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S30-4 The effects of coastal shrimp farming on birds in Indian mangrove forests and tidal flats

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Abstract Large areas of mangroves in India are disappearing rapidly due to booming shrimp aquaculture along its coasts. Such losses, pollution and direct conflict with aquafarmers has resulted in a decline in the number and diversity of birds along the coastal wetlands of India. In the Pichavaram mangroves, species numbers have fallen from 30 in 1995 to 24 at present. At the Point Calimere sanctuary, the flamingo (*Phoenicopterus minor*) population has dropped from 20 000 to a mere 5 000 birds. The Sunderbans wilderness of West Bengal is being eroded by shrimp farms and its bird life is also declining. In brackish Pulicat Lake, north of Madras, the flamingo population has dropped from more than 10 000 to just 1 000 due to pollution of feeding grounds by shrimp farm effluents. In natural tidal flats on the Nagaipattinam and Karaikal coasts, the waterbird population of 45 species averages 400 per tidal flat, while in the areas adjacent to shrimp farms, only 9 species of birds were recorded at an average of 80 birds per similarly sized area. Analysis of data from the Asian Midwinter Waterfowl Census over the past 10 years also reveals negative impacts on coastal bird life after aquaculture expansion. Guidelines for the construction of aquafarms by the National Environmental and Engineering Institute of India (NEERI) and Coastal Authority of India, and rulings from the Supreme Court of India, could form the basis for redressing such impacts.

Key words Aquaculture, Birds, Mangrove, Tidal flats, Population, Interaction

1 Introduction

India has a long coastline of over 7 500 km, with numerous brackish water lakes, estuaries, lagoons and backwaters suitable for shrimp farming. Aquaculture underwent rapid growth worldwide between the 1970s and early 1980s, and expanded along the coasts of India during the 1990s. Global aquaculture production has been steadily increasing over the last decade, in a boom reflected in shrimp production figures for India which increased from 0.78 million mt in 1987 to 1.77 million mt in 1996 (126%), with a corresponding increase in value from US$ 0.83 billion to US $ 1. 98 billion (139%) (FAO, 1998). The major states in India where aquaculture is practiced are, in the order of importance: West Bengal, Gujarat, Andhra Pradesh, Maharahstra, Orissa, Kerala and Tamil Nadu. Traditional paddy cum shrimp farming continue to be carried out in West Bengal, Kerala, Karnataka and Goa over about 50 000 ha. The total area under cultivation rose from 65 100 ha in 1990–1991 to 141 837 ha in 1998–1999. Production rose similarly from 35 500 to 82 634 tonnes over the same period.

The increase in aquaculture in India has brought it into conflict with users of natural aquatic resources, and organizations concerned about its ecological effects. The report of an investigation by the National Environmental Engineering Research Institute (NEERI, 1995) of India found that many coastal aquafarms were not scientifically designed and located, resulting in excessive ecological and social damage that far exceeded economic benefits. Damage extended to the spread of brackish water, loss of potable water, loss of traditional fishing grounds for fishermen, and loss of mangrove ecosystems which provide both protection against cyclones and other natural hazards and natural habitat for spawning of natural biota (Reddy, 1995). Further, indiscriminate destruction of mangroves resulted in loss of natural breeding grounds for the shrimps themselves.

Satellite data from the National Remote Sensing Agency (NRSA) show the extent of mangrove destruction, revealing that less than 10% of mangroves survive in Gujarat today (Qasim, 2000). In coastal Andhara Pradesh, mangroves covering 4 411 ha and 5 884 ha in Guntur and Krishina areas respectively in 1973 declined to 3 454 ha and 5 479 ha in 1992 (Reddy, 1995). Large scale conversion of mangroves and agricultural lands to aquaculture has taken place along the sides of the Vellar and Coleron Rivers, and in and around Pichavaram and Muthupet (Ramachandran et al., 1998; Jayanthi and Ramachandran, 2000; Ravichandran and Ramachandran, 2001). According to a report from CIBA (1997), many potential wetlands of avian importance in the coastal districts of Tamil Nadu have been lost to shrimp farms.

In addition to the effects of waste released from aquafarms, the physical pressure of high biomass shrimp and human activity can interact with wildlife in a number of ways (Gowen and Rosenthal, 1993). Thus aquafarming has impacted on predatory birds in particular (Anon, 1988;

Whilde, 1990), attracting them with convenient sources of fish and shellfish, often close to natural wintering grounds (Pillay, 1992), and then destroying them as pests (Pillay, 1990). Bird predation on shrimp ponds is reported to have decreased production by about 75% in Texas, USA (Pillay, 1992). Cormorants, fish eagles, herons, and kingfishers are considered to be the most destructive; other groups of relevance are grebes, gulls, and terns (Stickley, 1990).

Birds can also transmit disease. Herons appear to be the final host for fish tapeworms (cestodes) and herons, gulls, grebes, and goosanders the final hosts for fish flukes (trematodes) which infect both wild and farmed fish in larval stages. Birds are mechanical carriers of viruses as well; and other pathogenic organisms, such as salmonellae, faecal colliforms and the bacterium *Edwardsia tarda*, might be transmitted through the contamination of water bodies by bird faeces. Grebes, fish-eating eagles and crows are thought to be agents for the white spot virus (systemic ecto-meso dermic bacculo virus — SEMBV) which caused extensive damage to the aquaculture industry along the coasts of Tamil Nadu and Andhra Pradesh in 1995.

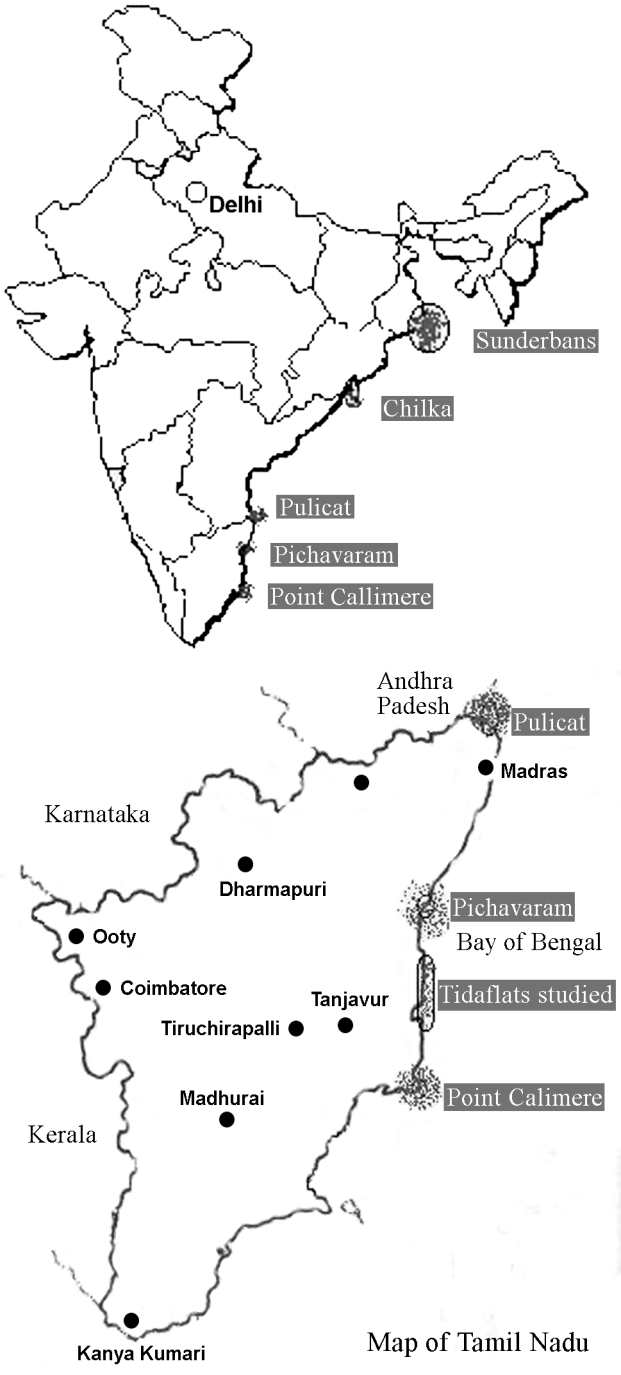

Fig.1 Map of India and Tamil Nadu showing study areas

Thus aquafarmers treat birds as pests and take measures to thwart them. Diverse deterrents are used, from antipredator nets to scaring devices, but those with most impact are entrapment and killing. Yet the greatest impact of aquafarming on birds is the disruption of natural habitat, however attractive it may be for opportunistic predatory species (Pillay, 1992). Accordingly, this paper examines the impacts of aquafarms on bird life along the east coast of India.

2 Materials and methods

Figure 1 shows areas of mangroves along the east coast of India discussed in this paper. Avian nomenclature follows Grimmett et al. (1999) except for the little green heron (*Butorides ardeola*) and herring gull (*Larus argentatus*) which are according to Ali and Ripley (1983). The data on waterbird populations in different wetlands was collected from various sources such as census and research reports (Perennou et al., 1990; Lopez and Mundkur, 1997), as well as dissertations and published papers. We also include our own field data from Pichavaram mangroves and adjacent wetlands, collected from 1989 on except between 1996–1999. Information on aquaculture, changes in land use pattern in the Pichavaram and Muthupet mangroves, and land reclaimed for aquaculture farming was collected from published papers.

The total number of birds present in the different wetlands was counted. The total number of species was also counted for estimations of species richness using the Shannon-Wiener diversity index (Shannon and Wiener, 1949) calculated by the formula

$$H' = - E\, p_i \log_e p_i$$

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

3 Results

Asian mid-winter waterbird census data from 1990 to

Table 1 Asian mid-winter waterbird census results from selected wetlands along the east coast of India in 1990 and 1995

Wetland	1990	1995
Pichavaram	12 299	5 559
Chembarambakkam	24 560	12 075
Kalyani Lake	2 777	893
Ballarpur Wildlife Sanctuary	5 663	2 640

Data from Perennou et al. (1990) and Lopez and Mundkur (1997).

2000 were analyzed, and the information from 1990, when aquaculture started to grow, was compared with that from 1995 for selected wetlands on the east Indian coast (Table 1). Over the 1990–1995 period, there has been a consistent decline in the number of waterbirds in each of those wetlands.

3.1 Avifaunal changes at the Pichavaram mangroves

Total numbers of birds rose from 5 156 in 1987 to 13 097 birds in 1992 but declined thereafter as the area under aquaculture increased (Fig. 2; Table 2). Shrimp farming peaked in 1995 and in that year 5 091 birds were recorded. By 2001, the bird population had fallen to a low of 1 278 individuals, followed by a slight increase in 2002. The number of species present (i.e., species richness) followed the same pattern. A total 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 (Fig. 2; Table 2).

Nagarajan and Thiyagesan (1998) found that adjoining croplands played an important role in attracting the birds to the Pichavaram mangroves. Aquafarm development, however, moved into them as well as the mangroves, requiring their assessment, together with adjacent abandoned fields, mudflats, marshes and open waters in the period between 1990 and 2001, based on Nagarajan (1990) with wetlands classified according to Nagarajan and Thiyagesan (1996). In 1990, bird density was highest at 105.63 individuals/ha in cropland but declined to 42.5/ha in 2001 (Table 3). There was reduction in waterbird density in all the habitats between 1990 and 2001, a trend most pronounced in the croplands.

3.2 Avifaunal changes in Point Calimere Wildlife Sanctuary

The total number of waterbird species at Point Calimere Wildlife Sanctuary (Fig. 1) between 1986 and 1999 is given in the Table 4. A total of 60 075 birds was present in 1986 which declined to 7 170 in 1999. Species richness was at 28 in all the years, but diversity indices declined from 1.0045 to 0.4582 between 1986 and 1999 (Table 4). The flamingo (*Phoenicopterus* spp.) population which usually consisted of around 20 000 individuals declined from 3 351 in 1986 to 350 in 1995.

3.3 Status of the Sunderbans mangroves

The Sunderbans wilderness of West Bengal, where the mangrove forest extends across 10 000 sq km (Fig. 1), is being eroded at its edges by the development of shrimp farms which have already reclaimed ca. 10 000 ha (Anon., 1993). According to Qasim (2000), the fish catch has been declining annually and this will affect endangered bird species. Tutu (2001) found that industrial shrimp cultivation is causing disturbance to migratory birds in the area.

3.4 Status of Pulicat and Chilka brackish water lakes

The Pulicat and Chilka lakes (Fig. 1) are important brackish water bird areas on the east coast of India. Both of them appear to be threatened by aquaculture expansion and there have been several incidences of conflict (Goss, 1992; Vivekanandan and Kurien, 1998; Anon, 1999; Mohanty, 1999; Noronha, 1999; Pearce, 1999; Pattnaik, 2000). The Asian Waterfowl Census 1994–1996 (Lopez and Mundkur, 1997) found that Chilika Lake, the largest brackish water body in India and a declared sanctuary and Ramsar Site, is being threatened by aquaculture. According to Patel (1996), the Pulicat Lake flamingo populations that numbered more than 10 000 in 1993 had declined to 1 000 in the following year due to pollution of their breeding grounds by aquafarm effluent.

3.5 Comparisons between bird populations on aquafarms and adjacent tidal flats

The avifaunal composition of seven mudflats along the east coast of Tamil Nadu — Mahenderapalli, Pazahayar, Thirumullaivasal, Chinnangudi, Tharangampandi, Karaikkal and Niravai — ranges from 146 birds to 795 birds on different mudflats; and the number of bird species ranges from 7 and 23, with a total richness of 45 species (Table 5). Bird species diversity indices range between 0.944 and 2.351. Avifaunal density in and around three selected areas containing three aquafarms in the midst of these mudflats are enlightening (J. Pandian, unpublished data). In 1999, the

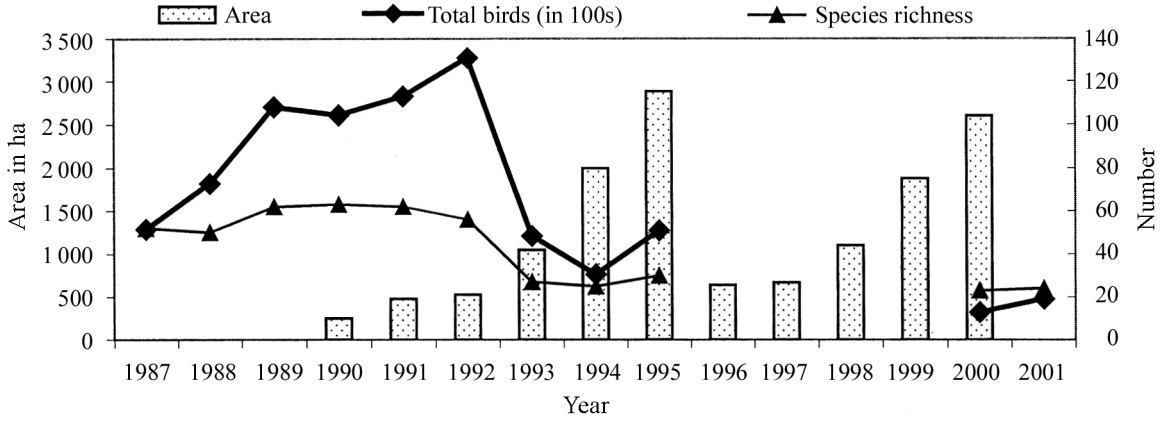

Fig. 2 Changes in bird numbers and species richness in the Pichavaram mangroves
The spotted bars indicate the area covered by aquaculture in Tamil Nadu across years.

Table 2 Waterbird population numbers in the Pichavaram mangrove forests, Tamil Nadu, between 1987 and 2001

Common name	Species	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2001
Gray heron	*Ardea cinerea*	15	33	45	48	39	52	12	2	18	2	6
Purple heron	*Ardea purpurea*	2	2	6	9	13	19	4	0	8	0	2
Indian pond heron	*Ardeola grayii*	90	240	105	72	85	0	1 600	1 100	1428	257	754
Great bittern	*Botaurus stellaris*	90	0	0	68	0	0	0	12	8	6	
Cattle egret	*Bubulcus ibis*	17	145	180	215	165	240	150	128	210	0	0
Little green heron	*Ardeola grayii*	35	0	0	0	0	0	22	48	56	6	14
Little heron	*Butorides striatus*	0	90	80	0	0	82	0	0	0	0	0
Western reef egret	*Egretta gularis*	14	18	15	25	18	32	0	0	0	0	0
Great egret	*Casmerodius albus*	6	80	40	22	28	47	182	58	162	48	63
Little egret	*Egretta garzetta*	135	375	450	415	380	415	1 250	898	1 300	359	520
Intermediate egret	*Mesophoyx intermedia*	65	290	160	140	160	315	0	0	0	0	0
Pacific reef heron	*Egretta sacra*	0	0	0	0	0	0	0	2	0	0	0
Cinnamon bittern	*Ixobrychus cinnamomeus*	4	6	6	0	0	0	0	0	0	0	0
Black bittern	*Dupetor flavicollis*	2	3	4	2	4	12	0	0	0	0	0
Yellow bittern	*Ixobrychus sinensis*	0	0	1	0	0	0	0	0	0	0	0
Black-crowned night heron	*Nycticorax nycticorax*	1 500	1 800	1 800	2 100	2 300	2 100	262	102	186	36	59
Asian openbill	*Anastomus oscitans*	30	18	377	43	46	17	68	52	182	158	163
White stork	*Ciconia ciconia*	19	0	5	8	17	38	0	0	0	0	0
Painted stork	*Mycteria leucocephala*	15	35	15	8	19	0	10	4	62	9	2
Crab-plover	*Dromas ardeola*	0	0	0	0	4	7	0	0	0	0	0
Small pratincole	*Glareola lactea*	0	15	6	3	5	0	0	0	0	0	0
Kentish plover	*Charadrius alexandrinus*	93	140	55	70	88	225	112	72	128	62	45
Little ringed plover	*Charadrius dubius*	35	85	70	95	120	170	220	180	316	109	0
Greater sand plover	*Charadrius leschenaultii*	7	0	6	4	6	9	12	0	18	0	0
Lesser sand plover	*Charadrius mongolus*	190	365	600	820	1 115	1 725	0	0	0	0	0
Pacific golden plover	*Pluvialis fulva*	165	180	215	280	190	220	0	0	0	0	0
Grey plover	*Pluvialis squatarola*	29	45	75	45	79	130	0	0	0	0	0
Red-wattled lapwing	*Vanellus indicus*	22	17	32	18	22	43	128	102	212	28	16
Yellow-wattled-lapwing	*Vanellus malabaricus*	6	0	0	8	0	31	0	0	0	0	0
Eurasian oystercatcher	*Haematopus ostralegus*	0	0	4	6	3	6	0	0	0	0	0
Pheasant-tailed jacana	*Hydrophasianus chirurgus*	0	0	5	0	0	0	0	0	0	0	0
Whiskered tern	*Chlidonias hybridus*	60	195	225	160	220	160	28	13	22	11	0
Gull-billed tern	*Gelochelidon nilotica*	37	85	160	95	130	185	8	0	12	0	0
Herring gull	*Larus argentatus*	130	28	80	50	45	24	0	0	0	0	0
Brown-headed gull	*Larus brunnicephalus*	835	160	150	225	190	230	0	0	0	0	0
Pallas's gull	*Larus ichthyaetus*	0	0	0	13	28	0	0	0	0	0	0
Black-headed gull	*Larus ridibundus*	145	49	85	125	180	150	0	0	0	0	0
Little tern	*Sterna albifrons*	40	45	94	90	110	96	68	49	122	28	52
River tern	*Sterna aurantia*	0	6	0	5	9	25	0	0	0	0	0
Lesser crested tern	*Sterna bengalensis*	0	0	0	120	0	0	0	0	0	0	0
Great crested tern	*Sterna bergii*	0	0	65	0	140	170	0	0	0	0	0
Caspian tern	*Sterna caspia*	0	17	15	30	47	55	42	18	47	18	0
Common tern	*Sterna hirundo*	75	130	95	65	110	140	0	0	0	0	0
Black-winged stilt	*Himantopus himantopus*	650	750	480	550	615	820	280	32	168	0	0
Pied avocet	*Recurvirostra avosetta*	15	19	15	8	14	26	0	0	0	0	0
Common sandpiper	*Actitis hypoleucos*	26	29	22	17	22	62	72	26	88	33	51
Ruddy turnstone	*Arenaria interpres*	0	4	28	15	6	0	0	0	0	0	0
Eurasian thick-knee	*Burhinus oedicnemus*	0	0	0	0	0	0	0	4	0	0	0
Dunlin	*Calidris alpina*	7	0	35	325	35	46	0	0	0	0	0
Curlew sandpiper	*Calidris ferruginea*	34	375	450	325	475	560	0	0	0	0	0
Little stint	*Calidris minuta*	250	680	2 800	2 250	2 415	2 600	124	87	186	50	62
Temminck's stint	*Calidris temminckii*	0	8	15	20	35	45	0	0	0	0	0
Common snipe	*Gallinago gallinago*	45	55	42	65	80	0	26	11	32	3	9
Broad-billed sandpiper	*Limicola falcinellus*	18	18	40	35	48	68	0	0	0	0	0
Asian dowitcher	*Limnodromus semipalmatus*	0	0	0	2	4	0	0	0	2	0	0
Bar-tailed godwit	*Limosa lapponica*	0	0	15	8	19	38	0	0	0	0	0
Black-tailed godwit	*Limosa limosa*	9	0	400	320	290	330	0	0	0	0	0
Whimbrel	*Numenius phaeopus*	25	35	42	25	36	57	0	0	0	0	0
Eurasian curlew	*Numenius arquata*	17	28	30	38	43	0	0	0	0	0	2
Ruff	*Philomachus pugnax*	35	0	250	127	95	155	0	0	0	0	0
Spotted redshank	*Tringa erythropus*	0	0	6	0	0	26	0	0	0	0	0
Wood sandpiper	*Tringa glareola*	20	0	22	6	11	39	16	8	10	0	0
Common greenshank	*Tringa nebularia*	0	42	25	20	18	22	0	0	0	25	15
Green sandpiper	*Tringa ochropus*	33	0	0	7	15	0	64	48	58	24	33
Marsh sandpiper	*Tringa stagnatilis*	45	275	550	620	715	840	25	16	18	2	14
Common redshank	*Tringa totanus*	63	155	85	115	65	85	58	0	14	0	6
Terek sandpiper	*Xenus cinereus*	0	8	7	15	9	8	0	0	0	0	2
Great thick-knee	*Esacus recurvirostris*	0	0	0	2	0	4	0	0	0	0	0
Little grebe	*Tachybaptus ruficollis*	0	0	25	0	0	0	0	0	0	0	0
Darter	*Anhinga melanogaster*	4	2	0	3	0	0	0	0	0	0	0
Great cormorant	*Phalacrocorax carbo*	6	18	0	0	0	0	0	0	0	0	0
Little cormorant	*Phalacrocorax niger*	17	2	30	15	3	8	0	0	0	0	0
Lesser flamingo	*Phoenicopterus minor*	6	0	28	0	0	0	0	0	0	0	0
Greater flamingo	*Phoenicopterus ruber*	13	0	0	28	24	36	0	0	0	0	0
Eurasian spoonbill	*Platalea leucorodia*	0	0	22	31	26	29	0	0	0	0	0
Black-headed ibis	*Threskiornis melanocephalus*	0	0	23	9	11	23	0	0	14	2	8
Total birds		5156	7290	10813	10435	11292	13097	4843	3060	5091	1278	1904
Species richness		52	50	62	63	62	56	27	25	30	23	24
Diversity index (H')		2.684	2.921	2.885	2.888	2.858	2.949	2.207	2.016	2.376	2.296	1.900

overall number of birds ranged from 62 to 115. Only six different species of waterbirds and three of terrestrial birds — *Milvus migrans*, *Haliaster indus*, and *Halcyon smyrnensis* — were observed on the farms; bird species diversity indices ranged between 1.389 and 1.896. Thirty-three species of aquatic birds present on the mud flats were not recorded on adjacent aquafarms.

4 Recommendations

The data reported here indicate clearly that extensive alienation of mangrove and other coastal wetlands has resulted in a marked quantitative and qualitative fall in bird numbers and diversity along the east coast of India. Towards redressing the trend, a number of observations and recommendations are pertinent.

The shrimp farming industry needs to seriously consider its effects on the environment. This, in general, should include better planning and management of coastal aquaculture developments, integrated coastal area management (ICAM), implementation of Environmental Impact Assessments (EIA) recommendations, monitoring of pollution, and environmental legislation. For shrimp culture, in particular, these measures include management of pond effluents, regulation of species introductions and chemical use, and rehabilitation of wild habitats and populations.

Detailed guidelines have been issued for the construction of farms by the National Environmental and Engineering Research Institute of India, the Coastal Authority of India and the rulings of the Supreme Court of India. These offer a base for the integrated use of coastal wetlands by people, birds and the environment. The goal of this plan, Integrated Coastal Area Management or ICAM, is to ensure sustainable use of coastal natural resources, maintenance of biodiversity and conservation of critical habitats by coordinating the initiatives of various economic sectors toward long-term optimal socio-economic outcomes, including resolution of conflicts (Clark, 1992). In addition to aquaculture, there are multiple users of the coastal zone, including urban settlement, industrial development, waste disposal, ports and marine transportation, fisheries, forestry and tourism. All are implicated in the ICAM plan.

Table 3 Waterbird densities (no./ha) in different habitats at Pichavaram, Tamil Nadu, in 1990, 2001 and 2002

Habitat	Year		
	1990[a]	2001[b]	2002[b]
Agricultural land	105.63	44.38	42.5
Abandoned field	21.5	22.0	18.0
Mudflats	7.13	8.25	3.0
Swamps	18	4.50	6.0
Marshy areas	8.25	4.50	5.25
Open waters	24.75	10.50	18.75

[a] Data from Nagarajan (1990); [b] Nagarajan, unpublished data

For mangrove areas in particular, priorities can be designated now (Bird and Kunstadter, 1986):

a) preservation-conservation for biodiversity and ecological function, including natural exchanges and storm buffering;

b) sustained yield of fisheries and silviculture;

c) reforestation; and

d) conversion to culture ponds, salt beds etc., preferably on previously altered sites.

Land use mapping of the entire coast is urgently needed, followed by on-the-spot assessment of bird use of each and every coastal wetland, for designing a coastal management plan to conserve both avian diversity and enable sustainable aquaculture.

Environmental Impact Assessments (EIA) are required to ensure compliance with site selection criteria that include not only standard grow-out parameters such as salinity and land elevation, which treat the farm as an isolated unit, but also the potential effects on the environment including wildlife.

Integrated programs are needed to manage mangrove vegetation to maintain functions such as storm protection, and nutrient/particulate export to near-shore communities. Remaining mangroves should be conserved and there should be enforcement of existing legislation that prohibits further conversion and allows for greenbelt areas. Abandoned ponds should be allowed to regenerate back to mangroves by breaking down dikes. Large-scale reforestation should be undertaken in severely degraded areas. Lessons can be learned from the experience of Bangladesh where a total of 120 000 ha have been afforested since 1966 to protect and stabilize coastal areas from cyclone damage (Saenger and Siddiqi, 1993). These mangroves can be managed silviculturally to produce up to $11 000/ha/yr (Primavera, 1993). Integration of forestry, fisheries and aquaculture in mangrove habitats has also taken place in the *tambak tumpang sari* of Indonesia (Naamin, 1986) and traditional mangrove-shrimp ponds in Vietnam.

Concerning management of pond effluents, intensive aquaculture has been recommended as an alternative to

Table 5 Comparison of water bird abundance, richness and diversity from seven mudflats on the east coast of Tamil Nadu

Locality	Total birds	Species richness	Diversity index
Mahendrapalli	343	18	1.7705
Pazhayar	146	15	2.0883
Thirumullaivasal	570	24	2.1349
Chinnangudi	795	14	1.7711
Tharangambadi	414	8	0.9439
Karraikkal	610	19	1.9618
Niravi	239	17	2.3799
Total	3 117	45	2.3596

From J. Pandian, unpublished data.

Table 4 Total counts of waterbird species at Point Calimere Wildlife Sanctuary, Tamil Nadu, in 1986, 1998 and 1999

Common Name	Species name	1986[a]	1998[b]	1999[b]
Grey heron	*Ardea cinerea*	235	64	20
Indian pond heron	*Ardeola grayii*	0	0	45
Cattle egret	*Bubulcus ibis*	0	61	0
Great egret	*Casmerodius albus*	6	18	299
Little egret	*Egretta garzetta*	307	0	296
Pacific reef egret	*Egretta sacra*	12	0	2
Black-crowned night heron	*Nycticorax nycticorax*	0	1	0
Kentish plover	*Charadrius alexandrinus*	856	0	0
Asian openbill	*Anastomus oscitans*	0	31	26
Painted stork	*Mycteria leucocephala*	1 017	1 018	156
Little ringed plover	*Charadrius dubius*	0	31	207
Greater sand plover	*Charadrius leschenaultii*	0	2	0
Lesser sand plover	*Charadrius mongolus*	394	0	0
Grey plover	*Pluvialis squatarola*	0	3	2
Pacific golden plover	*Pluvialis fulva*	2	7	0
Red-wattled lapwing	*Vanellus indicus*	0	2	14
Ruddy turnstone	*Arenaria interpres*	92	0	0
Whiskered tern	*Chlidonias hybridus*	109	0	0
Gull-billed tern	*Gelochelidon nilotica*	11	0	5
Caspian tern	*Sterna caspia*	604	8	4
Little tern	*Sterna albiforns*	643	972	153
River tern	*Sterna aurantia*	0	34	101
Common tern	*Sterna hirundo*	330	1 363	858
Black-headed gull	*Larus ridibundus*	0	24	0
Herring gull	*Larus argentatus*	90	4	0
Brown-headed gull	*Larus brunnicephalus*	0	525	5
Black-winged stilt	*Himantopus himantopus*	19	0	92
Avocet	*Recurvirostra avosetta*	2	0	0
Common sandpiper	*Actitis hypoleucos*	0	199	90
Curlew sandpiper	*Calidris ferruginea*	4 437	0	20
Little stint	*Calidris minuta*	46 666	237	4 184
Broad-billed sandpiper	*Limicola falcinellus*	9	0	0
Bar-tailed godwit	*Limosa lapponica*	0	0	3
Eurasian curlew	*Numenius arquata*	1	13	19
Common greenshank	*Tringa nebularia*	55	0	57
Marsh sandpiper	*Tringa stagnatilis*	21	425	3
Common redshank	*Tringa totanus*	351	51	17
Wood sandpiper	*Tringo glareola*	0	15	0
Terek sandpiper	*Xenus cinereus*	2	0	0
Spot-billed pelican	*Pelecanus philippensis*	89	14	13
Flamingos	*Phoenicopterus* spp.	3 351	250	350
Eurasian spoonbill	*Platalea leucorodia*	364	46	129
Black-headed ibis	*Threskiornis melanocephalus*	0	7	0
	Total birds	60 075	5 451	7 170
	Species richness	28	28	28
	Diversity index (*H*')	1.0045	0.4195	0.4582

a = Data from Sankar (1989).
b = Unpublished data from Tamil Nadu Forest Department Census Records.

extensification that would exploit wide mangrove areas. Such intensification, however, will only be viable if pollution levels in effluents are minimized and salinization of outlying areas prevented.

A research and information network is an ongoing imperative to coordinate research effort for mangrove evaluation and delineation of greenbelts, and to determine impacts of exotic species on biodiversity, common methodologies for evaluating environmental impact, nutrient requirements of species and quality standards for feeds, and impacts of drugs and chemicals (Briggs, 1993; FAO/NACA, 1994). The information network should include exchange of technicians and sharing of technology and experience gained in other areas, such as mangrove reforestation in Bangladesh, mangrove silviculture in the Matang Forest of Malaysia and shrimp restocking in Japan.

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