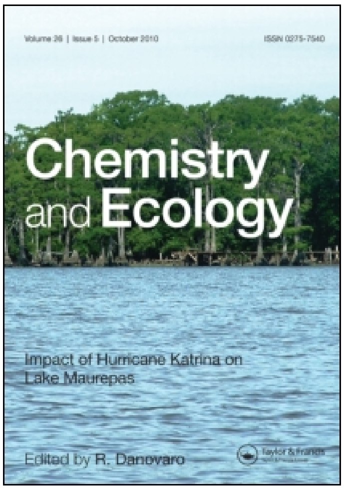

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ORGANOCHLORINE RESIDUES IN THE AVIFAUNA OF TAMIL NADU (SOUTHEAST COAST OF INDIA)

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Pollution due to persistent pesticides is not a regional but a global problem. Organochlorine pesticides are persistent chemicals, stored and accumulated in the tissues of a wide variety of invertebrates and vertebrates including marine species. In the present study the organochlorine residues HCHs, DDTs and PCBs were measured in different trophic groups of birds (scavengers, inland piscivores, coastal piscivores, insectivores, granivores and omnivores) collected from Tamil Nadu Coast, India. The residue accumulation as a function of sex did not depict distinct variation. However, females had lower residue levels than males in terms of their mean weight and feeding habits. A continuous monitoring programme is recommended to establish the studied organisms as indicator species.

Keywords: Organochlorines; Avifauna; Tamil Nadu Coast; India

1 INTRODUCTION

Environmental contamination from persistent organochlorines has been recognised as a threat to wildlife for more than two decades. Many of such residues have been found in tissues and eggs of birds in Europe and North America even three or four decades ago (Eades, 1966; Robinson and Roberts, 1968; Turner *et al.*, 1978). It has been well documented and also generally accepted that the environmentally persistent chlorinated hydrocarbons occur throughout terrestrial (Fishbein, 1972; Kaphalia and Seth, 1981) and aquatic ecosystems (Jensen *et al.*, 1969; Portmann, 1975; Tanabe *et al.*, 1984; Berg *et al.*, 1992) including polar regions (Sladen *et al.*, 1966; Risebrough *et al.*, 1976; Subramanian *et al.*, 1986; Wania and Mackay, 1993). In recent years, the concern regarding organic pollution in the aquatic environment is increasing as the modern technology, agriculture and associated developments of chemical industries have resulted in the production and release of vast quantities of man-made chemicals. Though the modern developments contribute to the improvement of our standard of living, some persistent chemicals pose serious environmental problems.

Organochlorine compounds (OCs) such as PCBs, DDTs (DDT, DDE, and DDD) and HCHs (α, β, γ and δ HCHs) are among the most widely known class of contaminants because of their ubiquity, potential for magnification in the food chain and harmful biological effects.

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These pollutants are also known to be transported to organisms of higher trophic levels through food chain. Organochlorines in different environmental and biotic components of coastal environment have also been widely studied (Rajendran, 1984; Shailaja and Sen Gupta, 1990; Takeoka *et al.*, 1991; Ramesh *et al.*, 1992; Tanabe *et al.*, 1993; 1998). Organochlorines were found to be accumulated in terrestrial (Frank *et al.*, 1977; Fimreite *et al.*, 1982; Elliot *et al.*, 1988; Boumphrey *et al.*, 1993) and aquatic birds (Bourne and Bogan, 1972; Ohlendorf *et al.*, 1974; Dubrawski and Falandysz, 1980; Subramanian *et al.*, 1986; Pearce *et al.*, 1989; Ramesh *et al.*, 1992).

DDTs and BHCs are widely distributed in all biological systems. Although BHC residues are excreted rapidly by birds (Koransky *et al.*, 1964), slow accumulation does occur in body tissues and body fat on chronic exposures. DDT and their derivatives are quite stable and are resistant to enzymatic action and so their residues accumulate in biological tissues. The general tendency is that the smaller animals have higher ratios of food consumption per unit weight, regardless of food habits. Thus, within the group of same food habit group, smaller individuals are likely to ingest larger amounts of food and hence more pesticide residues. Age and body sizes of the species are also important in influencing the accumulation of pesticide residues. However, understanding about food habits and food chain are important to determine the total body burden of pesticide residues. DDTs and their metabolites show consistent biomagnification in wild birds, presumably through the food-chain concentration. DDT levels present in birds are perhaps a reflection of the environmental status of the habitat and food choices of particular avian species.

The main sources of pesticide residues to the coastal environment of the Bay of Bengal at Mandapam, Muthupet, Pichavaram and Parangipettai are agriculture, shrimp farming, domestic and industrial wastewater drainage. HCHs (1,2,3,4,5,6-hexachlorocyclohexane isomers) and DDTs (1,1,1-trichloro-2,2′-bis *p*-chlorobiphenyl ethane) are the two major pesticides used in India for agricultural and vector control purposes, constituting nearly 90% of the total consumption of pesticides in India (Ray *et al.*, 1985). PCBs (Polychlorinated biphenyls) are now widely used in the industries in India (Tanabe *et al.*, 1984). It is therefore necessary to quantify the amount of these toxic chemicals in the tissues of birds because even a slight excess of such toxicants may produce deleterious effects on birds, which are already under enormous stress. Since birds are the integral part of the biosphere with a wide range of activities and are exposed to persistent contaminants, an attempt has been made to study the distribution and levels of DDTs, HCHs and PCBs in the residential and migratory birds collected from different locations in Tamil Nadu coast, India.

2 MATERIALS AND METHODS

Birds representing six groups (scavengers, inland piscivores, coastal piscivores, insectivores, granivores and omnivores) based on their habitats and feeding habits were collected in and around Parangipettai, mangrove areas of Pichavaram and Muthupet and coastal environment of Mandapam (Fig. 1) Immediately after collection, biometric data were recorded as summarised in Table I. Liver and muscle tissues were removed and stored in deep freezer for further analysis.

2.1 Processing of Samples for Analysis

Extraction and quantification of the HCH (BHC) isomers α (Alpha), β (Beta), γ (Gamma), δ (Delta), DDT and its metabolites (*o,p*′-DDT, *p,p*′-DDT and *p,p*′-DDE) and PCBs were

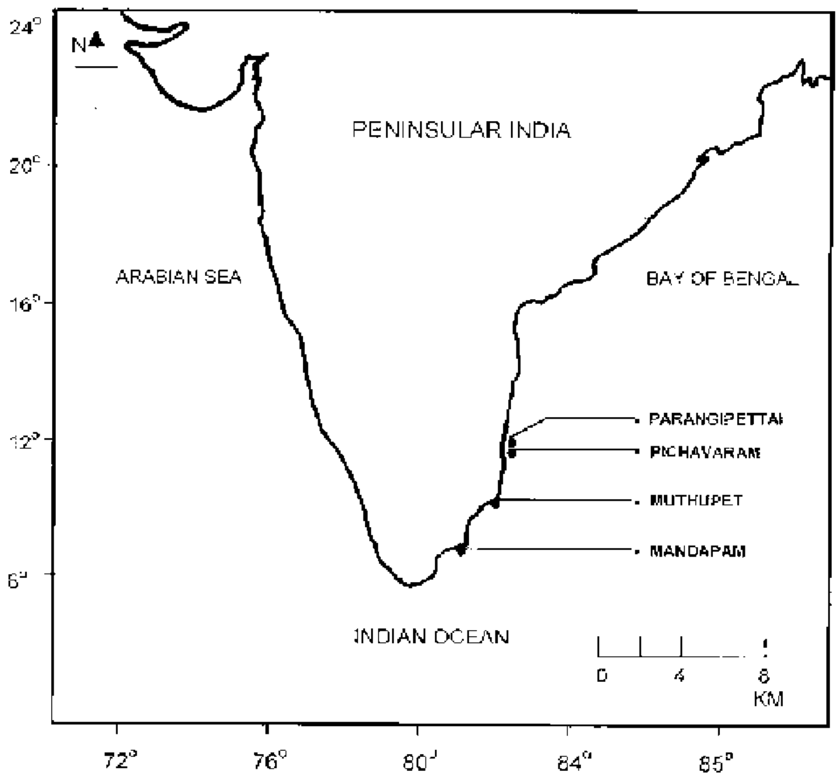

FIGURE 1 Sampling area and location of the sampling stations.

carried out following the methods of Tanabe *et al* (1993). Each sample weighing 25–30 g was homogenised with anhydrous sodium sulphate to remove the moisture. This homogenous mixture was subjected to Soxhlet extraction for 7 hours in a mixture of 300 ml diethyl ether and 100 ml *n*-hexane. The extract was made up to a required volume and a known quantity was used to estimate the extractable fat content. The remaining extract was concentrated to 5 ml in a KD (Kuderna–Danish) evaporator. The concentrate was added on to 20 g of florisil packed in a glass column (15 mm i.d. × 260 mm length). Organochlorine compounds absorbed to the florisil were eluted using a mixture of 120 ml acetonitrile and 30 ml hexane. The eluate was thoroughly shaken in a separatory funnel containing 600 ml water and 100 ml hexane. After partitioning, the hexane layer containing the organochlorines was washed with water, concentrated to 5 ml and added on 1.5 g of silica gel packed in a glass column (12 mm i.d. × 300 mm length). During fractionation, the first fraction eluted with 180 ml of *n*-hexane contained the PCBs and *p,p′*-DDE, and the second fraction eluted with a mixture of 20 ml dichloromethane and 80 ml *n*-hexane contained the HCH isomers, *o,p′*-DDT, *p,p′*-DDD and *p,p′*-DDT. Each fraction was concentrated, cleaned with 5 ml of 5% fuming sulphuric acid in concentrated sulphuric acid to remove interfering substances and then washed with hexane – washed water.

2.2 Quantification of Residues

Quantification of HCH isomers and DDT and its metabolites was performed by injecting the aliquots of the final extracts into a gas chromatograph (Hewlett Packard Model 5890 – Series II)

TABLE I Biometry of Birds Collected from the Study Areas.

S. no.	*Name of the species*	*Sex*	*Sampling site*	*Weight (g)*	*Total body length (mm)*	*Wing (mm)*	*Tail (mm)*	*Bill (mm)*	*Tarsus (mm)*
1	Little cormorant	1M + 2F	3	150–210	240–270	110–180	50–70	25–33	10–20
2	Pond heron	2M + 1F	4	155–236	280–410	100–185	80–110	69–80	18–25
3	Cattle egret	1M + 1F	4	139–165	220–298	120–170	70–55	22–29	13–26
4	Large egret	2M + 1F	4	290–350	210–320	90–120	45–51	28–32	15–20
5	Little egret	1M + 1F	4	185–210	75–95	30–40	10–15	8–10	9–12
6	Indian reef heron	1M + 2F	3	290–450	350–410	180–240	40–60	11–15	8–10
7	Smaller egret	1M + 1F	2	190–310	110–150	40–70	10–20	5–8	6–10
8	Black winged kite	1M + 1F	4	160–250	140–170	50–70	10–15	5–7	4–6
9	Pariah kite	1M + 1F	4	150–190	80–110	30–50	5–10	3–6	2–4
10	Brahminy kite	1M + 1F	4	250–340	250–360	90–110	10–20	5–8	10–15
11	Grey partridge	1M + 2F	4	150–180	110–160	30–50	5–7	3–6	6–8
12	Black-winged stilt	2M + 1F	2	190–250	150–240	110–170	65–75	10–12	10–15
13	Red wattled lapwing	1M + 1F	2	210–240	180–250	70–90	10–15	5–7	8–10
14	Kentish plover	1M + 1F	1	100–150	150–190	50–70	8–15	5–10	6–12
15	Little ringed plover	1M + 1F	1	110–130	150–170	60–80	5–10	3–5	4–8
16	Black tailed godwit	1M + 1F	1	160–190	190–250	90–110	30–50	10–15	15–20
17	Common redshank	1M + 1F	1	55–97	90–110	40–70	5–10	3–5	2–4
18	Marsh sandpiper	1M + 1F	1	90–110	180–240	110–155	10–20	5–10	3–5
19	Green shank	1M + 1F	1	160–195	170–210	40–70	20–30	6–10	4–5
20	Green sandpiper	1M + 1F	1	190–210	110–175	35–55	5–10	3–5	6–8
21	Wood sandpiper	1M + 1F	4	68–70	210–230	140–155	10–20	25–38	15–30

22	Common sandpiper	1M + 2F	3	129–150	210–265	180–240	40–70	20–50	25–48
23	Fantail snipe	1M + 1F	4	110–150	80–110	45–55	5–10	3–5	2–4
24	Herring gull	1M + 1F	1	186–207	150–210	90–130	10–20	10–23	10–20
25	Brown headed gull	1M + 1F	1	210–250	140–180	30–70	8–15	50–80	15–30
26	Black headed gull	1M + 1F	1	190–290	170–240	60–90	10–15	40–50	10–20
27	Blue rock pigeon	2M + 1F	4	210–250	130–180	80–110	30–50	10–15	45–50
28	Indian ring dove	1M + 1F	2	290–310	190–240	90–120	40–70	10–30	8–10
39	Spotted dove	1M + 1F	3	210–290	140–170	30–50	10–20	15–20	10–12
30	Lesser pied kingfisher	1M + 1F	3	260–310	160–210	40–80	50–90	30–50	10–30
31	Common kingfisher	1M + 1F	3	290–330	60–80	10–30	10–40	50–60	10–15
32	White-breasted kingfisher	1M + 1F	3	210–250	110–170	40–70	15–30	40–60	12–18
33	Green bee eater	1M + 2F	4	160–180	75–125	110–145	75–100	50–138	10–15
34	Indian roller	1M + 1F	4	150–230	190–250	110–140	70–130	50–70	12–17
35	Black drongo	2M + 1F	3	125–170	110–140	65–85	50–75	5–8	6–10
36	Treepie	1M + 1F	3	110–190	150–200	75–90	35–45	10–20	8–12
37	House crow	2M + 1F	4	120–150	130–170	65–85	10–15	5–7	4–6
38	Jungle crow	2M + 1F	4	120–140	110–180	55–60	5–10	4–6	5–7
39	Redvented bulbul	1M + 1F	4	70–100	20–30	10–15	3–5	2–3	3–6
40	White browned bulbul	1M + 1F	3	60–70	50–70	25–30	5–10	2–5	2–4
41	Common babbler	1M + 1F	3	150–170	30–50	10–40	5–8	2–4	4–6
42	Tailor bird	1M + 1F	4	130–180	50–80	10–20	5–10	5–8	3–7
43	Magie-robin	1M + 1F	4	70–100	30–50	10–30	3–5	2–4	1–3
44	Indian robin	1M + 1F	2	60–70	30–40	40–60	10–20	3–5	5–7
45	White wagtail	1M + 1F	3	40–50	70–90	25–35	5–10	3–9	5–10
46	Purple sunbird	1M + 1F	2	50–70	10–20	5–8	2–4	2–3	3–5
47	House sparrow	1M + 2F	4	30–50	8–10	4–9	2–3	1–2	1–3

Note: M, Male; F, Female; 1. Mandapam; 2. Muthupet; 3. Pichavaram; 4. Parangipettai.

equipped with ^{63}Ni electron capture detector (GC-ECD). Glass columns (2 mm i.d. × 1.8 m length) packed with any one of the following was employed (packed columns).

1. 3% OV-1 WHP 100/120
2. 3% OV-25 WHP 100/120
3. 3% OV-225 WHP 100/120

2.3 The Operating Conditions of the GC were as Follows

The temperature of injector and detector were 275 and 300°C, respectively. Column temperature was 185 °C held for 15 minutes and programmed to rise at the rate of 2 °C min^{-1} to 215 °C and held for 10 minutes. Nitrogen (IOLAR Grade I) was used as the carrier gas at a flow rate of 30 ml per minute. Standard mixtures and fortified samples were frequently used to check the accuracy. Organochlorine insecticide residues were quantified by comparing the individually resolved peak heights with those of the corresponding peak heights of the standards, which were obtained from Ultra Scientific Co., USA.

PCBs in birds samples were quantified by a GC equipped with ^{63}Ni electron capture detector. The column consisted of fused silica (025 mm i.d. × 25 ml length) with chemically bonded silicone OC-101. Column temperature was 140 °C held for 2 minutes and programmed to rise at rate of 15 °C min^{-1} to 230 °C and held for 5 minutes. Nitrogen was used both as a carrier and make-up gas (flow rate about 1.5 ml min^{-1}). Total PCB concentrations in the bird samples were calculated by adding concentrations of the individually resolved peaks of different PCB isomers and congeners. The recovery efficiency varied between 89–93%. Results were recorded on wet weight basis and not corrected for recovery.

3 RESULTS AND DISCUSSION

The concentrations of major organochlorine residues (HCHs – α, β, γ and δ isomers, DDTs – sum of *p,p′*-DDE, *p,p′*-DDD, *o,p′*-DDT and *p,p′*-DDT and PCBs) in the bird tissues are shown in Table II. Concentrations of HCHs ranked first among all the three-organochlorine residues followed by DDTs and PCBs. In general, levels of HCHs were higher than DDTs in most bird species whereas concentrations of PCBs were lower than those of HCHs and DDTs. Higher levels of HCHs in birds could be ascribed to exposure of these birds to HCH contaminated food. Interestingly, Black headed gull (*Larus ridibundus*), Brown headed gull (*Larus brunnicephalus*), Herring gull (*Larus argentatus*) and Indian reef heron (*Egretta gularis*) had higher levels of DDTs than the Black winged kite (*Elanus caeruleus*), Pariah kite (*Milvus migrans*) and Brahminy kite (*Haliastur indus*).

According to feeding habits of the birds, the accumulation pattern of HCHs can be summarised as follows:

Scavengers > Inland piscivores > Coastal piscivores > Insectivores > Omnivores > Grainvores

DDTs showed the following different pattern of accumulation:

Coastal piscivores > Scavengers > Insectivores > Omnivores > Inland piscivores > Grainvores

TABLE II Concentrations (ng g^{-1} wet wt.) of Organochlorine (Mean ± SD) in Indian Wild Birds of Different Feeding Habits (*n*).

Trophic group (n)	*Fat (%)*	*HCHs*	*DDTs*	*PCBs*
Scavengers: Black winged kite, Pariah kite and Brahminy kite (6)	4.01 ± 1.31	1895.91 ± 1325.65	707.67 ± 362.52	88.49 ± 63.15
Inland piscivores: Little cormorant, Pond heron, Cattle egret, Large egret, Little egret, Smaller egret, Lesser pied kingfisher, Common kingfisher and White breasted kingfisher (21)	4.27 ± 2.11	1119.36 ± 754.16	161.18 ± 67.12	42.35 ± 19.51
Coastal piscivores: Indian reef heron, Herring gull, Black headed gull, Brown headed gull (9)	7.24 ± 4.74	989.53 ± 547.79	722.42 ± 481.15	75.34 ± 48.60
Insectivorous: Green bee eater, Indian roller, Black drongo, Purple sunbird, Marsh sandpiper, Green shank, Green sandpiper, Wood sandpiper, Common sandpiper and Fantail snipe (23)	3.53 ± 1.36	289.79 ± 168.88	399.88 ± 213.01	49.48 ± 19.64
Grainvores: Blue rock pigeon, Indian ring dove and Spotted dove, Red vented bulbul, White browned bulbul, Common babbler, Tailor bird, Magie robin, Indian robin and White wagtail (21)	2.96 ± 0.65	55.22 ± 24.37	39.62 ± 18.21	36.56 ± 13.43
Omnivores: Grey patridge, Black-winged stilt, Red wattled lapwing, Kentish plover, Little ringed plover, Black tailed godwit, Common redshank, Tree pie, House crow, Jungle crow and House sparrow (27)	8.67 ± 3.93	302.72 ± 113.02	217.70 ± 104.55	40.76 ± 13.27

Note: Values in parenthesis indicate the sample size of birds.

Accumulation pattern of PCBs in birds displayed the following order:

Scavengers > Coastal piscivores > Insectivores> Inland piscivores
> Grainvores > Omnivores

The retention of organochlorine residues by birds belonging to higher trophic levels, such as kites, is consistent with the observation of Ramesh *et al* (1992). Bioaccumulation patterns observed in birds at different levels of the food chain suggest that feeding ground is a vital factor in the accumulation of organochlorine residues. For example, inland piscivores, like pond heron, accumulated larger quantities of HCH residues than omnivores, like Kentish plover, Redwattled lapwing etc. The pond heron forage mainly in the vicinity of agricultural fields, canals and ditches, thus exposing these specimens to HCHs, which result in the accumulation of higher residue concentrations (Ramesh *et al.*, 1992). Scavengers and fish-eating groups like inland piscivores and coastal piscivores also accumulated higher residue levels of HCHs resulting from the application of insecticides for vector control and agricultural purposes as reported by Dubrawski and Falandysz (1980) from Poland, Matthieseen (1985) from Zimbabwe and Mora and Anderson (1991) from Mexico.

In the present investigation, marked variations in the accumulation patterns were observed according to species as well as to organochlorine residues (Mean ± SD) showed in (Tab. II). Uniformly observed lower concentrations of PCBs in resident birds suggest that their contamination is lower than that of DDTs and HCHs in India. Earlier studies have shown the presence of lower concentrations of PCBs as compared to DDTs and HCHs in Indian biological samples (Tanabe *et al.*, 1990; Ramesh *et al.*, 1992; Kannan *et al.*, 1992; 1995). Global comparison of organochlorine concentrations made by these authors indicated that resident birds in India have the highest residues of HCHs and moderate-to-high residues of DDTs. It is, therefore, reasonable that migratory birds wintering in India acquire considerable amount of HCHs and DDTs. India is the greatest consumer of HCHs in the world (Dave, 1996). Under the National Malaria Eradication Program of the Government of India, about 85% of the DDT produced in India were used for vector control (Singh *et al.*, 1988). Such a pattern reflects the contamination trend observed in the industrialized countries of the Northern Hemisphere (White and Krynitsky, 1986; Becker, 1989; Barron *et al.*, 1995). For example, Fyfe *et al.* (1991) reported higher concentrations of insecticide residues in carnivorous and insectivorous birds than in omnivorous and grainvorous birds. Frank *et al.* (1977) documented a similar trend in Kenya, where carnivorous birds from agricultural watersheds had greater residue levels. Generally, birds positioned at the top of the food chain such as kites, gulls and eagles, accumulate elevated levels of organochlorine contaminants (Newton, 1988).

Information pertaining to sex difference in organochlorine residues in birds varied. While a few studies reported the presence of higher concentrations of organochlorines in males (Larsson and Lingegren, 1987; Duursma *et al.*, 1989) and several other studies reported greater concentrations in females (Norstrom *et al.*, 1976; Lemmetyinen *et al.*, 1982; Elliott and Shutt, 1993). The reduction of organochlorine levels in the whole body burdens of females indicate excretion through egg laying in breeding grounds.

The concentrations of organochlorine residues in both sexes are given in the Tables III and IV. The residue accumulation as a function of sex did not depict any distinct pattern between male and female specimens. But comparing the mean weight and levels of residues accumulated by groups based on feeding habits revealed that females of different trophic groups had lower levels than the males. These differences in residue levels might be due to the loss through biological functions such as egg laying and variations in exposure to the contaminants or both. In the present

TABLE III Concentrations (ng g^{-1} wet wt.) of Organochlorine (Mean ± D) Measured in the Avifauna Males (*n*).

Trophic group (n)	*Weight*	*Fat (%)*	*HCHs*	*DDTs*	*PCBs*
Scavengers (3)	268.2	3.78 ± 1.51	1847.76 ± 1407.38	730.59 ± 423.11	104.73 ± 62.26
Inland piscivores (11)	256.4	4.42 ± 1.74	1471.17 ± 524.48	191.38 ± 84.49	56.15 ± 13.02
Coastal piscivores (4)	318.3	11.93 ± 4.36	837.61 ± 589.71	1072.09 ± 604.61	106.63 ± 36.79
Insectivores (11)	128.6	5.06 ± 0.87	284.43 ± 115.40	474.84 ± 203.41	61.44 ± 15.96
Grainvores (11)	151.2	3.36 ± 0.52	59.75 ± 20.32	59.94 ± 12.16	48.69 ± 12.78
Omnivores (14)	294.3	8.12 ± 3.10	328.69 ± 104.56	286.45 ± 91.36	39.83 ± 9.24

Note: Values in parenthesis indicate the sample size of birds.

study, only a limited number of specimens were analysed and hence an accurate comparison of sex differences could not be made. From a comparison made between males and females of the same feeding habit, even though they do not belong to the same species, it can be observed higher levels of all the three organochlorine residuals in males (Tabs. III and IV). As far as PCBs are concerned, their levels in the birds were lower than for the other two organochlorine compounds (HCHs and DDTs). PCBs, at first, were found to be distributed along the coasts of industrial areas (Keith and Gruchy, 1973), but soon it was found that they were also the major organochlorine components of the pelagic seabirds in most of the world oceans around the developed nations (Bourne and Bogan, 1972; Risebrough and Carmignani, 1972; Fisher, 1973), whereas in the less developed and developing nations, the levels of PCBs were much lower than other organochlorine compounds (Kannan *et al.*, 1992; Ramesh *et al.*, 1992, Tanabe *et al.*, 1993; Iwata *et al.*, 1993). In the present study, among the migrant species, coastal piscivores accumulated greater amounts of PCBs than insectivores and inland piscivores, similarly to that observed for resident birds. In avian species, PCB accumulation was related to the content and composition of prey, to their age and to the residence time at the contaminated sites (Struger and Wesetoh, 1985). In addition, unlike organochlorine pesticides, PCBs usage has been concentrated in areas of high industrial activity along coastal regions and therefore, serious contamination by PCBs is found in the coastal environment (Tanabe *et al.*, 1989). This explains the higher concentrations of PCBs in coastal piscivorous birds, second only to scavengers observed presently (Tab. I).

The variations of organochlorines estimated in the present study showed HCHs as the predominant compound in all the birds except one or two species. This could be attributed to the increasing consumption of HCHs over other organochlorines in India particularly since the banning of the use of DDT for agriculture in 1984. After the ban on the use of DDT for agricultural purposes, the level of HCHs has been increasing until its recent ban in 1999. This changing pattern of distribution and accumulation of insecticide residues (*i.e.* higher levels of HCHs than DDTs) in the abiotic and biotic components of India

TABLE IV Concentrations (ng g^{-1} wet wt.) of Organochlorine (Mean ± SD) Measured in the Avifauna Females (*n*).

Trophic group (n)	*Weight*	*Fat (%)*	*HCHs*	*DDTs*	*PCBs*
Scavengers (3)	190.2	3.39 ± 1.41	1647.76 ± 1407.38	550.21 ± 423.65	71.31 ± 60.75
Inland piscivores (10)	264.4	4.19 ± 1.95	1157.74 ± 562.91	156.64 ± 62.85	34.32 ± 4.48
Coastal piscivores (5)	368.3	4.85 ± 3.50	813.92 ± 517.06	511.73 ± 504.07	63.18 ± 33.43
Insectivores (12)	196.6	2.85 ± 1.01	200.81 ± 121.64	354.01 ± 178.02	45.99 ± 17.93
Grainvores (10)	135.1	2.12 ± 0.68	47.50 ± 20.91	29.04 ± 13.26	32.94 ± 11.19
Omnivores (13)	258.2	6.58 ± 3.03	226.40 ± 104.04	155.46 ± 61.53	21.87 ± 9.38

Note: Values in parenthesis indicate the sample size of birds.

could also be seen in the observations of Ramesh *et al.* (1989; 1990; 1991; 1992) and Kannan *et al.* (1992).

Among the four isomers of HCHs, β-isomer dominated followed by α, γ, and δ isomers in all the birds (Fig. 2). The mean percentage composition of α-HCH ranged from 2.2 to 25.2% in Common redshank and in Black winged kite respectively. The maximum mean percentage of β-HCH was observed in Indian roller (93.4%) and the minimum in Large egret (69%). The lowest and highest mean compositions of γ-HCH were 2.1 and 12.5%, observed in Brown-headed gulls and Pariah kites, respectively. The mean composition of δ-HCH ranged between 1.1% in Common babbler and House sparrow and 6.4% in Black winged kite. Most of higher trophic level organisms, including birds, are capable of degrading synthetic organic chemicals accumulated in their body tissues, but β-HCH is more stable than α and γ-HCH to enzymatic degradation. The low water solubility, vapour pressure and resistance to microbial degradation makes β-HCH the most persistent isomer in the environment (Tanabe *et al.*, 1984; Ramesh *et al.*, 1992; Kannan *et al.*, 1992). Moreover, isomerization of γ-HCH to β-HCH in the ambient environment (Hayes, 1982) could also contribute to the higher accumulation of β-HCH in higher trophic level organisms, like birds.

Regarding the variations in the composition of DDT and its metabolites in the tissues of bird samples, the percentage of p,p'-DDE was higher than the other DDT compounds (Fig. 3). The values of p,p'-DDE ranged from 72 to 88.3% in White browned bulbul and Black tailed godwit respectively. The maximum value of p,p'-DDD was 14.6% in Green sandpiper, while the minimum (5.2%) was observed in Magpie robin. The consumption of o,p'-DDT varied from 3.3% in Spotted dove to 8.9% in Smaller egret. The observed values of p,p'-DDT composition ranged from 2% in Jungle crow to 6.2% in Large egret. DDT, the first organochlorine pesticide, is broken down by biological activity into the related compounds, DDD, TDE, and DDE. The DDT and TDE are soon broken down further but DDE is very persistent. So, the 'Chronology of DDT pollution' can be assessed by determining the proportion of DDE in total DDT (Bourne, 1976). The transformation of DDT into DDE is greater in birds than in fishes (Ramesh *et al.*, 1992), suggesting higher metabolic capacity in birds. Exposure to DDE enriched food material may also contribute to such a higher percentage of DDE in birds. The residue concentrations of DDTs and HCHs in birds have not shown any sign of reduction when compared with previous data. Verma (1990) suggested that DDT levels in Indian fauna might decline in future due to the ban of DDT from agricultural usage.

The magnitude of exposure to various contaminants in wintering grounds in India can be assessed by collecting birds at the end of the wintering season. Further, comparison of the concentrations of PCBs in resident birds collected in 1987–1991 (Ramesh *et al.*, 1992) with those of the present study indicates that PCB pollution is increasing in recent years. Further studies to determine the concentrations of these compounds in eggs of resident avifauna are necessary to identify the most vulnerable species.

The two-way analysis of variance, carried out to identify differences in organochlorine content of birds, showed that there were no significant differences in the levels individual organochlorines among different bird species. However, there were significant differences between the various organochlorines in birds (Tab. V). The two-way analysis of variance carried out to point out differences in organochlorine of male birds showed that there were no significant differences in their levels between different birds. However there were significant differences between the levels of different organochlorines (Tab. VI). A similar analysis, carried out in females, showed similar results (Tab. VII). The levels of organochlorine did not vary significantly between birds but there were significant differences between the levels of various organochlorines.

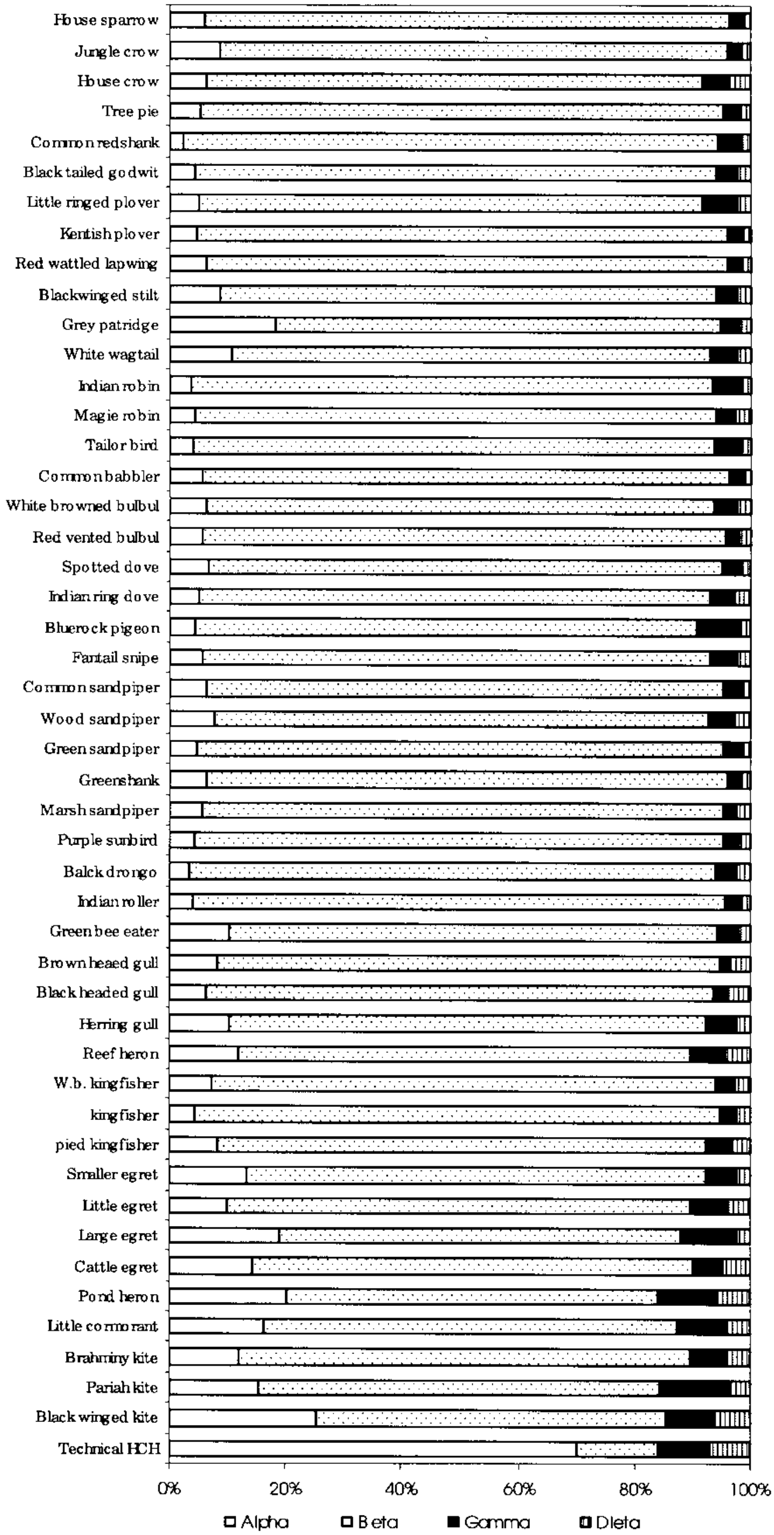

FIGURE 2 Percentage composition of HCH isomers in birds collected from different biotopes.

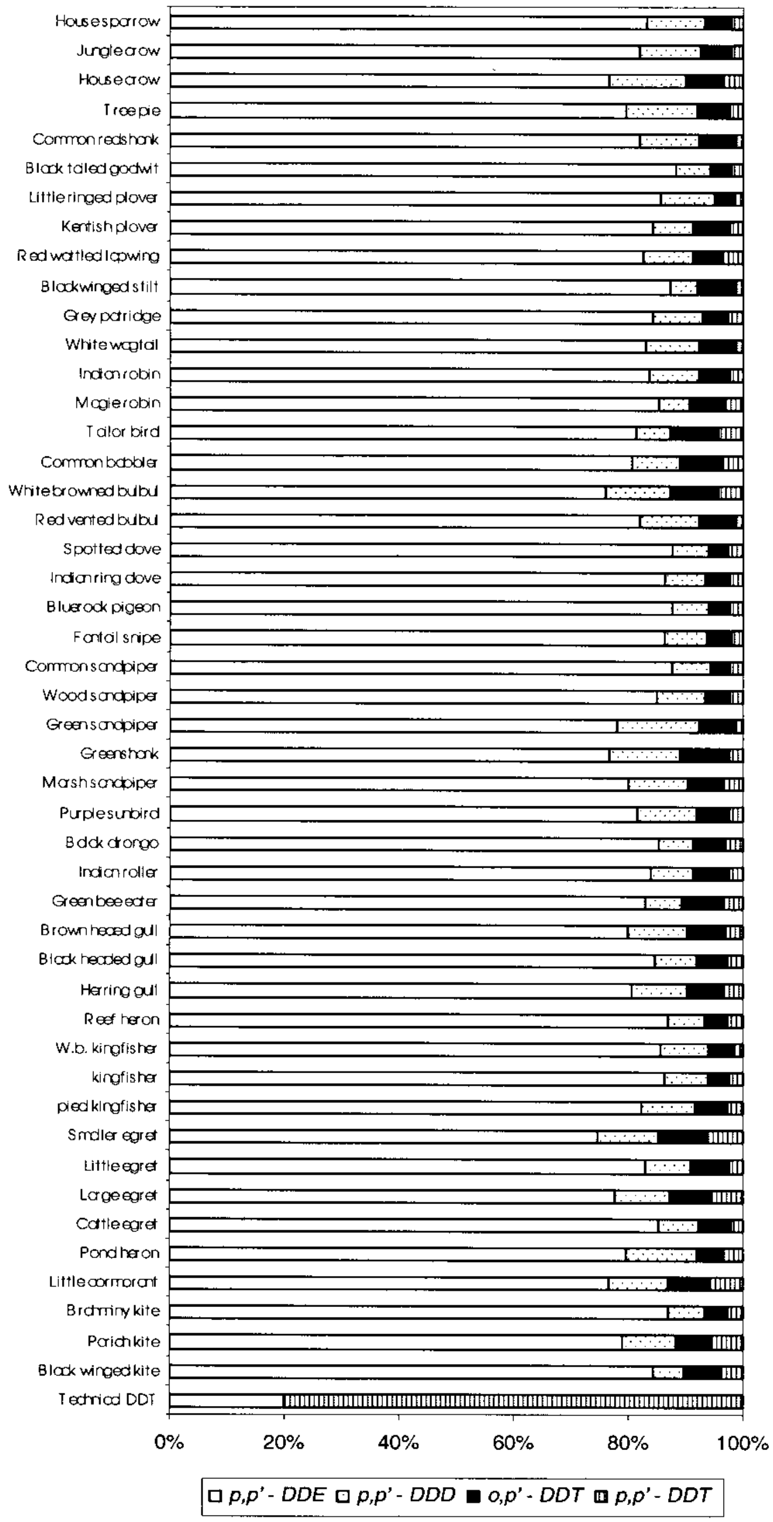

FIGURE 3 Percentage composition of DDT and its metabolites in bird species collected from different biotopes.

TABLE V Two-Way Analysis of Variance to Find Out the Variations in the Levels of Organochlorines in Birds of Various Feeding Habits During 1996–1998.

Source of variation	*S.S.*	*D.F.*	*M.S.*	*F value*	*P value*	*F crit.*
Rows	931638.16	5	186327.63	1.60	0.220	2.90
Columns	2128685.37	3	709561.79	6.09	0.006	3.28
Error	1745546.86	15	116369.79			
Total	4805870.41	23				

TABLE VI Two-Way Analysis of Variance to Find Out the Variations in the Levels of Organochlorines in Male Birds of Various Feeding Habits During 1996–1998.

Source of variation	*S.S.*	*D.F.*	*M.S.*	*F value*	*P value*	*F crit.*
Rows	1129915	5	225983.09	1.65	0.207	2.90
Columns	2706502	3	902167.17	6.59	0.004	3.28
Error	2052903	15	136860.18			
Total	5889320	23				

TABLE VII Two-Way Analysis of Variance to Find Out the Variations in the Levels of Organochlorines in Female Birds of Various Feeding Habits During 1996–1998.

Source of variation	*S.S.*	*D.F.*	*M.S.*	*F value*	*P value*	*F crit.*
Rows	765418.7	5	153083.7	1.54	0.236	2.90
Columns	1617313	3	539104.2	5.42	0.009	3.28
Error	1489917	15	99327.7			
Total	3872648	23				

4. CONCLUSIONS

An assessment of the magnification of organochlorine residues in the Indian wild birds generally shows higher accumulation, and the levels may increase further. PCBs deserve some attention as their levels might increase in future, because India is now using PCBs in several of its industries. All the four isomers of HCH (α, β, γ and δ) were observed in all the birds analysed. The order of accumulation pattern of these isomers in birds was in the following order:

$$\text{Beta} > \text{Alpha} > \text{Gamma} > \text{Delta}$$

Regarding the metabolites of DDT, both the parent compounds, p,p'-DDT and o,p'-DDT and metabolite p,p'-DDE were present. The transformation of DDT to DDE was higher in birds than in other animals. The coastal environments like estuary, mangroves and lagoons are biologically productive and a gateway for organochlorine and other pollutants. The main source for the above pesticides to these environments is the agricultural drainage coupled with monsoonal inflow during agro-chemical operations. Mandapam and Parangipettai coastal environs, Muthupet lagoons and Pichavaram mangroves are not heavily polluted with pesticides, when compared with other similar areas of the world. Further, more detailed monitoring is needed in the future.

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