

**Population
Dynamics of
Waterbirds in
Pichavaram
Mangroves,
Tamilnadu,
Southern India**



Abstract

We assessed the temporal variations in the population dynamics of waterbirds in the Pichavaram mangroves between 1987 and 2006. The abundance and richness of waterbirds declined from late 80s to mid 2000s where as the diversity was consistent. Totally 75 waterbird species belonging to 17 different families and six different orders were recorded. The families viz., Charadriidae, Scolopacidae, Sternidae, Ciconiidae, Ardeidae and Threskiornithidae were recorded across the decades, whereas Glareolidae, Haematopodidae, Phoenicopteridae and Phalacrocoracidae were not recorded after early 90s. Several waterbird species did not visit Pichavaram mangroves after early 90s. The variations in waterbird population indicated that the Pichavaram mangroves were rich in waterbirds before early 90s. Although, there were several factors identified as threats for waterbirds, the most significant was the deprivation of freshwater flow to Pichavaram areas which completely changed the land use pattern and productivity of mangroves and the adjoining areas. The abandonment of agriculture due to lack of water in Pichavaram areas after mid 1990s, have reduced the foraging grounds of waterbirds.

Keywords : Pichavaram mangroves, waterbirds population dynamics, richness, threats

Introduction

India has wide diversity of wetland microhabitats of both inland (mainly freshwater) and coastal (saline water) areas and hence there is a wide variation and diversity of wetland birds. Intertidal zone is the most important foraging habitat for migrant shorebirds (Velasquez and Hockey 1991; Piersma et al. 2005). The east coast of India, especially the Tamil Nadu region, is of major significance for waterbirds because many extensive wetlands are found here (Thiyagesan and Nagarajan, 1995). These wetlands are especially important as wintering areas for water birds. In which, mangroves are most productive ecosystems on earth, deriving nourishment from terrestrial and tidal waters, which support a wide diversity of fauna and flora. In the east coast of India, Pichavaram mangrove is one of the most pristine mangrove forests in Tamil Nadu. Also, an appreciable number of bird species migrate annually from breeding sites in arctic Siberia via India to wintering grounds in Australia (Sampath and Krishnamurthy, 1989, 1990) and these areas are critical for the continuance of migration and, ultimately, for the survival of many shorebirds (Myers, 1983).

According to Todt (1989) the density and diversity of water birds could be influenced by habitat diversity and quality. So, the avifaunal population parameters could be used as indicators to assess the habitat quality. The Core area of Pichavaram mangroves have a wide diversity of microhabitats such as forested wetlands, tidal mudflats, swamps marshy areas etc., which attract a mixed variety of birds for roosting, nesting, feeding and other activities. Bird population parameters such as species richness, density and diversity are frequently used as indicators of habitat quality (Nilsson and Nilsson 1978, Weller 1978). In addition, the waterbirds are in the apex of the food chain in aquatic ecosystems and they are capable of discriminating minute changes in the environment and prey characteristic features (e.g. Goss-Custard *et al.*, 1995; Nagarajan *et al.*, 2002 a, b, c 2006, 2008; LeRossignol *et al.*, 2011; Nagarajan 2014). Therefore, they can be used as indicators to assess the changes in the environment and habitat quality.

Although the Centre of Advanced Study in Marine Biology, Annamalai University has been investigating extensively the ecology of Pichavaram mangroves since 1959, the investigations on avifauna is not well documented and there is paucity of information (Kathiresan 2000). So, in this chapter we explore the changes in the population dynamics of waterbirds in Pichavaram mangroves across the decades and possible reasons for the same.

Study Area

The Pichavaram (11°25' N: 74°47' E) has one of the significant and largest mangrove forest in India, near the temple town of Chidambaram, which is one of the unique biodiversity spots in South India (Figure 1). It is located between the Vellar in the north, the Coleroon in the south and the Uppanar in the west. It communicates with the sea by a shallow opening, which is the mouth in the sand littoral strand. It consists of number of small and large islets surrounded by numerous creeks, canals and channels. They include 51 islets ranging from 10 m² to 2 km² separated by an intricate system of creeks and channels that connect the Vellar, Uppanar and Coleroon estuaries. The depth of the waterways through the mangroves varies from 0.3 to 3m. Geographically, it located 11°24'-11°27' Latitudes and 79°46'- 79°48'E Longitudes. The Pichavaram mangroves are considered as one of the healthiest mangroves in the world. Pichavaram mangroves consist of a number of islands interspersing a vast expanse of water covered with mangrove trees primarily *Avicennia spp.* and *Rhizophora spp.* The sandy area is dominated by the *Salicoma brachiata*, *Suaeda maritime*, *Sesuvium portulacastrum*, *Arthrocnemum indicum* and *Excoecaria agallocha* are some other plants. The endangered mangrove vegetation of Pichavaram include *Acanthus ilicifolius*, *Aegiceras corniculatum*, *Avicennia marina*, *Avicennia officinalis*, *Bruguiera cylindrica*, *Ceriops decandra*, *Lumnitzera racemosa*, *Rhizophora apiculata*, *Suaeda maritime*, and *Suaeda monoica*. The area is about 2800 acres and is separated from the sea by a sand bar which is a patch of extraordinary loveliness. The Pichavaram mangrove biotope, with its peculiar topography and environmental condition, supports the existence of many rare varieties of economically important shell and fin fishes (Fig. 1).



Figure 1 : The map of the study area, Pichavaram mangroves

Materials And Methods

The data on waterbird populations in different parts of Pichavaram mangroves were collected during mid January (when usually the waterbird census takes place e.g. Perennou *et al.*, 1990; Lopez and Mundkur, 1997) using 7x50" binoculars. Waterbird species were identified with the help of their special features using Ali (1969), Ali and Ripley (1983) and Grimmett *et al.* (1999). The data collections were done by direct count method (Nagarajan and Thiyagesan 1996) during morning hours. Different microhabitats of mangroves were reached by foot and by non-mechanized boats to avoid disturbances to bird and to reduce the double count. The total numbers of individuals in different species were counted and considered as abundance. The waterbird census data did not include the waterfowls i.e. order Anseriformes. The total number of species was also counted to estimate species richness and diversity was calculated using the Shannon-Wiener diversity index (Shannon and Wiener, 1949) by using the following formula

$$H' = -\sum p_i \log_e p_i$$

where p_i is the proportion of the i th species in the sample.

Data was used for the period between 1987 and 2006, however, during some years the waterbird census was not carried out.

Hence, the available data were grouped into:-

- i) Late 80s (1987 to 1989).
- ii) Early 90s (1990 to 1992).
- iii) Mid 90s (1993 to 1995).
- iv) Early 2000s (2001 to 2002).
- v) Mid 2000s (2006) for analysis and comparison.

Results

Changes in the Population Dynamics of Waterbird Species

Among the 76 species of waterbirds across the decades, Kentish plover (*Charadrius alexandrinus*), Little ringed plover (*Charadrius dubius*), Red-wattled lapwing (*Vanellus indicus*), Common sandpiper (*Actitis hypoleucos*), Little stint (*Calidris minuta*), Common redshank (*Tringa totanus*), Whiskered tern (*Chlidonias hybrida*), Caspian tern (*Hydroprogne caspia*), Openbill stork (*Anastomus oscitans*), Painted stork (*Mycteria leucocephala*), Large egret (*Ardea alba*), Grey heron (*Ardea cinerea*), Pond heron (*Ardeola grayii*), Little green heron (*Ardeola striatus*), Little egret (*Egretta garzetta*), Night heron (*Nycticorax nycticorax*) and Oriental White ibis (*Threskiornis melanocephalus*) were the species recorded in all the decades. Lesser sand plover (*Charadrius mongolus*), Yellow-wattled lapwing (*Vanellus malabaricus*), Little pratincole (*Glareola lactea*), Brown-headed gull (*Chroicocephalus brunnicephalus*), Black-headed gull (*Chroicocephalus ridibundus*), Herring gull (*Larus argentatus*), Pied Avocet (*Recurvirostra avosetta*), Rudy Turnstone (*Arenaria interpres*), Dunlin (*Calidris alpina*), Curlew sandpiper (*Calidris ferruginea*), Temminck's stint (*Calidris temminckii*), Broadbilled sandpiper (*Limicola falcinellus*), Blacktailed godwit (*Limosa limosa*), Bartailed godwit (*Limosa lapponica*), Curlew (*Numenius arquata*), Ruff (*Philomachus pugnax*), Spotted redshank (*Tringa erythropus*), Common tern (*Sterna hirundo*), Little tern (*Sterna albifrons*), River tern (*Sterna aurantia*), Indian lesser crested tern (*Thalasseus bengalensis*), Greater crested tern (*Thalasseus bergii*), White stork (*Ciconia ciconia*), Little heron (*Butorides striatus*), Indian reef heron (*Egretta gularis*), Chestnut bittern (*Ixobrychus cinnamomeus*), Black bittern (*Ixobrychus flavicollis*), Yellow bittern (*Ixobrychus sinensis*), Oriental Darter (*Anhinga melanogaster*), Lesser flamingo (*Phoenicopterus minor*), Greater flamingo (*Phoenicopterus roseus*), Little grebe (*Tachybaptus ruficollis*), Large Cormorant (*Phalacrocorax carbo*) and Little cormorant (*Phalacrocorax niger*) were not recorded after early 90s. Bird species viz., Great Stone curlew (*Esacus recurvirostris*), Crab plover (*Dromas ardeola*), Indian lesser crested tern (*Thalasseus bengalensis*), Chestnut bittern (*Ixobrychus cinnamomeus*), Yellow bittern (*Ixobrychus sinensis*), Lesser flamingo (*Phoenicopterus minor*), Little grebe (*Tachybaptus ruficollis*) and Large Cormorant (*Phalacrocorax carbo*) were found rarely among the decades (Table 1).

The total abundance of waterbirds in late 80s was 7758 which increased to 11617 during early 90s. Subsequently, the abundance declined and it was lowest during early 2000s with a population of 1586. The waterbird species richness declined from 67 (Late 80s) to 25 (Early 2000s). Although, the abundance and species richness declined across the decades, the diversity (H') was high and remarkable which ranged from 3.0086 (Late 80s) to 2.0211 (Early 2000s). Until, early 90s the diversity was more than 2.9033 which indicated that the quality of mangroves (abundance and availability of prey) were excellent to attract the waterbirds (Table 1).

Table 1 : Waterbird abundance, species richness and diversity at Pichavaram Mangroves, Tamilnadu, southern India across the decades. The waterbird census data did not include the waterfowls i.e. order Anseriformes.

S No.	Common Name	Scientific Name	Family	Late 80s	Early 90s	Mid 90s	Early 2000s	Mid 2000s
1	Kentish plover	<i>Charadrius alexandrinus</i>	Charadriidae	96	128	104	54	713
2	Little ringed plover	<i>Charadrius dubius</i>	Charadriidae	63	128	239	55	842
3	Greater sand plover	<i>Charadrius leschenaultii</i>	Charadriidae	5	7	10	0	0
4	Lesser sand plover	<i>Charadrius mongolus</i>	Charadriidae	385	1220	0	0	0
5	Pacific golden plover	<i>Pluvialis fulva</i>	Charadriidae	187	230	0	0	2
6	Grey plover	<i>Pluvialis squatarola</i>	Charadriidae	50	85	0	0	20
7	Red wattled lapwing	<i>Vanellus indicus</i>	Charadriidae	24	28	147	22	22
8	Yellow-wattled lapwing	<i>Vanellus malabaricus</i>	Charadriidae	2	13	0	0	0
9	Stone curlew	<i>Burhinus oedicnemus</i>	Burhinidae	0	0	3	0	33
10	Great Thick-knee	<i>Esacus recurvirostris</i>	Burhinidae	0	2	0	0	0
11	Crab plover	<i>Dromas ardeola</i>	Dromadidae	0	4	0	0	0
12	Little pratincole	<i>Glareola lactea</i>	Glareolidae	7	3	0	0	0
13	Eurasian oystercatcher	<i>Haematopus ostralegus</i>	Haematopodidae	2	5	0	0	0
14	Pheasant tailed jacana	<i>Hydrophasianus chirurgus</i>	Jacanidae	2	0	0	0	50
15	Brown-headed gull	<i>Chroicocephalus brunnicephalus</i>	Laridae	382	215	0	0	0
16	Black-headed gull	<i>Chroicocephalus ridibundus</i>	Laridae	93	152	0	0	0
17	Pallas's Gull	<i>Ichthyaetus ichthyaetus</i>	Laridae	0	14	0	0	2
18	Herring gull	<i>Larus argentatus</i>	Laridae	79	40	0	0	0
19	Blackwinged stilt	<i>Himantopus himantopus</i>	Recurvirostridae	627	662	160	0	0
20	Pied Avocet	<i>Recurvirostra avosetta</i>	Recurvirostridae	16	16	0	0	0
21	Common sandpiper	<i>Actitis hypoleucos</i>	Scolopacidae	26	34	62	42	85
22	Ruddy Turnstone	<i>Arenaria interpres</i>	Scolopacidae	11	7	0	0	0
23	Dunlin	<i>Calidris alpina</i>	Scolopacidae	14	135	0	0	0
24	Curlew sandpiper	<i>Calidris ferruginea</i>	Scolopacidae	286	453	0	0	0
25	Little stint	<i>Calidris minuta</i>	Scolopacidae	1243	2422	132	56	0
26	Temminck's stint	<i>Calidris temminckii</i>	Scolopacidae	8	33	0	0	0
27	Common snipe	<i>Gallinago gallinago</i>	Scolopacidae	47	48	23	6	0
28	Broadbilled sandpiper	<i>Limicola falcinellus</i>	Scolopacidae	25	50	0	0	0
29	Asian Dowitcher	<i>Limnodromus semipalmatus</i>	Scolopacidae	0	2	1	0	58
30	Blacktailed godwit	<i>Limosa limosa</i>	Scolopacidae	136	313	0	0	0
31	Bartailed godwit	<i>Lomosa lapponica</i>	Scolopacidae	5	22	0	0	0
32	Eurasian Curlew	<i>Numenius arquata</i>	Scolopacidae	25	27	0	0	0
33	Whimbrel	<i>Numenius phaeopus</i>	Scolopacidae	34	39	0	0	2
34	Ruff	<i>Philomachus pugnax</i>	Scolopacidae	95	126	0	0	0
35	Spotted redshank	<i>Tringa erythropus</i>	Scolopacidae	2	9	0	0	0
36	Wood sandpiper	<i>Tringa glareola</i>	Scolopacidae	14	19	11	0	0
37	Common Greenshank	<i>Tringa nebularia</i>	Scolopacidae	22	20	0	20	16
38	Green sandpiper	<i>Tringa ochropus</i>	Scolopacidae	11	8	57	29	0
39	Marsh sandpiper	<i>Tringa stagnatilis</i>	Scolopacidae	290	725	20	8	0
40	Common redshank	<i>Tringa totanus</i>	Scolopacidae	101	88	24	3	47
41	Terek sandpiper	<i>Xenus cinereus</i>	Scolopacidae	5	11	0	1	0

S No.	Common Name	Scientific Name	Family	Late 80s	Early 90s	Mid 90s	Early 2000s	Mid 2000s
42	Whiskered tern	<i>Chlidonias hybrida</i>	Sternidae	160	180	21	6	58
43	Gull-billed tern	<i>Gelochelidon nilotica</i>	Sternidae	94	137	7	0	0
44	Caspian tern	<i>Hydroprogne caspia</i>	Sternidae	11	44	36	9	144
45	Common tern	<i>Sterna hirundo</i>	Sternidae	100	105	0	0	0
46	Little tern	<i>Sterna albifrons</i>	Sternidae	60	99	80	40	0
47	River tern	<i>Sterna aurantia</i>	Sternidae	2	13	0	0	0
48	Lesser crested tern	<i>Thalasseus bengalensis</i>	Sternidae	0	40	0	0	0
49	Greater Crested Tern	<i>Thalasseus bergii</i>	Sternidae	22	103	0	0	0
50	Openbill stork	<i>Anastomus oscitans</i>	Ciconiidae	142	35	101	161	361
51	White stork	<i>Ciconia ciconia</i>	Ciconiidae	8	21	0	0	0
52	Painted stork	<i>Mycteria leucocephala</i>	Ciconiidae	22	9	26	6	88
53	Large egret	<i>Ardea alba</i>	Ardeidae	42	32	134	56	62
54	Grey heron	<i>Ardea cinerea</i>	Ardeidae	31	46	11	4	11
55	Purple heron	<i>Ardea purpurea</i>	Ardeidae	4	14	4	1	0
56	Pond heron	<i>Ardeola grayii</i>	Ardeidae	145	52	1376	506	36
57	Little green heron	<i>Ardeola striatus</i>	Ardeidae	12	0	42	10	86
58	Eurasian Bittern	<i>Botaurus stellaris</i>	Ardeidae	30	23	7	3	0
59	Cattle egret	<i>Bubulcus ibis</i>	Ardeidae	114	207	163	0	0
60	Little heron	<i>Butorides striatus</i>	Ardeidae	57	27	0	0	0
61	Little egret	<i>Egretta garzetta</i>	Ardeidae	320	403	1149	440	229
62	Indian reef heron	<i>Egretta gularis</i>	Ardeidae	16	25	0	0	0
63	Chestnut bittern	<i>Ixobrychus cinnamomeus</i>	Ardeidae	6	0	0	0	0
64	Black bittern	<i>Ixobrychus flavicollis</i>	Ardeidae	3	6	0	0	0
65	Yellow bittern	<i>Ixobrychus sinensis</i>	Ardeidae	1	0	0	0	0
66	Median egret	<i>Mesophoyx intermedia</i>	Ardeidae	172	205	0	0	74
67	Night heron	<i>Nycticorax nycticorax</i>	Ardeidae	1700	2167	183	48	1000
68	Oriental Darter	<i>Anhinga melanogaster</i>	Anhingidae	2	1	0	0	0
69	Eurasian Spoonbill	<i>Platalea leucorodia</i>	Threskiornithide	7	29	0	0	24
70	Oriental White ibis	<i>Threskiornis melanocephalus</i>	Threskiornithide	8	15	5	5	2
71	Lesser flamingo	<i>Phoenicopterus minor</i>	Phoenicopteridae	11	0	0	0	0
72	Greater flamingo	<i>Phoenicopterus roseus</i>	Phoenicopteridae	5	30	0	0	0
73	Little grebe	<i>Podiceps ruficollis</i>	Podicipedidae	9	0	0	0	0
74	Large Cormorant	<i>Phalacrocorax carbo</i>	Phalacrocoracidae	8	0	0	0	0
75	Little cormorant	<i>Phalacrocorax niger</i>	Phalacrocoracidae	16	9	0	0	0
Total Birds				7758	11617	4336	1586	4067
Richness				69	67	30	25	27
Diversity (H')				3.0086	2.9033	2.2584	2.0211	2.3017

Changes in the Population Dynamics of Waterbird Groups

Family-wise Distribution

Totally, waterbirds species from 17 families were recorded across the years. In which the families viz., Charadriidae, Scolopacidae, Sternidae, Ciconiidae, Ardeidae and Threskiornithide were recorded across the decades. The species from families of Glareolidae, Haematopodidae, Phalacrocoracidae, Phoenicopteridae and Phalacrocoracidae were not

recorded after early 90s. Out of 17 families 15 families were recorded in late 80s and early 90s. The lowest numbers of five families were recorded during early 2000s and then it increased to 10 families. The diversity (H') fluctuated from 0.6294 (Early 90s) to 1.6735 (Late 80s). The diversity was lowest during early 90s which was due to high turnover of Scolopacidae and Ardeidae. Subsequently, the diversity got increased and reached to 1.6322 during mid 2000s (Table 2).

Table 2 : Abundance, species richness and diversity of different waterbird families at Pichavaram Mangroves, Tamilnadu, India across the decades. The waterbird census data did not include the waterfowls i.e. family Aridiidae.

Family	Late 80s	Early 90s	Mid 90s	Early 2000s	Mid 2000s
Charadriidae	811	1838	500	130	1651
Burhinidae	0	2	3	0	33
Dromadidae	0	4	0	0	0
Glareolidae	7	3	0	0	0
Haematopodidae	2	5	0	0	0
Jacaniidae	2	0	0	0	50
Laridae	554	420	0	0	2
Recurvirostridae	643	678	160	0	0
Scolopacidae	2401	4591	330	165	156
Sternidae	448	721	143	55	202
Ciconiidae	171	65	127	166	449
Ardeidae	2652	3207	3069	1066	1498
Phalacrocoracidae	2	1	0	0	0
Threskiornithide	15	44	5	5	26
Phoenicopteridae	16	30	0	0	0
Podicipedidae	9	0	0	0	0
Phalacrocoracidae	24	9	0	0	0
Total 7758	11617	4336	1586	4067	
Richness	15	15	6	5	9
Diversity (H')	1.6735	0.6294	1.0397	1.0773	1.6322

Order-wise Distribution

Among the six orders of waterbirds, namely Charadriiformes, Ciconiiformes, Pelecaniformes, Phoenicopteriformes, Podicipediformes and Suliformes, the first three orders were recorded across the decades. The later three orders were not found after early 90s. The richness was highest with six orders during late 80s and then gradually declined to three orders in mid 90s which was consistent until mid 2000s. The orderwise diversity was highest during late 80s ($H'=0.7826$) and lowest during early 90s ($H'=0.6486$). Then the diversity progressively increased to 0.9529 during early 2000s (Table 3)

Table 3 : Abundance, species richness and diversity of different waterbird orders at Pichavaram Mangroves, Tamilnadu, southern India across the decades. The waterbird census data did not include the waterfowls i.e. order Anseriformes

Order	Late 80s	Early 90s	Mid 90s	Early 2000s	Mid 2000s
Charadriiformes	4868	8261	1136	349	2094
Ciconiiformes	171	65	127	166	449
Pelecaniformes	2669	3252	3073	1071	1524
Phoenicopteriformes	16	30	0	0	0
Podicipediformes	9	0	0	0	0
Suliformes	24	9	0	0	0
Total 7758	11617	4336	1586	4067	
Richness	6	5	3	3	3
Diversity (H')	0.7826	0.6487	0.6981	0.8345	0.9529

Discussion

We recorded totally 75 waterbird species belonged to 17 different families and six different orders in the Pichavaram Mangrove across the decades which also indicated that the mangroves were rich in waterbirds before early 90s.

Sampath and Krishnamoorthy (1989, 1990) made pioneering reports about birdlife of this area. Subsequently our work for the past one decade (e.g. Nagarajan and Thiyagesan, 1995, 1996, 1998, 2006, 2007, Thiyagesan and Nagarajan 1995, 1997) has been bringing continuous research information on various aspects of birdlife of this area. Earlier, Nagarajan (1990), Nagarajan and Thiyagesan (1996) reported 27 species of waterbirds in different habitats of mangroves and adjoining croplands between November 1989 and April 1990. Nagarajan and Thiyagesan (2006) reported 76 species of waterbirds in their yearly survey of waterbirds between 1987 and 2001, which was the only long term report available for this area.

Thiyagesan *et al.* (2009) recorded totally 105 bird species belonged to 12 different orders in the Pichavaram Mangrove area between 2004 and 2006 and in which 51 species were aquatic birds. Among 105 bird species 91 were recorded in the first year of study (2004-2005) and 14 more species were recorded in the second year of study (2005-2006). This study indicated that the mangroves are rich in migratory shorebird species. It is well established that waterbirds are specific in their choice of wetlands and show a spatial distribution based on wetland dynamics (e.g. Federickson and Reid, 1990; Skagen and Knopf 1993). This spatial pattern is often strongly associated with prey distribution and abundance (Kelsey and Hassall 1989; Sumathi *et al.* 2008). Shorebirds feed mainly on benthic invertebrates (van de Kam *et al.*, 2004), which show wide variation in density and diversity between wetlands. Even within wetlands, they often show a patchy distribution (Piersma *et al.*, 2005), and this may have led to some of the differences in shorebird abundance (Nagarajan and Thiyagesan, 1996).

Earlier, Kathiresan (2000) reported that the Pichavaram mangroves attracted 200 different species of birds which consisted of residents, local migrants and true migrants. At the mangroves, so far, 177 species of birds belonging to 15 orders and 41 families have been recorded (Sampath and Krishnamoorthy, 1989; 1990). The season for birds is from September to April every year. Peak population of birds could be seen from November to January. This is due to high productive nature (in terms of prey organisms) of the ecosystem and coincidence of the time of arrival of true migrants from foreign countries and local migrants from their breeding grounds across India. The availability of different habitat types such as channels, creeks, gullies, mud flats and sand flats and adjacent sea shore offers ideal habitats for different species of waterbirds.

The species richness (i.e. number of species present), of 50 species was recorded in 1987, which increased to a maximum of 63 in 1990 and then declined rapidly to a low of 23 in 2001 (Nagarajan and Thiyagesan 2006). Nagarajan and Thiyagesan (1998) found that adjoining croplands played an important role in attracting the birds to the Pichavaram mangroves. In addition the cyclone, developmental activities such as ecotourism, climate change affected the avian diversity in Pichavaram mangroves (Thiyagesan and Nagarajan, 1995, 1997; Nagarajan and Thiyagesan, 2006; Sandilyan *et al.*, 2008; Nagarajan, 2014).

The aquatic habitats are dynamic in nature, and the level of the substratum fluctuates rapidly within a day due to tide and the annual variations caused by precipitation and evaporation. Furthermore, the precipitation and evaporation influence physio-chemical properties of water and thus by habitat use of birds (e.g. Sayre and Rundle, 1984; Poysa, 1989; Rostogi and Pathk, 1990; Pandiyan *et al.*, 2006). In addition, Nagarajan and Thiyagesan (1996) emphasized that the habitat selection and changes in waterbird diversity are primarily influenced by prey availability and accessibility. Hence, it is inferred that the Pichavaram mangroves supports considerable avian diversity which was influenced by the season of the year, habitat characteristics and prey availability.

Our long term study focused on the avifaunal composition of Pichavaram mangrove wetlands indicated that within last two decades (i.e. from 1984-1988; and from 2004 to 2007) 40% of waterbird species richness declined in the area (Sandilyan *et al.*, 2010a). Nagarajan (2011) reviewed the fluctuations of wetlands and waterbirds of Tamilnadu and indicated that narrated that there was a decline in the area of wetlands and the waterbirds. Furthermore, the waterbirds showed preference for different microhabitats for various activities. For example, they preferred the agricultural lands for foraging and mangroves for roosting (Nagarajan and Thiyagesan, 1997). Hence, we narrate the role played by different factors on the population of avian diversity.

Factors Causing Population Dynamics of Waterbirds

Several factors were identified by different research as potential factors for causing the changes in the avifaunal diversity. Nagarajan (2011) grouped these factors into three different categories viz., Man-made factors, Man induced factors and Natural factors.

Man-made factors: The factors that are directly made by human which causes problems to avifaunal diversity and

survival. The factors are bird hunting and poaching, pollution of all kinds (water, air, soil, thermal, pesticide and ocean), accumulation of plastics and e-waste, cattle grazing, over-fishing, tourism and recreation, unsustainable development activities.

Man-induced factors: The factors which are being activated due to indirect effects of human activities such as habitat degradation, habitat loss, habitat alteration, conversion of land and changing land use pattern.

Natural factors: Factors which are naturally happen and affect the avifaunal diversity and survival which include natural disasters i.e. cyclone, storm, drought, acid rain, tsunami, etc.,

Among these, one of the major factors is freshwater scarcity and changes in the water quality of wetlands.

Water availability

All the wetlands are affected due to scarcity of water and alteration of watershed conditions. In addition, the changes occurred in the precipitation and restriction of spreading of rainfall across the season to few days. Hence, large quantity of water is being wasted to mix with sea, instead of the groundwater recharge. Furthermore, draining of wetlands and pumping of groundwater has depleted the ground water recharge and storage.

Reduction in Freshwater Discharge and its Impacts

The shortage of freshwater alters the quality of existing water bodies. The significant change is in the levels of ions and salinity. Salinity rise was noticed by many researchers in various wetlands. Most of the reports concluded that the freshwater recharge was considerably deprived which intern increase the salinity level in most of the wetlands. For example, salinity in the Pichavaram mangroves of Tamilnadu, Southern India ranges between 0.6 and 36.2‰ while in Muthupet mangroves (Tamilnadu) the ranges are from 5 to 47‰. In Sundarbans mangroves of West Bengal, salinity ranges from 0.4‰ to 27.5‰ and in west coast of India, the range is between 7‰ and 22‰. Even within, the mangrove different regions and microhabitats show variations in salinity. In addition, significant salinity fluctuations in adjoining habitats of Pichavaram mangroves were also reported (cited in Sandilyan et al., 2010b). Selvam (2003) reported that, freshwater recharge was considerably deprived in many of the Indian mangroves. Prior to 1980s the Pichavaram mangroves received 73 TMC (thousand million cubic feet) of fresh water form River Coleroon. By late eighties, it had decreased to 31 TMC, with a further depletion and reached to 3-5 TMC.

Conclusion

The population of the waterbirds declined drastically across the decades in terms of abundance and species richness. But the diversity was consistent and the values (H') indicated that the number of individuals distributed among the species was uniform. Some of the sensitive species such as Lesser sand plover (*Charadrius mongolus*), Yellow-wattled lapwing (*Vanellus malabaricus*), Little pratincole (*Glareola lactea*), Brown-headed gull (*Chroicocephalus brunnicephalus*), Black-headed gull (*Chroicocephalus ridibundus*), Herring gull (*Larus argentatus*), Pied Avocet (*Recurvirostra avosetta*), Ruddy Turnstone (*Arenaria interpres*), Dunlin (*Calidris alpina*), Curlew sandpiper (*Calidris ferruginea*), Temminck's stint (*Calidris temminckii*), Broadbilled sandpiper (*Limicola falcinellus*), Blacktailed godwit (*Limosa limosa*), Bartailed godwit (*Lomosa lapponica*), Eurasian Curlew (*Numenius arquata*), Ruff (*Philomachus pugnax*), Spotted redshank (*Tringa erythropus*), Common tern (*Sterna hirundo*), Little tern (*Sterna albifrons*), River tern (*Sterna aurantia*), Indian lesser crested tern (*Thalasseus bengalensis*), Large crested tern (*Thalasseus bergii*), White stork (*Ciconia ciconia*), Little heron (*Butorides striatus*), Indian reef heron (*Egretta gularis*), Chestnut bittern (*Ixobrychus cinnamomeus*), Black bittern (*Ixobrychus flavicollis*), Yellow bittern (*Ixobrychus sinensis*), Oriental Darter (*Anhinga melanogaster*), Lesser flamingo (*Phoenicopterus minor*), Greater flamingo (*Phoenicopterus roseus*), Little grebe (*Podiceps ruficollis*), Large Cormorant (*Phalacrocorax carbo*) and Little cormorant (*Phalacrocorax niger*) did not visit Pichavaram mangroves after early 90s. There were several factors identified as threats for waterbirds in this area. The most significant is the deprivation of freshwater flow to Pichavaram areas which completely changed the land use pattern and productivity of mangroves and the adjoining areas. The abandonment of agriculture due to lack of water in Pichavaram areas after mid 1990s, reduced the foraging grounds of waterbirds.

Acknowledgements

We are grateful to Management, Principal, and Head of Zoology of AVC College for providing the facilities and Mr. T. Karthik, Junior Research Fellow, A.V.C. College (Autonomous) for making the study area map.

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