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Research Article

Species diversity and distribution pattern of avifauna from Thane creek, Maharashtra, India

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ABSTRACT

Bird survey in Thane creek was conducted during winter season in 2015-2016. Total 69 species of birds were encountered belonging to 11 orders and 17 families in the entire creek. As per the IUCN Red list, of the 69 bird species, six near threatened and one vulnerable species were recorded. 60.87 percent birds were migratory winter visitors, 36.23 percent birds were residents and local migrants, and the remaining 2.89 percent birds were residents as well as winter visitors. Scolopacidae family had the highest representation with 14 bird species. Order Phoenicopteriformes had the highest number of individuals (N = 20539) with lesser flamingo contributing 80.22 percent. The Shannon-Weiner diversity indices revealed higher diversity upstream (2.56) followed by midstream (1.78) and downstream (1.12). Similarly, the evenness index showed the species were more evenly distributed upstream (0.219) followed by midstream (0.110) and downstream region (0.060). On the contrary, the dominance was higher downstream (0.501) followed by midstream (0.319) and upstream region (0.124). Order Phoenicopteriformes had the highest percent encounter rate with majority encountered in downstream followed by midstream region and sporadically distributed in the upstream region of the creek. The family with moderate to less number of individuals are majorly encountered in the upstream region of the creek. The birds showed a specific distribution pattern primarily because of food availability and also because of other biotic and abiotic factors.

Key words: Foraging habitat, Pollution, Shore birds, Thane creek, West coast of India

INTRODUCTION

Thane creek is Asia's largest creek about 26 kms in length. It originates from the Ulhas River estuary with a very narrow connection near Balkum in Thane city and gradually widens up downstream and mixes in the open waters of Arabian Sea at Mumbai harbour. The substratum of the creek is made up of rocks and boulders and the sediment on the banks are silty and silty clayey throughout with very less proportion of sand and gravel at an extreme downstream area near the mouth of the creek. The water temperature in the creek varied between 19.8°C to 27°C; pH is observed to be in the range of 7.06 to 7.96, while the Dissolved Oxygen fluctuated between 0.41 mg/l to 10.16 mg/l, Salinity shows seasonal variations between 5.77 ppt. to 34.48 ppt. and Total suspended solids varies between 0.03 gm/l to 0.076 gm/l. Temperature, pH, salinity and DO showed an increasing trend towards seaward end and the TSS values are quite high due to poor flushing and load of floating debris of non-living material. Average moisture content of soil found to be 76.10% and texture is majorly silty clayey with silt, clay, sand composition is 72.25%, 29.79% and 2.08 % respectively (Quadros *et al*. 2016). The entire creek is surrounded by a dense canopy of mangroves. A total of 15 mangrove species were recorded along the creek dominated by *Avicennia sp*. Further maximum number of plants (3112 /hectare) recorded from the middle-east bank region and the minimum (8 / hectare) from the upper east bank region. The presence of mangroves along both banks has made Thane creek a highly productive ecosystem (Quadros *et al*. 2016). Athalye (2001) recorded 18 fish species from Thane creek with dominance of *Mugil cephalus*, *Mystius gulio* and *Tilapia mossambica* which reduced to 12 species (Quadros & Athalye, 2012). Apte *et al* (2020) documented nematoda, flatworm, polychaeta, oligochaeta, gastropoda, bivalvia, arthropoda, sipuncula, cnidaria, phoronida and chordata from the mudflats of Thane creek with high diversity and density during the winter season on which migratory shore birds forage continuously during low tides when mudflats expose. Thane Creek is an important stopover site for many winter visiting migratory shorebirds. In August 2015, the Maharashtra Government declared 1690 hectares of the area of Thane creek as Thane Creek Flamingo Sanctuary; 896 hectares of mangrove forest and 794 hectares of the water body that covers most of the mid and downstream portion of the creek. In August 2022 Thane creek is declared as RAMSAR site.

Thane creek is impacted by many threats for the past several years; not only the domestic sewage and

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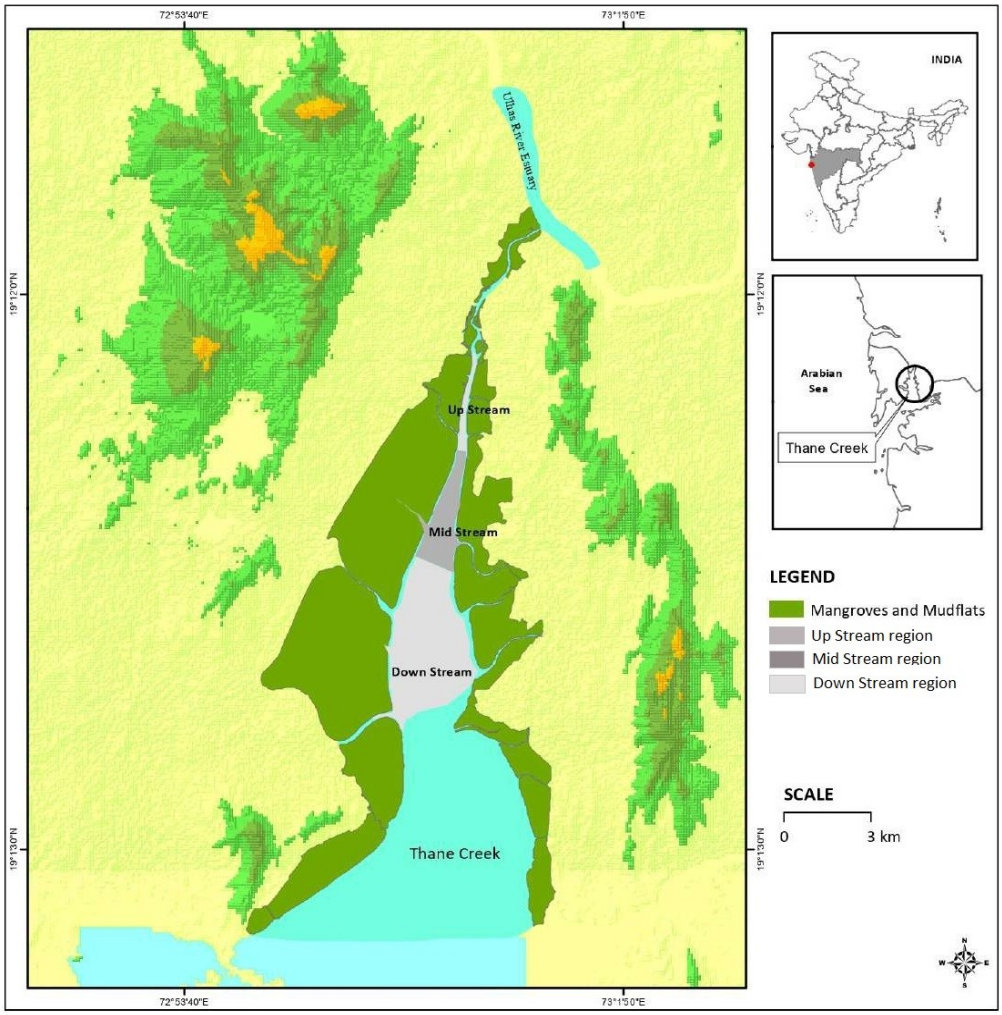

Figure 1. The location of study area.

industrial effluent released in the creek, there is also indiscriminate dumping of large quantity of solid wastes (Quadros, 2002 & Quadros *et al*. 2016). Plastic in various sizes and types is among the major contributors to the waste proving a threat to Thane creek ecosystem. Macro plastics get entangled in the pneumatophores and branches of mangroves which disrupt the water flow of small inlets in the creek and also hamper the growth rate of mangroves. Some toxic compounds like Phthalates and bisphenol-A released during the degradation process of plastics can reduce fertility, increase hatching failure, and disrupt larval development of key mangrove fauna (Hammer, Kraak & Parsons, 2012; Kantharajan *et al*. 2018). Micro-plastics, with the larger area of exposure, adsorb more contaminants such as polychlorinated biphenyls, polycyclic aromatic hydrocarbons, and other pesticides than natural sediments. The presence of these pollutants poses a potential risk to the migratory birds including flamingos which forage on the mudflats of Thane creek (Kantharajan *et al*. 2018; Chaudhari-Pachpande & Pejaver, 2016).

Estuarine areas and coastal habitats from all continents of the world except Antarctica harbour shorebirds. However, they are not found evenly distributed on mudflats but are usually found where food availability is more in the sediment (Green *et al*. 2015). There is little information available on shore birds using inter tidal flats from Indian sub-continent (Pandiyan & Ashokan, 2016); Thane creek has been extensively studied for its fish diversity, plankton and benthic diversity, mangrove ecology, industrial and domestic pollution, heavy metal toxicity, etc. with comparatively less emphasis on avian studies (Chaudhari-Pachpande & Pejaver, 2016; Nitsure & Pejaver, 2002).

Migratory shore birds do regular short distance migration between roosting and foraging site. During high tides when mudflats get submerged in water these birds migrate to nearby wetlands until next low tide. There are no studies on the use of foraging and roosting sites by birds from Thane creek. Such studies are very important for maintaining the network of stopover sites that link the breeding and wintering ground through flyways. Roosting sites are also equally important because disturbance at roost site may cause less use of foraging site by the birds (Green *et al*, 2015). Birds are one of the best indicators of the environmental quality of any ecosystem (Nitsure & Pejaver, 2002) and are an important component of the mangrove ecosystem, where their occurrence and distribution help to understand the health and status of the wetland habitat (Chaudhari-Pachpande & Pejaver, 2016). Information on stop over site and bird distribution in the intertidal feeding area is necessary for conservation of the estuarine mudflats (Pandiyan & Asokan, 2016).

In the present study, we have documented the diversity and attempted to understand the distribution pattern of shorebirds in Thane creek.

MATERIAL AND METHODS

The study was conducted in Thane creek (Long. 72°.55' to 73°.00' E and Lat. 19°.00' to 19°.15' N) (Figure 1)

during winter season of 2015 - 16 which is the peak season for migratory waders and other shorebirds. Birds were identified by using field guides (Ali & Ripley, 1987; Grimmett, Inskipp & Inskipp, 2013) and bird counts were taken by following the methods by (Bibby, Burgess & Hill, 1992). Bird observations were made by travelling through a boat inside the creek. One mechanized boat and two non-mechanized boats were used for bird observation. The shallow and narrow inlets of the creek where the big, mechanized boat cannot penetrate, the non-mechanized boats were used for sampling. Total five boat trips were made on different days during lowest of low tides and the average values were considered to minimize the sampling error and obtain a fairly accurate bird count. During low tides, the maximum area of mudflats gets exposed and maximum birds land on these mudflats for foraging on benthic organisms, therefore, the lowest of low tides were chosen during the study. The total count method was used during the study and the entire creek from upstream to the downstream and both the banks were observed for diversity and abundance of birds. The birds were observed using Olympus 8x42 binoculars and the photographs were taken using Canon SX50 HS point and shoot camera and Nikon Coolpix L120 digital camera (Figure 5). Wherever flocks of birds were encountered manual counts of birds were taken and GPS coordinates were recorded using Garmin eTrex 20 GPS. In the case of large flocks of flamingos, multiple photos were taken and analysed on computer for total bird count.

RESULTS

Total 69 species of birds were encountered during the study belonging to 11 orders and 17 families (Table 1). From the total species recorded six species namely Black-tailed Godwit (*Limosa limosa*), Curlew Sandpiper (*Calidris ferruginea*), Eurasian Curlew (*Numenius arquata*), Lesser Flamingo (*Phoeniconaias minor*), Black-headed Ibis (*Threskiornis melanocephalus*), and Painted Stork (*Mycteria leucocephala*) are Near Threatened and one species i.e., Greater Spotted Eagle (*Clanga clanga*) is Vulnerable as per IUCN Red list. From the total birds 60.87 percent birds were migratory winter visitors, 36.23 percent birds were resident and local migrants, and the remaining 2.89 percent birds were resident as well as winter visitors.

Family Scolopacidae represented the highest number of bird species i.e., 14 followed by Laridae with 12 species; Anatidae and Ardeidae each with eight species; Charadriidae with six; Accipitridae with five species, Recurvirostridae, Phoenicopteridae, Threskiornithidae, Phalacrocoracidae, and Hirundinidae with two species each; and Ciconiidae, Rallidae, Pandionidae, Alcedinidae, Corvidae and Columbidae with one species each (Figure 2).

Order Phoenicopteriformes had the highest number of individuals that is (N = 20539 ± 13823 SD) followed by Charadriiformes with (N = 7913 ± 8474 SD), (Laridae – N = 1631 ± 911 SD), Scolopacidae – (N = 4197 ± 4529 SD), Recurvirostridae – (N = 547 ± 285 SD), Charadriidae – (N = 1538 ± 2748 SD) followed by Anseriformes with (N = 2134 ± 1504 SD) individuals. Rest all bird orders have less than 120 individuals (Figure 3 & 4).

Species specific average bird count of all five boat trips were analysed using the formula 01

$$Sp_{\text{-avg}} = \sum_{i=1}^{5} Sp_{\text{-ti}} \frac{(Sp_{\text{-t1}} + Sp_{\text{-t2}} + Sp_{\text{-t3}} + Sp_{\text{-t4}} + Sp_{\text{-t5}})}{5}$$

Formula 01

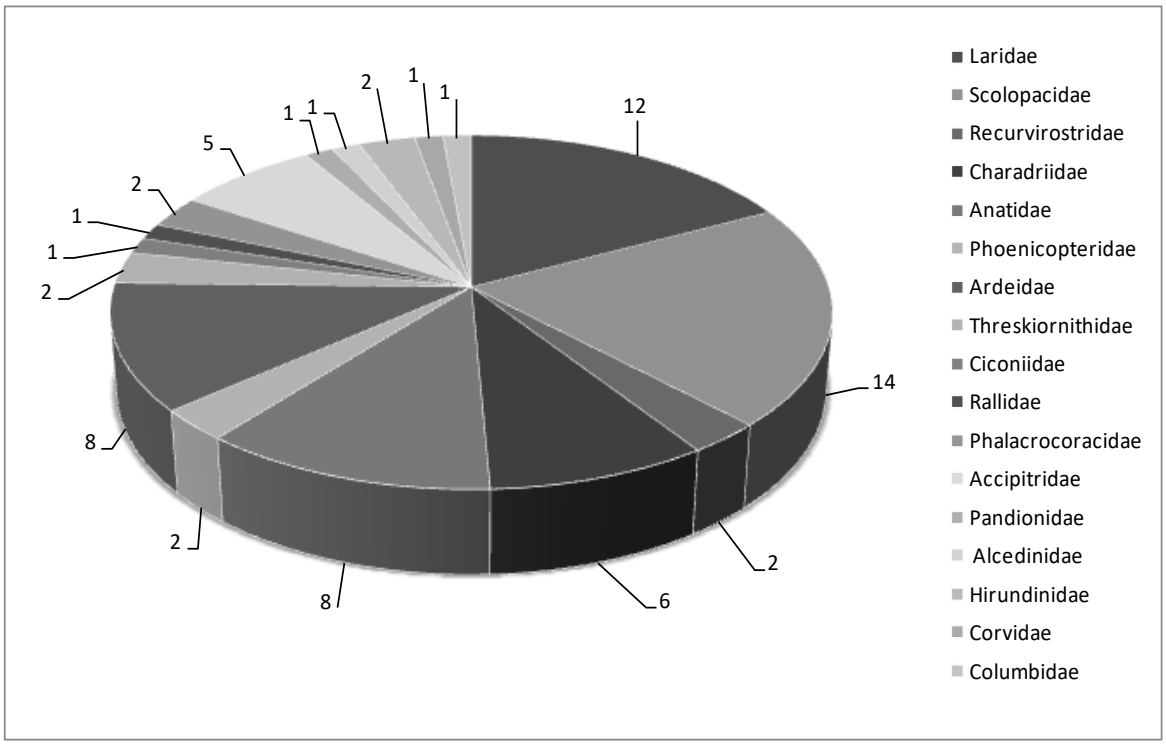

Figure 2. Family-wise number of bird species in Thane Creek.

Table 1. List of bird species encountered during the study

Sl. No.	Common Name	Scientific Name	IUCN Status	Migratory Status
	Order - Charadriiformes			
	Family - Laridae			
1	Heuglin's Gull	*Larus fuscus*	LC	WV
2	Slender-billed Gull	*Chroicocephalus genei*	LC	R
3	Mew Gull	*Larus canus*	LC	WV
4	Pallas's Gull	*Ichthyaetus ichthyaetus*	LC	WV
5	Brown-headed Gull	*Chroicocephalus brunnicephalus*	LC	WV
6	Black-headed Gull	*Chroicocephalus ridibundus*	LC	WV
7	Steppe Gull	*Larus cachinnans*	LC	WV
8	Caspian Gull	*Larus cachinnans*	LC	WV
9	Common Tern	*Sterna hirundo*	LC	WV
10	Caspian Tern	*Hydroprogne caspia*	LC	WV
11	Whiskered Tern	*Chlidonias hybrida*	LC	WV
12	Gull-billed Tern	*Gelochelidon nilotica*	LC	WV
	Family - Scolopacidae			
13	Common Greenshank	*Tringa nebularia*	LC	WV
14	Common Redshank	*Tringa totanus*	LC	WV
15	Black-tailed Godwit	*Limosa limosa*	NT	WV
16	Little Stint	*Calidris minuta*	LC	WV
17	Temminck's Stint	*Calidris temminckii*	LC	WV
18	Common Sandpiper	*Actitis hypoleucos*	LC	WV
19	Wood Sandpiper	*Tringa glareola*	LC	WV
20	Terek Sandpiper	*Xenus cinereus*	LC	WV
21	Marsh Sandpiper	*Tringa stagnatilis*	LC	WV
22	Curlew Sandpiper	*Calidris ferruginea*	NT	WV
23	Eurasian Curlew	*Numenius arquata*	NT	WV
24	Ruff	*Calidris pugnax*	LC	WV
25	Dunlin	*Calidris alpina*	LC	WV
26	Sanderling	*Calidris alba*	LC	WV
	Family Recurvirostridae			
27	Black-winged Stilt	*Himantopus himantopus*	LC	WV
28	Pied Avocet	*Recurvirostra avosetta*	LC	WV
	Family Charadriidae			
29	Little Ringed Plover	*Charadrius dubius*	LC	R
30	Lesser Sand Plover	*Charadrius mongolus*	LC	WV
31	Greater Sand Plover	*Charadrius leschenaultii*	LC	WV
32	Pacific Golden Plover	*Pluvialis fulva*	LC	WV
33	Kentish Plover	*Charadrius alexandrinus*	LC	WV
34	Red-wattled Lapwing	*Vanellus indicus*	LC	R
	Order - Anseriformes			
	Family - Anatidae			
35	Lesser Whistling Duck	*Dendrocygna javanica*	LC	R
36	Spot-billed Duck	*Anas poecilorhyncha*	LC	R
37	Northern Pintail	*Anas acuta*	LC	WV
38	Northern Shoveler	*Spatula clypeata*	LC	WV
39	Eurasian Wigeon	*Mareca penelope*	LC	WV
40	Common Teal	*Anas crecca*	LC	WV
41	Garganey	*Spatula querquedula*	LC	WV
42	Ruddy Shelduck	*Tadorna ferruginea*	LC	WV

Table 1 Continued in next page

	Order - Phoenicopteriformes			
	Family - Phoenicopteridae			
43	Greater Flamingo	*Phoenicopterus roseus*	LC	WV
44	Lesser Flamingo	*Phoeniconaias minor*	NT	WV
	Order - Pelecaniformes			
	Family - Ardeidae			
51	Pond Heron	*Ardeola grayii*	LC	R
45	Purple Heron	*Ardea purpurea*	LC	R
46	Grey Heron	*Ardea cinerea*	LC	R
48	Cattle Egret	*Bubulcus ibis*	LC	R
47	Little Egret	*Egretta garzetta*	LC	R
49	Intermediate Egret	*Ardea intermedia*	LC	R
50	Great Egret	*Ardea alba*	LC	R
52	Western Reef Egret	*Egretta gularis*	LC	R
	Family -Threskiornithidae			
53	Eurasian Spoonbill	*Platalea leucorodia*	LC	WV/R
54	Black-headed Ibis	*Threskiornis melanocephalus*	NT	R
	Order - Ciconiiformes			
	Family - Ciconiidae			
55	Painted Stork	*Mycteria leucocephala*	NT	WV/R
	Order - Gruiformes			
	Family - Rallidae			
56	Common Coot	*Fulica atra*	LC	R
	Order - Suliformes			
	Family - Phalacrocoracidae			
58	Little Cormorant	*Microcarbo niger*	LC	R
57	Indian Cormorant	*Phalacrocorax fuscicollis*	LC	R
	Order - Accipitriformes			
	Family - Accipitridae			
59	Eurasian Marsh Harrier	*Circus aeruginosus*	LC	WV
60	Brahminy Kite	*Haliastur indus*	LC	R
61	Greater Spotted Eagle	*Clanga clanga*	VU	WV
62	Shikra	*Accipiter badius*	LC	R
63	Black Kite	*Milvus migrans*	LC	R
	Family - Pandionidae			
64	Osprey	*Pandion haliaetus*	LC	WV
	Order - Coraciiformes			
	Family - Alcedinidae			
65	White-throated Kingfisher	*Halcyon smyrnensis*	LC	R
	Order - Passeriformes			
	Family - Hirundinidae			
66	Barn Swallow	*Hirundo rustica*	LC	R
67	Wire-tailed Swallow	*Hirundo smithii*	LC	R
	Family - Corvidae			
68	House Crow	*Corvus splendens*	LC	R
	Order - Columbiformes			
	Family - Columbidae			
69	Rock Pigeon	*Columba livia*	LC	R

LC – Least Concern, NT – Near Threatened, VU – Vulnerable, R – Resident, WV – Winter Visitor

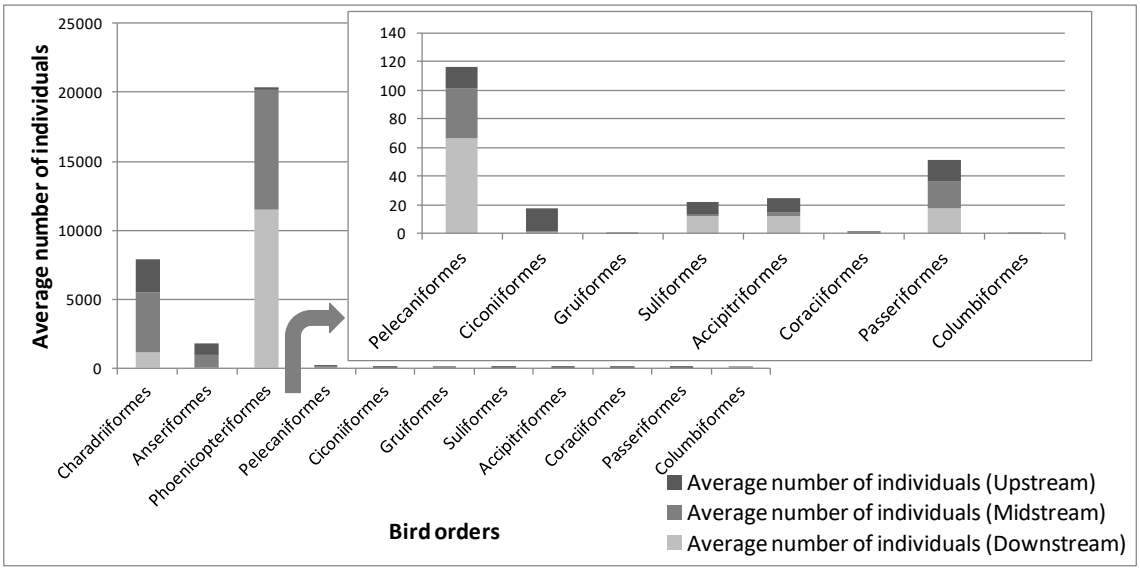

Figure 3. Order wise average number of individuals

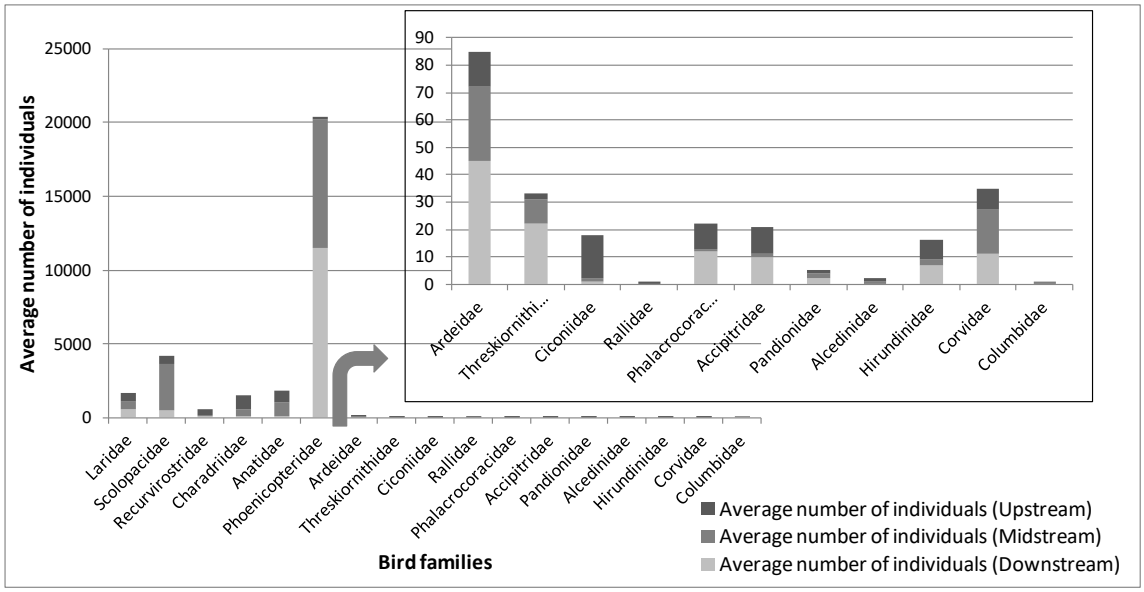

Figure 4. Family wise average number of individuals

The order and family wise average number of birds were calculated with formula 02

$$N = \sum_{i=1}^{n} Sp._{avgi}\ (Sp._{avg1} + Sp._{avg2} + \ldots + Sp._{avgn})$$

Formula 02

The percent encounter rate of bird order and family with respect to stream specific total bird count and with respect to total bird count of all streams together were calculated with formula 03 & 04.

$$E_{\%Ssp} = \left(\frac{N}{N_{Ssp}}\right) \cdot X\ 100$$

Formula 03

$$E_{\%Tot} = \left(\frac{N}{N_{Tot}}\right) \cdot X\ 100$$

Formula 04

Where,

$Sp._{t1}$ to $Sp._{t5}$ is species specific bird count for all five boat trips.

$Sp._{avg}$ is species specific average bird count from all five boat trips.

$Sp._{avg1\ to}$ $Sp._{avgn}$ is species specific average bird count for all species in one order or family, here n will change according to number of bird species in particular order or family.

N represents average number of birds in one order or one family.

$E_{\%Ssp}$ is percent encounter rate with respect to stream specific total bird species. Here N_{Ssp} is total bird count specific to stream

$E_{\%Tot}$ is percent encounter rate with respect to total bird count in all streams together. Here N_{Tot} is total bird count of all streams together.

With respect to total bird count of all streams together; Order Phoenicopteriformes had the highest encounter rate with maximum encounter in the downstream area followed by midstream and very less in the

Table 2. Percent encounter rate of bird orders

Bird orders	Percent encounter rate (wrt stream specific total bird count) (in %)			Percent encounter rate wrt total bird count in all streams together (in %)		
	Upstream	Midstream	Downstream	Upstream	Midstream	Downstream
Charadriiformes	69.664	31.244	8.788	7.865	14.491	3.720
Anseriformes	24.204	6.617	0.607	2.733	3.069	0.257
Phoenicopteriformes	4.204	61.706	89.752	0.475	28.619	37.993
Pelecaniformes	0.438	0.256	0.514	0.049	0.119	0.218
Ciconiiformes	0.438	0.007	0.008	0.049	0.003	0.003
Gruiformes	0.029	0.000	0.000	0.003	0.000	0.000
Suliformes	0.263	0.007	0.093	0.030	0.003	0.040
Accipitriformes	0.292	0.021	0.093	0.033	0.010	0.040
Coraciiformes	0.029	0.007	0.00	0.003	0.003	0.000
Passeriformes	0.438	0.128	0.140	0.049	0.059	0.059
Columbiformes	0.000	0.007	0.000	0.000	0.003	0.000

Table 3. Percent encounter rate of bird families

Bird families	Percent encounter rate (wrt stream specific total bird count) (in %)			Percent encounter rate wrt total bird count in all streams together (in %)		
	Upstream	Midstream	Downstream	Upstream	Midstream	Downstream
Laridae	15.981	3.781	4.306	1.806	1.753	1.822
Scolopacidae	15.952	22.634	3.636	1.803	10.496	1.539
Recurvirostridae	10.178	1.038	0.397	1.150	0.481	0.168
Charadriidae	27.530	3.802	0.459	3.111	1.763	0.194
Anatidae	24.176	6.616	0.607	2.732	3.068	0.257
Phoenicopteridae	4.199	61.697	89.738	0.475	28.611	37.983
Ardeidae	0.379	0.192	0.350	0.043	0.089	0.148
Threskiornithidae	0.058	0.064	0.171	0.007	0.030	0.072
Ciconiidae	0.467	0.007	0.008	0.053	0.003	0.003
Rallidae	0.029	0.000	0.000	0.003	0.000	0.000
Phalacrocoracidae	0.262	0.007	0.093	0.030	0.003	0.040
Accipitridae	0.292	0.007	0.078	0.033	0.003	0.033
Pandionidae	0.029	0.014	0.016	0.003	0.007	0.007
Alcedinidae	0.029	0.007	0.000	0.003	0.003	0.000
Hirundinidae	0.204	0.014	0.055	0.023	0.007	0.023
Corvidae	0.233	0.114	0.086	0.026	0.053	0.036
Columbidae	0.000	0.007	0.000	0.000	0.003	0.000

upstream area of the creek. Order Charadriiformes is the second-highest encountered order with the maximum encounter in midstream followed by upstream and downstream. Further in the order Charadriiformes, family Scolopacidae was encountered maximum in the midstream area followed by upstream and downstream areas; the maximum encounter of family Laridae was in the downstream area followed by upstream and midstream areas, both family Charadriidae and Recurvirostridae were majorly encountered in the upstream area followed by midstream area with very less encounter in the downstream area. The family with a moderate number of individuals i.e., Anatidae is majorly encountered in midstream followed by upstream and very less in downstream region. Families with less number of individuals viz. Ciconiidae, Rallidae, Phalacrocoracidae, Accipitridae, Pandionidae, Alcedinidae, Hirundinidae, and Corvidae were encountered with less than 0.1 percent encounter rate (Table 2 & 3).

With respect to stream specific total bird count; In upstream region order Charadriiformes showed the highest percent encounter rate (69.664%) comprising of family Charadriidae (27.53%) followed by Anatidae (24.176%), Laridae (15.981), Scolopacidae (15.952%), Recurvirostridae (10.178%) and Phoenicopteridae (4.199%) the remaining families showed less than 1 percent encounter rate. In midstream region Order Phoenicopteriformes showing the highest percent encounter rate (61.706%) followed by Charadriiformes (31.244%) That comprised of family Scolopacidae (22.634%), Charadriidae (3.802%), Laridae (3.781%) and Recurvirostridae (1.038%). Anatidae showed 6.616% encounter rate and rest all families were less than 1 percent. In downstream region Order Phoenicopteriformes showing the highest percent encounter rate (89.752%) followed by Charadriiformes (8.788%) that include family Laridae (4.306%) and Scolopacidae (3.636%) rest all families with less than 1 percent encounter rate (Table 2 & 3).

The Shannon-Weiner diversity indices revealed higher diversity upstream (2.56) followed by midstream (1.783) and downstream (1.125). Similarly, the evenness index showed the species were more evenly distributed upstream (0.219) followed by midstream (0.110) and downstream zone (0.060). On the contrary, the dominance was higher downstream (0.501) followed by midstream (0.319) and upstream zone (0.124) (Table 04).

To calculate the diversity indices birds were segregated as per upstream, mid stream and downstream region then average bird count of all five boat trips were taken. Paleontological statistics (PAST) version 4.06 statistical software was used. The results are detailed in table 04.

$$\text{Shannon index } H = \sum_{i=1}^{S} p_i \ln p_i$$

Formula 05

$$\text{Dominance } D = \sum \left(\frac{n}{N}\right)^2$$

Formula 06

Simpson index = 1 – D

Formula 07

Where,

p is the proportion of n/N;
n is individuals of one particular species;
N is Total number of individuals of all species;
ln is natural log;
∑ is the sum of the calculations and s is the number of species.
H is Shannon index
D is dominance

DISCUSSION

Thane creek is an important feeding ground for many migratory birds. Every year thousands of migratory shorebirds visit Thane creek during the winter season. Availability of food, prey density and mobility, existence of competitors, slope of the foraging land and other factors decides the flock size and density of birds (Khaleghizadeh, 2010). During low tides as the water starts reseeding the mudflats get exposed providing feeding habitat to waders. The birds mostly feed on benthic macro fauna such as polychaetes, oligochaetes, crustaceans, insects and their larvae, mollusc and fish larvae (Quadros, 2002; Nitsure & Pejaver, 2002; Chaudhari-Pachpande & Pejaver, 2016). Majority of these birds are the small and moderate-sized waders. Other birds such as Gulls and Terns feed in shallow waters on shoal of finfish larvae and crustaceans like *Acetes sp.* which is an important contributor in crustacean fishery and common in Thane creek (Aravindakshan & Kharbari, 1987); It is the major food item of fishes, prawns and cephalopods revealed from gut content analysis (Deshmukh, 2002; Jaiswar & Chakraborty, 2005). The diet composition analysis of nine commercially important fishes from northern Arabian Sea revealed 32.74 % composition as prey item by *Acetes sp*. (Vase *et al*. 2021). Larger piscivorous birds like egrets and herons feed on larger fishes (Dimalexis, Pyrovetsi & Sgardelis, 1997; Choi, Kwon & Yoo,

Table 4. Diversity indices of bird distribution in upstream, midstream and downstream region of Thane creek.

	Up stream	Mid stream	Down stream
No. of species	59	54	51
No. of Individuals	3425	14073	12844
Dominance_D	0.1242	0.3186	0.5009
Simpson_1-D	0.8758	0.6814	0.4991
Shannon_H	2.559	1.783	1.125
Evenness_e^H/S	0.219	0.1101	0.0604

Figure 5. Flock of different bird species from Thane creek. A. Lesser Flamingo (*Phoeniconaias minor*), B. Greater Flamingo (*Phoenicopterus roseus*), C. Curlew Sandpiper (*Calidris ferruginea*), D. Painted Stork (*Mycteria leucocephala*), E. Black-tailed Godwit (*Limosa limosa*), F. Spot-billed Duck (*Anas poecilorhyncha*), G. Mixed flock of Brown-headed Gull (*Chroicocephalus brunnicephalus*), Black-headed Gull (*Chroicocephalus ridibundus*) and Slender-billed Gull (*Chroicocephalus genei*), H. Lesser Whistling Duck (*Dendrocygna javanica*)

2008). Latest study by Apte *et al* (2020) found 20 groups of macro benthic invertebrates in Thane creek with higher diversity in winter season. Arthropoda was found to be group wise most diverse phylum and polychaetes shows 15 families from intertidal mudflats. Average biomass of macro benthos in winter is found to be 14.96 gm/m^3 and average density of polychaetes (2966/m^3) and gastropods (15343/m^3) which then drops down in succeeding seasonal phase.

The two species of flamingos form huge congregations in the creek, with the Lesser Flamingo (*Phoeniconaias minor*) solely outnumbering all other birds. They are filter feeders and are seen continuously foraging on mudflats and shallow waters by forming flocks. Lesser Flamingos forage on cyanobacteria and benthic diatoms while the Greater Flamingos forage on copepods, mollusks, annelid worms, small fish, seeds, brine shrimps (*Artemisia spp*.), and other small planktonic and benthic animals in addition to algae; because of the smaller size of prey items flamingos require to spend more time in foraging (Kumssa & Bekele, 2014). During high tides when mudflats get submerged these birds roost in the nearby wetlands which are either natural or artificial aquaculture ponds, Saltpans or mangrove vegetation.

We observed that Flamingos and other shorebirds have a specific pattern of distribution in the creek; flamingos were seen more at the mid and downstream region of the creek and had sporadic distribution in the upstream region of the creek. The distribution patterns in the birds are primarily because of food availability and also because of other biotic and abiotic factors. Thane creek has influence of highly populated cities like Thane, Navi Mumbai, and Mumbai, and many small-scale and large industries release domestic sewage and industrial effluent load into the creek (Quadros, 2002; Nitsure & Pejaver, 2002; Nikam *et al*. 2009; Chaudhari-Pachpande & Pejaver, 2016). The salinity of the creek is very low upstream as compared to the mid and downstream region because of less seawater influence in the upstream region. Due to siltation and widening of mudflats along the banks, the creek is getting shallower and narrower upstream. Mendiratta & Gedam (2014) have reported the reduction in the width of the creek based on the spatio-temporal study using the classified Land-sat images for Thane Creek. The solid waste was found to accelerate the process by blocking the water flow of small inlets which are the veins of the creek leading to very little mixing of water in the mainstream. This ultimately leads to poor water exchange and reduction in oxygen levels leading to low benthic faunal abundance which can be attributed for less avifaunal abundance upstream.

We also found species are more evenly distributed upstream because distribution of birds from order Phoenicopteriformes and Charadriiformes in mid and downstream portions was very high resulting in lesser evenness at mid and downstream region compared to the upstream region; and the dominance was high in the downstream region followed by midstream and upstream region. Many of the times, Gulls and Terns were seen congregating and foraging on water surface on crustaceans mainly *Acetes sp.* in mid and downstream region. *Acetes* are planktonic in nature and an abundant group in macro-zooplankton and their abundance is directly proportional to increasing salinity. They also form aggregations in specific seasons of the year (Zafar & Alam, 1997) on which birds congregate and forage voraciously.

Distribution of wader species is primarily based on the availability of specific food of their interest. Shorebirds are known to specialize on different types of prey, provide clues about differential distributions of prey types in the mudflats (Mathot, Piersma & Elner, 2018). Foraging studies of birds can help to understand the distribution of macro fauna in the mud more clearly. However, foraging sites with rich faunal distribution where migratory birds can refuel themselves quickly are irregularly spaced worldwide and, on that basis, the migratory flyways may have evolved (Butler, Davidson & Morrison, 2012). Identification and study of such stop over sites can give a clear picture about habitat status and understanding about major threats to sensitive migratory shorebirds.

As Thane creek is a major stop over site for many migratory shore birds which includes near threatened and vulnerable species; conservation of such habitats is necessary. It is important to focus on the major threats which are siltation, domestic and industrial pollution in the upstream region of creek. Siltation is the root cause as it is reducing the mixing of waters and flushing activities upstream leading to accumulation of pollutants in the waters and mudflats and ultimately it starts leaching in to the mud therefore time to time excavation of the silt from the channels is necessary to regulate the natural flushing activity of the water during tides. The mangrove cover around creek has increased from 50.7 km^2 in 1972 to 57.6 km^2 in 2016. The land use land cover (LULC) by Vijay *et al* (2020) reveals that the mudflats have also reduced because of mangrove growth into the open creek waters. The geospatial assessment of the Thane Creek revealed that the average width of the creek also gradually decreased in upper region by 3.85% from 1972 to 1994 and 13.2 % up to 2016; in middle portion it decreases by 7.4% from 1972 to 1994 and by 20 % until 2016; the highest reduction is in upstream portion where it is reduced by 18.6 % from 1972 to 1994 and then by 46% up to 2016 (Vijay *et al*. 2020). The management of such mangrove growth in open creek water and on the mudflats is necessary which will reduce the siltation rate and narrowing of the channels in upstream region of creek.

CONCLUSION

From our preliminary study we have documented the diversity and attempted to understand the distribution pattern of avifauna in Thane creek. We found that birds have area and species-specific pattern of distribution throughout the creek which is mainly because of the availability of food of their interest which is not uniformly available in mudflats. The faunal diversity in mudflats and in water is affected by domestic and industrial pollution load which is high in the upstream region of creek leading to very poor use of upstream region of creek by shore birds. However long-term annual bird observation studies are required for more confirmative distribution pattern and species-specific results.

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Conflict of Interest:

The author declares that there is no Conflict of Interest.

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