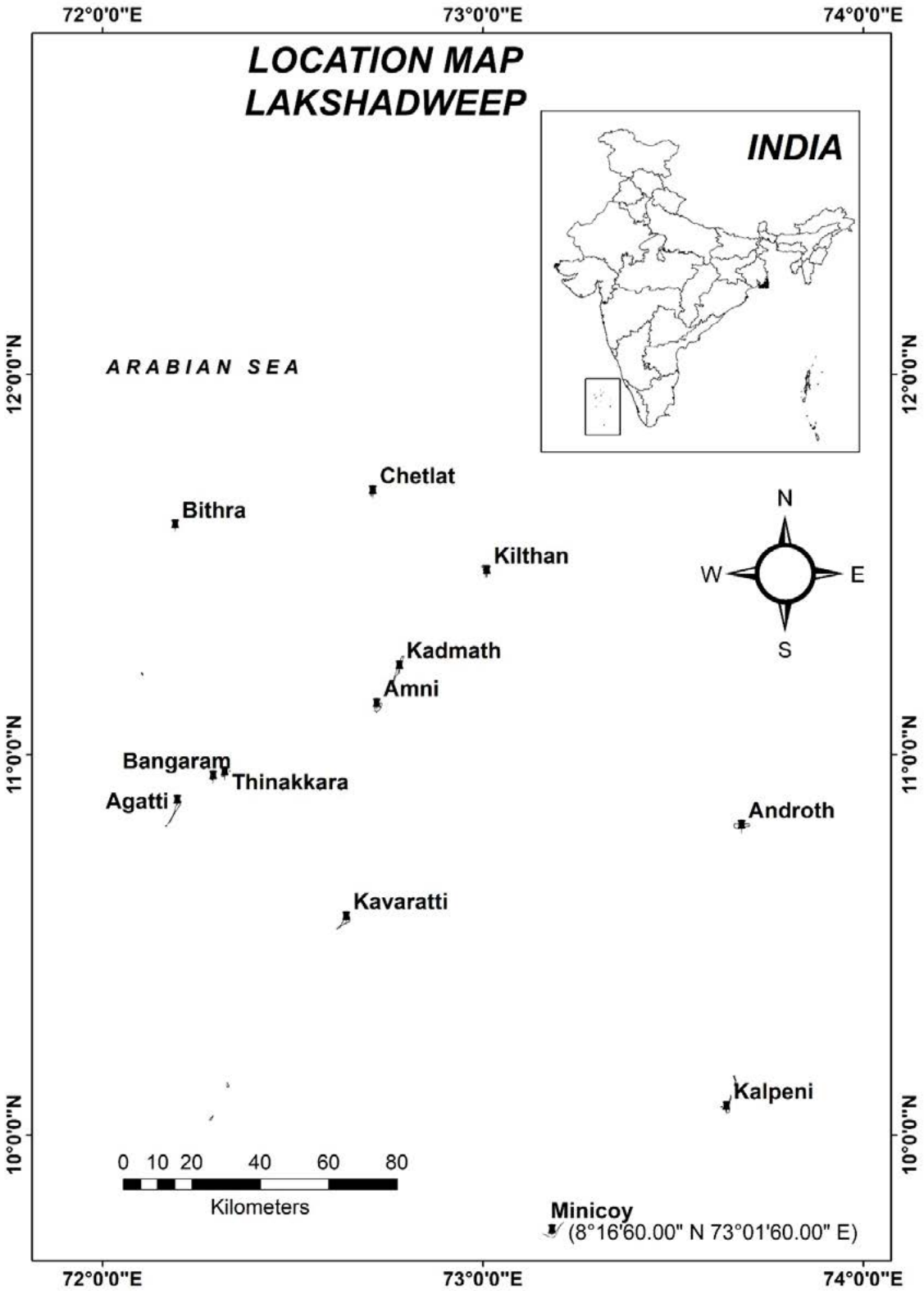


Figure 2: Location map of Lakshadweep islands

*Ichthyaetus ichthyaetus*

*Larus fuscus*

*Chroicocephalus genei*

*Chroicocephalus brunnicephalus*

*Chroicocephalus eidibundus*

*Hydroprogne caspia*

*Sterna hirundo*

*Gelochelidon nilotica*

*Chlidonias hybrida*

*Thalasseus bergii*

*Thalasseus bengalensis*

*Strenula albifrons*

*Onychoprion fuscatus*

*Onychoprion anaethetus*

*Anous stolidus*

*Stercorarius parasiticus*

*Stercorarius pomarinus*

*Stercorarius longicaudus*

*Numenius arquata*

*Numenius phaeopus*

*Actitis hypoleucos*

*Charadrius leschenaultii*

*Charadrius mongolus*

*Charadrius alexandrinus*

*Haematopus ostralegus*

*Dromas ardeola*

*Arenaria interpres*

*Calidris alba*

*Pluvialis fulva*

*Pluvialis squatarola*


Figure 3: Species of Charadriiformes reported along the Kerala coast and Lakshadweep islands

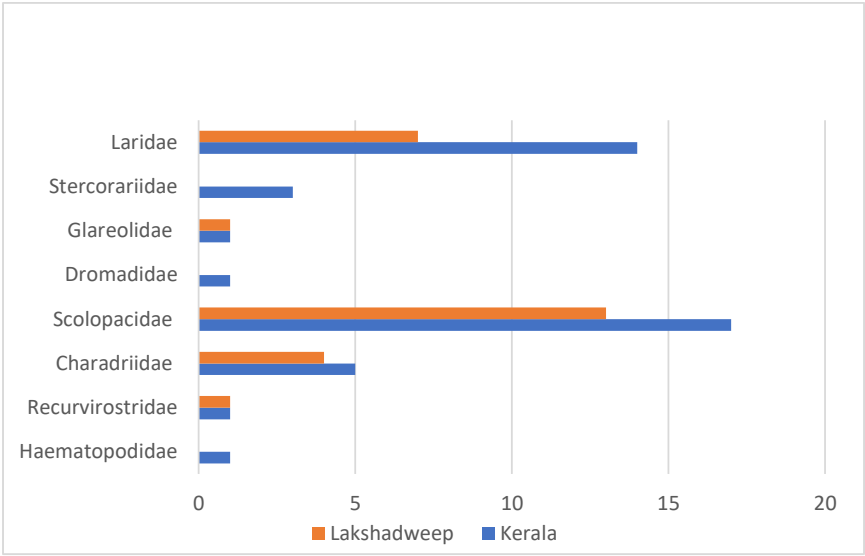


**Figure 4:** Distribution of families along Kerala coast and Lakshadweep islands

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