May (when birds depart for their breeding grounds) in north-east Scotland. Assuming that fat loads in March are the same as the average 6.5% of total body mass in the Northumberland sample and that all the spring increase is fat, fat loads at spring departure would be approximately 21%, certainly sufficent for a flight to breeding grounds in northern Scandinavia or Iceland.

Confirmation of these patterns must, however, await information on the body condition of larger samples than those available to me. If anyone else has undertaken condition analyses of Purple Sandpipers I would be please to hear from them.

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SHOREBIRDS (CHARADRIIFORMES) OF THE PICHAVARAM MANGROVES, TAMIL NADU, INDIA

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INTRODUCTION

Of the different types of coastal wetlands, Mangroves are one of the most productive ecosystems (Parish 1987). Mangroves harbour many invertebrate and vertebrate species, and due to their high productivity and foliage could also provide food and roosting sites to a large number of species of birds. There is an extensive literature on the general importance of coastal wetlands. However, there have been only a few studies on the shorebirds of most Asian countries, although information on the population structure of shorebirds of Eastern Asia and Pacific region is available (Parish & Wells 1984, 1985; Howes *et al.* 1986; Parish *et al.* 1986, 1987). In India, population structure has been investigated by Ali (1981, 1986), Ali & Hussain (1981, 1982), Ali & Sugathan (1985) and Hussain *et al.* (1984). The Pichavaram mangroves, the shorebirds of which are dealt with in the present paper, is among India's notable mangroves, and is especially important as a wintering area for birds. Appreciable number of many species of birds annually migrate from arctic Siberia to wintering grounds in India *en route* passage to Australia.

Location of the study area

The Pichavaram mangroves (11°29'N; 79°49'E) is located on the south east coast of India (Bay of Bengal) near Chidambaram in South Arcot District of Tamil Nadu (Figure 1). This mangrove area also includes 50 islets scattered over an area of 11 000 ha. These islets are separated by intricate waterways, and gullies traversing the wooded portion of the mangroves. Freshwater drains into the canal from the irrigation system of the delta. Some of the islets are vegetated and others unvegetated.

Edaphic character of the mangroves

In these mangroves, the area of waterways comprised of about 40% and forest 50% of the total area. The remaining 10% is sand flats, mud flats and oyster beds (Krishnamurthy & Jeyaseelan 1983).

i) Sand flats

There are three flats each with an area of 1 ha. These flats are located near the sea (Figure 1). They are profusely sandy in nature

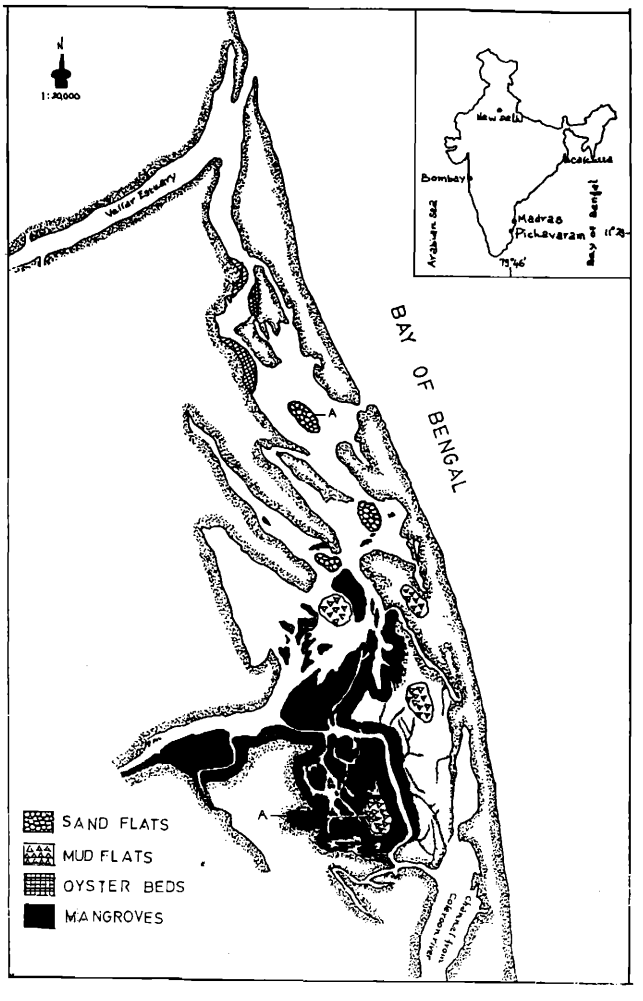

Figure 1. The study area in the Pichavaram mangroves in south-east India. A indicates the sandflat and the mudflat on which waders were counted regularly.

with submerged marine algae and are devoid of mangrove trees. They are influenced by the semidiurnal tides, being submerged during high tides and exposed during low tides; because of tidal action they remain wet throughout the year.

ii) Mud flats

There are four naturally formed mud flats in these mangroves (Figure 1). These mud flats are covered with sparse growth of *Suaeda* spp. and other vegetation. These mud flats used to have many mangrove trees. However, because of indiscriminate and illegal treefelling, all have now been cleared, except for a few around the periphery. These mud flats get ony rain water during monsoon periods (October - December). The water is retained until March or April depending upon the nature of the mud flats and rain. During monsoons these mud flats attract appreciable numbers of shorebirds.

iii) Oyster beds

There are three oyster beds of varying sizes found in the mangroves. Each bed spreads over an area of 1-2 ha. The oysters colonize the intertidal hard grounds and muddy creeks. Since these beds are located in the intertidal areas, they are used by shorebirds during low tides. There are four species of oysters recorded: *Crassostrea madrasensis, C. gryphoides, C. discoidea* and *Saccostrea cucullata*. These beds harbour sea weeds and macrobenthic organisms such as mussels, polycheates, amphipods, *Apseudes*, nematodes and other crustaceans in greater density.

Intertidal area and shore region

Muddy intertidal areas are found all along the waterways in the mangroves. These areas, during low tides, attract a good number of shorebirds.

Mangrove vegetation and its productive nature

In these mangroves about 20 species of typical mangrove vegetation have been recorded (Krishnamurthy *et al.* 1981). The most common species are *Rhizophora* spp. They are *Rhizophora apiculata, Rhizophora mucronata* and *Rhizophora lamarckii*. Of the three, the last one is a less common hybrid variety. They line both banks of the innumerable creeks and rivulets; with the stilt roots, these trees form an effective barrier and shelter myriads of organisms. The other common species of mangrove trees are *Avicennia marina, Bruguiera cylindrica* and *Exoecaria agallocha*. In recent times the species that are getting extinct are *Sonneratia* and *Xylocarpus* species.

Since the mangrove is situated closer to the sea, it enjoys tidal influence. A good mangrove forest needs a regular flow and mixture of freshwater, estuarine water and sea water. The average water depth of this mangrove is about 3 m. With the abundance of trees in the mangroves, the litter fall into the waterways is great and in turn increases nutrient input to the waterways. These nutrients support the growth of primary producers like phytoplankton and epiphytic algae, whilst secondary producers or consumers like zooplankton and benthic organisms are abundant. These macrobenthic organisms form the staple food for shorebirds. In the mangroves over 200 species of fishes, 20 species of prawns, 20 species of crabs and 35 species of molluscs have so far been recorded (Krishnamurthy & Jevaseelan 1983). All these attract a good number of various groups of birds.

Climatic factors

The annual precipitation in this area is about 1 300 mm. This area gets copious rain from October to December by northeast monsoons. However, there are well-known year-to-year vagaries of monsoons which affects rainfall patterns.

Availability of benthic organisms

Among the four habitats of the mangroves namely the sand flats, mud flats, oyster beds and intertidal areas (shore region), the sand flats have a highly productive macrobenthos. Commonly available macrobenthos in coastal areas are polycheates, gammarid amphipods, isopods (*Apseudes*), bivalves, gastropods, prawn larvae, crabs and fish fry. Chironomid larvae, which are seasonal and occur from November to March, are also available in the mud flats. On the sand flats *Apseudes* and polycheates were found abundantly. The density of benthos in the mangrove waterways varied from 2 000 to 15 000 organisms/m^2.

Bird counts and season

Regular visits and detailed counts of birds were done in one sand flat (A) and one mud flat (A) (Figure 1). However, the other areas were also visited but birds could not be counted. Using 10 x 50 binoculars birds were censused

Table 1. Population of shorebirds recorded at the two sites (one sand flat and one mud flat) of the Pichavaram mangroves from August 1986 to July 1987.

		August	September	October	November	December	January	February	March	April	May	June	July
Oystercatcher	*Haematopus ostralegus*	-	-	-	2	-	-	1	-	-	-	-	-
Blackwinged Stilt	*Himantopus himantopus*	450	680	785	2760	1950	860	140	15	-	-	-	-
Avocet	*Recurvirostra avosetta*	-	-	25	35	25	18	25	13	-	-	-	-
Stone Curlew	*Burhinus oedicnemus*	-	-	-	-	3	-	2	-	-	-	-	-
Great Stone Plover	*Esacus megnirostris*	-	-	-	-	2	1	-	-	-	-	-	-
Small Indian Pratincole	*Glareola lactea*	-	-	-	5	-	6	-	2	-	-	-	-
Red Wattled Lapwing	*Vanellus indicus*	-	-	25	38	45	25	33	24	28	19	12	15
Yellow Wattled Lapwing	*Vanellus malabaricus*	-	-	28	6	6	8	8	10	6	15	6	-
Grey Plover	*Pluvialis Squatarola*	-	35	65	175	220	180	190	-	11	8	-	-
Eastern Golden Plover	*Pluvialis dominica*	25	43	128	225	325	360	275	180	240	125	160	45
Large Sand Plover	*Charadrius leschenaultii*	-	-	-	-	2	-	4	-	-	-	-	-
Little Ringed Plover	*Charadrius dubius*	15	33	48	55	60	55	35	48	35	19	22	16
Ringed Plover	*Charadrius hiaticula*	-	1	-	-	-	1	-	-	-	-	-	-
Kentish Plover	*Charadrius alexandrinus*	18	35	44	65	75	92	85	60	42	22	15	8
Lesser Sand Plover	*Charadrius mongolus*	-	85	285	2385	2800	2650	2825	2150	625	-	-	-
Whimbrel	*Numenius phaeopus*	4	9	11	14	18	16	17	12	2	-	-	-
Curlew	*Numenius arquata*	6	6	7	12	5	6	8	15	-	-	-	-
Black-tailed Godwit	*Limosa limosa*	-	8	19	28	145	155	380	290	35	-	-	-
Bar-tailed Godwit	*Limosa lapponica*	-	2	2	4	12	8	12	-	-	-	-	-
Spotted Redshank	*Tringa erythropus*	-	-	6	-	-	2	1	4	-	-	-	-
Redshank	*Tringa totanus*	42	18	49	175	285	315	280	270	140	110	85	65
Marsh Sandpiper	*Tringa stagnatilis*	-	65	865	1675	2700	2960	2650	1860	25	8	-	-
Greenshank	*Tringa nebularia*	-	17	22	45	40	65	55	32	4	-	-	-
Green Sandpiper	*Tringa ochropus*	-	-	-	4	-	5	-	3	-	-	-	-
Wood Sandpiper	*Tringa glareola*	-	-	1	2	-	-	-	-	-	-	-	-
Terek Sandpiper	*Tringa terek*	1	4	6	6	15	6	8	-	-	-	-	-
Common Sandpiper	*Tringa hypoleucos*	2	6	12	18	25	18	28	12	6	-	-	-
Turnstone	*Arenaria interpres*	-	-	12	22	16	5	13	-	-	-	-	-
Asiatic Dowitcher	*Limnodromus semipalmatus*	-	-	-	-	3	-	2	-	-	-	-	-
Snipe	*Gallinago gallinago*	-	15	29	60	75	80	75	85	24	-	-	-
Little Stint	*Calidris minuta*	15	185	435	1845	2350	3340	3250	2725	420	125	155	28
Temminck's Stint	*Calidris temminckii*	-	-	8	-	4	15	6	-	-	-	-	-
Dunlin	*Calidris alpina*	-	-	15	65	160	85	120	140	20	-	-	-
Curlew Sandpiper	*Calidris testacea*	-	-	395	790	1430	2200	1920	1560	125	-	-	-
Broad-billed Sandpiper	*Limicola falcinellus*	-	-	95	165	125	175	85	45	-	-	-	-
Ruff	*Philomachus pugnax*	-	-	140	360	280	365	320	195	12	65	48	6

three days each month for a period of one year from August 1986 to July 1987. The census was undertaken between 06.00 and 10.00 hrs., by walking around the areas. The average number of the three counts per month was taken as the census figure. The number of birds counted in the two sites (sand flat and mud flat) are pooled and given in Table 1.

So far we have recorded 200 species of birds from these mangroves; among which 36 are shorebirds. The bird season lasts from September to March. The birds start arriving in small numbers from September onward. The arrival gathers momentum during October to reach a peak during November, lasting until January. During February and March birds start to leave the area.

Among the 36 species of shorebirds the most common species are the Little Stint *Calidris minuta*, the Curlew Sandpiper *Calidris testacea*, the Marsh Sandpiper *Tringa stagnatilis*, and the Black-winged Stilt *Himantopus himantopus*. However, some other species were also sighted over the mangrove area but their populations fluctuated widely (Table 1). Small populations of Eastern Golden Plover *Pluvialis dominica*, Redshank *Tringa totanus*, Little Stint *Calidris minuta* and Ruff *Philomachus pugnax* remain in these mangroves even during summer. Among the shorebirds a large majority are true migrant species. The only exceptions are Red-wattled Lapwing *Vanellus indicus*, Yellow-wattled Lapwing *Vanellus malabaricus*, Little Ringed Plover *Charadrius dubius* and Kentish Plover *Charadrius alexandrinus*. These residents breed in the mangroves and adjoining coastal areas.

Habitat preference by shorebirds

A distinct preference for certain habitats was shown by shorebirds. Species such as *Calidris minuta, Tringa stagnatilis, Charadrius mongolus* and *Himantopus himantopus* seem to prefer mud flats, where they were seen in large numbers. This could be because of the prevailing muddy substratum and the availability therein of their most preferred food items such as amphipods and chironomid larvae. However, in contrast, species such as *Calidris testacea, Numenius arquata, Numenius phaeopus* and *Limosa limosa* were seen abundantly on adjoining sand flats. This could be due to the greater availability of their most preferred food namely polycheates (*Nereis* spp.). Their long bills enable them to probe deep into sand in search of burrowing polcheates. However, although clear habitat preferences occur among the various species of shorebirds, when the sand flats are submerged during high tide all species flock together on the mud flats where they feed until the water recedes from the sand flats.

The food of shorebirds

It is apparent that the macrobenthos formed the staple diet of shorebirds. We collected polycheates, chironomid larvae, ostracods, *Apseudes*, amphipods, gastropods and bivalves from the foraging sites (sand and mud flats) of the shorebirds. It was not possible to investigate food selection by direct observation, so we collected and analysed droppings from foraging sites instead. It was very difficult to distinguish the droppings of different species. However, all thr droppings analysed contained macrobenthic remnants and the jaws of polycheates. This was further substantiated by gut analysis of Little Stint, Curlew Sandpiper, Marsh Sandpiper, Lesser Sand Plover and Redshank on the adjacent Vedaranyam Salt Swamp. In this study it was found that the five species had specific food preferences. Little Stints preferred feeding on chironomid larvae, Larsh Sandpipers on amphipods and Curlew Sandpipers on polycheates. The most preferred food of Lesser Sand plover were chironomid larvae and gastropods and for Redshank were amphipods and polycheates (Sampath *et al.* 1989).

Threat to the Mangroves

This mangrove was once extensive and has shrunk

considerably during the last few years because of excessive human pressure from many quarters. The indiscriminate and illegal tree felling still continues unabated. It is estimated that about 40% of the total tree stand has now been removed for fire wood, construction material and minor timber for fishing gears. In addition to the illicit felling, the mangrove trees are dying naturally because of the silting of the islets. Because of the dwindling nature of the mangrove, this area is now unable to bear the brunt of cyclonic storms and floods and hence erosion of the mangrove region is occurring. This leads to a shrinkage of the area of this mangrove. Floods are also eroding the bottom sediment which has the greatest density of the macrobenthic organisms, which form the staple diet of fishes and birds.

Grazing by cattle is also another serious problem. One of the victims for the grazing is *Avicennia marina*. Grazing causes stunted growth of this species. Indiscriminate collection of oysters (for lime production from their shells) leads to the depletion of the extent of the oyster beds. Also, juvenile fish and prawns are exploited by overfishing. This type of irrational fishing leads to loss of resources in the mangroves. Another serious threat to the mangrove is the proliferation of tourism. A huge number of tourists visit this mangrove every year. They engage boats and roam all over the mangroves. Their entry into the mangroves causes a great nuisance to the entire fauna and flora of this mangrove. Visits to the core area for birds is especially hazardous to the roosting and foraging birds.

CONCLUSION

Despite the above threats, this mangrove still maintains its ecological viability. Not only is there still great faunal and floral diversity, but also there is still a wealth of birds. There is a need to monitor the biological nature of the area and its conservation. Research on many aspects has been undertaken for over three decades by scientists from the Centre of Advanced Study in Marine Biology.

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