INT. J. BIOL. BIOTECH., 7 (1-2): 127-133, 2010.

GUILD BASED POPULATION STRUCTURE OF SHOREBIRDS FROM KARACHI COAST, PAKISTAN

Syed Najam Khurshid[1], Sohail Brakati [2] and Solaha Rahman[2]

[1]*Water Sector Improvement Project, Sindh, FAO.*
[2]*Department of Zoology, University of Karachi, Karachi-75270, Pakistan.*

ABSTRACT

Seasonal changes in population structure of 53 species of Waterbirds from four localities along the Karachi Coast, Pakistan were studied for a period of four years (1993-1996). The concept of Guild Structure was introduced for the first time to classify the bird species. Six guilds were defined on the basis of food and feeding style etc. Food preferences of bird species were also studied. Abundance of birds of different guilds was related to the availability of food.

Keywords: Guild, Population, Shorebirds, Food preference

INTRODUCTION

The importance of Indus valley as the fourth major flyway of the world is well documented (Roberts, 1991). This is mainly due to the presence of a variety of coastal habitats and wetland system. In 1987, the International Wetlands and Waterfowl Research Bureau launched an international waterfowl census programme to study the waterfowl population in general.

A status overview of Asian wetlands (Scott and Poole, 1989) has identified beaches of Hawkesbay, Sandspit, Clifton, Korangi and Gharo creeks along the Karachi coast and the outer Indus Delta among the threatened wetlands in Asia. Pakistan became a signatory to the Ramsar convention and nine wetlands of the Indus region were designated as wetlands of international importance, especially as waterfowl habitats. Waterfowl censuses were, therefore, made regularly along the coastline of Karachi.

Population estimation of shorebirds employing guild structure, though is not new, has not so far been used in Pakistan. The concept of 'Guild' given by Root (1967) is based on information about feeding style, degree of social foraging, diurnal habits and habitat characteristics that are projected on the guild structure. Some notable publications dealing with the foraging habits of birds are those of Davies (1977), Pienkowski (1978, 1979), Bibby and Green (1980), Ruiz *et al*., (1996) etc. The present communication describes the variation in the population of shorebirds and food preferences of 53 species of birds from four representative sites along the Karachi coast.

MATERIAL AND METHODS

Four coastal sites viz. Hawkesbay, Clifton, Korangi Creek and Cape Monz were visited at regular monthly intervals for a period of four years (1993 to 1996). Birds counting were made at the roosting time as well as after one hour of foraging time. Conditions like clouds, poor light, fast wind and extremely low temperature were avoided during counting. Birds were counted employing Block Method (Howes, 1987) in which blocks of birds were assessed within a flock. The block can be of 10, 25, 50 or 100 birds. The block was then used as a model to measure the remaining flocks. Counting and identification of bird species was made with the help of:

1. A small size light weight binocular with specification of 10 x 21 CF (Nikon); 2.1 mm exit pupil ; 4.4 brightness; 8.6 mm eye relief; 88 mm width; 210 mm length; and 117 gm weight.
2. Nikon Spotting scope (model ED 78 A, type SCHMIDT'S prism) with 78 mm objective diameter having focusing range of approx. 5m to infinity; 1.6 mm exit pupil; 100 mm width id; 50 x magnification with real field view of 0.88^{o}. 1.53 gm weight.

RESULTS AND DISCUSSION

The Karachi coast is reported to inhabit more then 93 waterfowl species (Ghalib *et al.*, 1993). Fifty three species were selected for the present investigation. The concept of Guild introduced by Root (1967) was used to evaluate the seasonal changes in the abundance of 53 species of shorebirds based on feeding style and social foraging. The objective structuring of the shorebird community of four study sites yielded 6 guilds: 1, Herbivores (coots, ducks); 2, stalking birds (egrets, herons, spoonbills and flamingos); 3, Fishing birds (terns, cormorants,

gulls); 4, visual surface foraging birds (plovers, common sandpipers, whimbrels, redshanks, lapwings and terek sandpiper); 5, tactile surface foraging birds (godwits, sanderlings, curlews, little stints, dunlins, teminic stints and oystercatcher) and 6, pelagic foraging birds (green shanks, black winged stilts and avocets).

Birds of Guild numbers 1 to 3 behaves differently catching the fish as their food. Herons, for instance, walk, wait and surprise their prey; Gulls and Cormorants swim and dive to catch fish and carry ashore before swallowing them whereas Terns catch fish by diving from air to pick individual fish from the surface of swimming fish schools.

The remaining species i.e. birds of guild numbers 4 to 6 are ground feeding waders which are categorized on the basis of their sensory mechanism of food detection and feeding style. These consist of two groups of surface foragers one of which predominantly use visual tactile means to find their prey (Guild 5), including godwits, sanderlings and curlews. The third group (Guild 6) consists of pelagic foragers (avocets and stilt like birds) fishing in the water layer. These species use visual as well as tactile senses to detect their prey. In the tidal areas, creeks and backwaters, many fish eating shorebirds (waders, terns and herons) were found together, especially during hectic feeding hours.

The number of birds belonging to 53 species varied during the four years of study: 181897 (1993), 211349 (1994), 113682 (1995) and 98687 (1996). The number of birds varied from site to site during the study period (Tables 1- 4). For instance, in 1993, maximum number of birds was seen at Clifton (66013), followed by Hawkesbay (63386), Korangi (35011) and Cape Monz (17487). The total number of birds at four sites varied from a minimum of 181897 (1993) to a maximum of 211349 (1994).

A total of 163,404 birds were counted at Hawkesbay. The bird population exhibited a regular decline from 63386 (1993) to 52396 (1994), 29346 (1995) and 18276 (1996). Decline in number of various species of birds was indicative of the unsuitable habitat for the birds at Hawkesbay especially for the herbivorous (Guild-1) birds. However, birds of Guild-3 emerged as dominating group in terms of their numbers (Khurshid *et al*., in press).

A total of 225492 birds were counted at Clifton. The number of birds decreased in 1995 and 1996 after a sudden increase in 1994. Birds of guild-5 represented 63 % of the total birds' population. Reduction of population of some species (dunlin, for example) may be related to the loss of feeding zone. Some species showed irregular annual changes in their population at Clifton. It was also noticed that species of the same guild may behave differently. For instance, *Vanellus malabaricus* declined from 418 in 1993 to 130 in 1996, whereas population of *V. indicus* remained almost constant.

A total of 153357 birds were observed at Korangi creek. The number increased from 35011 in 1993 to 44995 in 1996. Noticeable fact is that herbivorous birds (Guild-1) were totally absent. Two species of Guild-5 i.e. *Calidris minuta* and *C. alpina* were present in such great number that they represented 75 per cent of the total birds of Guild-5. Habitat of Korangi creek was found more suitable for small size birds of Guild- 4. Birds of Guild-2 were represented in very small number ranging from 8 to 10 only. Birds of Guild-5 heavily contributed to the bird's fauna of Korangi creek.

Cape Monz provided an ideal place for roosting and feeding due to the presence of a variety of habitats. The area is mostly rocky with patches of muddy, sandy and sandy cum rocky substratum. A total of 63542 birds were counted during the study period. Maximum number of birds was noted in Guild-3. Changes in number of birds varied widely in birds of different guilds. The population of birds of Guild-l at Cape Monz was also affected drastically due to unavailability of fresh water as these are dependent on hydrophytes.

Food preference for 53 species of birds is presented in Figs. **1- 6**. The predominant food of all the five species of birds of Guild-1 is seeds and weeds (Fig. **1**). Coots solely depend on seeds and weeds as food. The next preferred food for species of Guild 1 comprises of eggs and chicks whereas mallard (*Anas platyrhynchos*) preferred gastropods. The birds of Guild-1 showed low priority to worms, beetles and insects.

Food preferences of Guild 2 birds are shown in Fig. **2**. Most of the species showed preference to fish as food. Two of the nine bird species of Guild 2 i.e. spoonbills (*Platalea leucorodia*) and flamingos (*Phoenicopterus rubber*), prefer copepods and amphipods, respectively. Mudskippers are considered as second or third choice by most of the Guild 2 species. Some crustacean species form a considerable portion of the diet of at least 6 species as second or third choice.

Fig. **3** shows the food preference position of birds of Guild 3. It may be seen that 2 species (great and little cormorant) are solely dependent on fishes as their food. No other food item was seen in their gut contents. Moreover, 14 out of 16 bird species give first preference to fish. Crustaceans are also considered as favourable food after fish by 9 species of birds. Molluscan shells (gastropods and bivalves) were also taken as food by at least 6 species. Whiskered terns are unique in the sense that they prefer insects and crustaceans more than fish which is their last choice. Piersma *et al*. (1990) stated that Herons, pelicans and Terns feed on fish. Ali and Ripley (1987) described the food of common Tern mainly fish but at times crustaceans molluscs and insects were also included. In the present study only pelicans were found piscivorous.

Guild No. 1

Species	*Predominant*	*Dominant*	*Sub-dominant*	*Few*	*Rare*
Common teal					
Pintail					
Shoveller					
Mallard					
Coot					

Fig. 1. Food preference chart for herbivorous birds (Guild-1).

Guild No. 2

Species	*Predominant*	*Dominant*	*Sub-dominant*	*Few*	*Rare*
Reef Heron					
Little Egret					
Median Egret					
Large Egret					
Grey Heron					
Purple Heron					
Spoonbill					
Flamingo					
Pond Heron					

Fig. 2. Food preference chart for stalking birds (Guild - 2).

FOOD LEGENDS			
	Fishes		Cyst Amphipods
	Eggs and Chicks		Insect Larvae
	Insects		Seeds & Weeds
	Crustaceans		Limpets
	Gastropods		Bivalve shells
	Worms		Oyster
	Mudskipper		Beetels/Weevils
	Copepods		Rodents

Guild No. 3

Species	*Predominant*	*Dominant*	*Sub-dominant*	*Few*	*Rare*
Great Cormorant					
Little Cormorant					
Sooty Gull					
Great Black-headed Gull					
Black headed Gull					
Brown-headed Gull					
Slender billed Gull					
Herring Gull					
Lesser Blacked Gull					
Gull-billed Tern					
Caspian Tern					
Sandwitch Tern					
Common Tern					
Little Tern					
Black-shafted Tern					
Whiskered Tern					

Fig. 3. Food preference chart for fishing birds (Guild - 3).

Guild No. 4

Species	*Predominant*	*Dominant*	*Sub-dominant*	*Few*	*Rare*
Little Ringed Plover					
Ringed Plover					
Kentish Plover					
Mongolian Plover					
Greater Sand Plover					
Grey Plover					
Yellow-Wattled Lapwing					
Red-Wattled Lapwing					
White-tailed Lapwing					
Whimbrel					
Redshank					
Terek Sandpiper					
Common Sandpiper					

Fig. 4. Food preference chart for Visual surface foraging birds (Guild - 4).

Guild No. 5

Species	*Predominant*	*Dominant*	*Sub-dominant*	*Few*	*Rare*
Oystercatcher					
Sanderling					
Little Stint					
Temminck's Stint					
Dunlin					
Bartailed Godwit					
Curlew					

Fig. 5. Food preference chart for Tactile surface foraging birds (Guild - 5).

Guild No. 6

Species	*Predominant*	*Dominant*	*Sub-dominant*	*Few*	*Rare*
Avocet					
Black Winged Stilt					
Greenshank					

Fig. 6. Food preference chart for Pelagic foraging birds (Guild - 6).

State of food preference in birds of Guild 4 is shown in Figure 4. The food contents of these birds are ' either crustaceans or insects. Mongolian plovers (*Charadrius monogolus*) give some preference to gastropods over crustaceans. However, crustaceans are included as an important component of food in one category or another in all species of Guild 4. One exception is that of redshank (*Tringa tetanus*) which did not show any preference for crustaceans.

Food preferences of "Tactile Surface foraging birds" (Guild 5) are shown in Fig. **5**. Oystercatchers, as expected, prefer oysters as dominant food. Oysters were not observed as food content in any other bird. The dominant and subdominant category of oystercatcher also belongs to Phylum Mollusca i.e. limpets and gastropods, respectively. Gastropods are also preferred as first choice by one (bartailed godwit) and as second choice by 4 species. Insects and crustaceans were the predominant food of sanderlings (*Calidris alba*), little stints (*C. minuta*) and temminck's stints (*C. temminckii*).

The food priorities of three species of birds belonging to Guild 6 are shown in Fig. **6**. The principal food of these birds differs from each other. Avocet prefers amphipods and copepods as their first and second choice, respectively. Black-winged stilt showed inclination for insects and copepods as first and second choice, respectively; Greenshank (*Tringa nebularia*), on the other hand, disregards the insects, amphipods and copepods. It prefers fish and worms as first and second food items, respectively.

The representatives of Guild-1 i.e. ducks and coots were found only at Cape Monz and the back waters of Hawkesbay (Tables 1 - 2), because they prefer fresh or brackish water. Similarly the birds of Guild-3 which mostly comprised of stalking birds were found in all the study areas. These birds (herons and egrets) are also an indicator of

wetland health. Guild-4 represented the visual surface feeders, their habitat preference showed that they prefer those intertidal areas which are widely spread with low depth of water. Guild- 5 supports tactile surface forging birds, this group of birds prefer the intertidal areas having 2-4 cm water depth. This group is evenly distributed in all the selected study sites (Tables 1 – 4). Guild-6 consists of pelagic foraging birds. These birds are also evenly distributed in all the four sites but they preferred is marshy areas and therefore were also found in the fresh water marshes.

The results of the present study are in support of the inference drawn by Butler *et al*., (2001) that shore bird population is dependent on productivity of the area and type of habitat. The highest population of birds at Cape Monz was of Guild 3 and at Korangi Creek, Clifton and Hawkesbay was of Guild 5 showing that the species vary according to the nature of habitat and attract specific type of birds which are classified on the basis of feeding styles. It was also seen that species placed in Guild 1 were only observed at Cape Monze and Hawkesbay and almost no representative at Clifton and Korangi Creek.

The surface feeding waterfowl, locating their prey either by visual or through tactile means require exposed mudflats which are submerged long enough to have built up large populations of macro-invertebrates. These conditions were mostly available at Clifton and Hawkesbay which, as a result, supported relatively large number of waders. The waterfowl belonging to Guild-3 i.e. gulls and terns require conditions where fish is easily available and hence they are more numerous at Cape Monz followed by Korangi Creek and Hawkesbay. The pelagic feeding waterfowl or stalking birds require shallow water with good fish stocks and it is clear that such conditions are available at Korangi Creek so the birds belonging to Guild-2 are mostly available there.

A comparative study of the four sites from 1993 to 1996 reveals that crustaceans (isopods, decapods and copepods) are relatively more abundant in these areas and are exploited by the major group of the shorebirds. Figures of relative abundance of birds on the basis of availability of food and suitable roosting grounds reveal that the Karachi coast is the favourite site for shorebirds, specially for the forage Guilds- 4, 5 and 6. This is again due to the presence of the crustacean feeders which are trying to maintain themselves by adapting to unstable feeding and roosting grounds.

Regular census of aquatic birds showed that of the small waders, little stint (*Calidris minuta*), Kentish plover (*Charadrius alexandrinus*), sand plover (*C. lesheaultii*), little-ringed plover (*C. dubius*) and sanderling (*Calidris alba*) were the most dominant species on the coast.

Clifton has lost its ideal intertidal habitat due to which the population of birds has been drastically reduced. The population of Guild-1 (herbivore ducks, coots) remains very low in this area (Clifton). The Hawkesbay habitat is still showing its validity according to the numbers of birds of Guild-1, while the important habitat of all the guilds, "Cape Monz" has lost its birds population due to the contaminated water of the Hub Power Company water plant.

Flamingoes (Guild-2) were observed on Clifton only in 1993 (1400 birds) and 1995 (2525 birds), they were absent in 1994 and 1996. Occurrence of flamingoes in such abundance in a deteriorating environment of Clifton has been observed for the first time. According to Roberts (1991), flamingos can be seen in Pakistan throughout the year along the coast line of Pakistan but not from Clifton. A total of 12193 flamingos were counted from the four study sites during the four years varying from 534 (Cape Monz) to 6806 (Korangi). Their number varies from a minimum of 1887 (1994) to a maximum of 4747 (1995).

Population of the white-tailed lapwing (*Chttusia leucura*) is not regular around the coast of Karachi, though this species is an inhabitant of freshwater marshy areas and lakes (Roberts, 1991). It is a winter migrant, irregular and uncertain changes in population may be seen from a figure of 78 (1993) and 50 (1994) birds, and a complete absence in 1995 and 1996 from Hawkesbay; only 130 birds (1996) from Korangi Creek with a complete absence during the first three years of study (1993-95). The species was not observed at all on Clifton and Cape Monze. Ali and Ripley (1987) stated that this species is a winter migrant and effect marshy grassy edges of large lakes.

Census and counts, undertaken during the study period (1993-1996) yielded quite precise information on the densities of bird populations. The number of individuals of various species per unit area varied very widely between habitats in relation to their food availability. Some of the study areas, like backwaters and open mudflats of Hawkesbay/Sandspit have a higher total density, because of a greater consumable biomass at different trophic levels.

Biomass remains very high between August and December with peak months being September and October, and to a lesser extent April (Nooruddin, 1967a, b; Saifullah and Moazzam, 1978; Moazzam and Rizvi, 1979; Banse, 1984; Vannucci, 1988). According to Vannuchi (1988), salinity is inversely correlated with biomass production. Microscopic animals (zooplankton) and plants (phytoplankton) flourished when the salinity remained low. These two factors greatly influenced the number and population of the aquatic birds, specially the migrants.

Majority of the migrant birds in the present study belonged to Guilds 4, 5 and 6; they prefer to feed on crustaceans. Among the crustaceans, species belonging to decapods and copepods are more important in keeping the birds population stable. The migratory birds were seen reaching the study area for the first time in July. Though in the beginning these crustaceans and other organisms were present in low number from May to July, but started

increasing thereafter till September; after a decline in October the number increased again in November and continued till April. During the period when copepods and decapods are available in less number, the area is utilized by those bird species which prefer to feed within the low depth (0-2 cm) of water, such as stints, little ringed plover, common sandpiper etc. and the resident birds like black-winged stilt. A number of organisms, such as, crustaceans, amphipods, isopods, larval fries, decapods etc. are carried towards the intertidal zone at high tides to fill the small and large size ditches present over there, especially in the backwaters of Hawkesbay. The area is exploited by a number of migrant as well as resident birds as a source of food.

The pelagic food web consists of adults, juveniles and larval stages of a variety of organisms during the north east monsoon season (from November to February). These months are the peak periods of migrants as maximum number of birds can fulfill their feeding requirement. It was noted that birds avoid facing any possibility of food competition.

From February to March, with increase in temperature, the number of copepods and icthyoplanktons also decreased. This change had a direct impact on the total number of birds in the area. The decline in bird's population of different kinds could be due to decrease in the number of crustacean larvae, different molts, juveniles and adults; the birds started migrating towards south following a decrease in crustaceans. This is in support of our hypothesis that birds are totally dependent on the availability of food.

A comparative study of four years indicates that the rise of salinity is also one of the main reasons for the decline of coastal fauna and flora. Furthermore, high salinity had a negative impact on the oxygen content of the coastal water. This has affected the ability of Teleost fish fauna to regulate the intake of oxygen, as a result of which they remain on the water surface.

Since young organisms, in general, show little tolerance for salinity than the birds, the high salinity of the coastal areas does not directly affect the population of the migrant and local birds. An indirect effect, however, can be seen if any one of the components of the food web is disturbed. The four years of present study also revealed that the bird population is shifting slightly towards the south eastern areas of the coast, with every passing year.

The geo-physical appearance of the Karachi coast was analyzed to determine the habitat preference and to calculate availability of the food at feeding grounds. These feeding grounds are shrinking, deteriorating and disappearing due to human activity. Pollution, contamination, climatic changes, temperature, salinity, wind, tidal activity, fishing and crab hunting are increasing day by day. According to Beg *et al*., (1992) main source of water borne pollution in the coastal areas of Karachi include industrial, municipal, transport and port activities at the rate of 375 gm BOD per capita per day. These are the main causes of the decline of bird food in the quality as well as quantity.

The relative abundance of birds at Clifton is decreasing because of human pressure, whereas industrial and agricultural pressures have demolished the ideal population at Cape Monz. The Korangi Creek, which was once considered a paradise of the coastal bird's fauna, has lost its oyster bed and now the industrial effluents and poisonous water has changed the biodiversity of the creek habitat drastically. The reclamation of land and polluted water of the drainage system are the main factors due to which Hawkesbay is loosing its fertility.

In addition, human interference has drastically reduced the mangrove forests resulting in the elimination of benthos as well as phytoplankton. The rate of fishing has also gone down resulting in a sharp decrease in the quantity of fish caught from the back waters. Reduction in the production of fish from the backwaters has also resulted in the decline of the population of stalking birds; a number of fishing birds (terns, sea gulls and cormorants) have shown considerable decline in number.

Predation is one of the most important mortality factors, due to which the bird population declines. Although, with the exception of Guilds 2 and 3, all the members of Guilds 1, 4, 5 and 6, in the present study, are migrant and not breeding in our coastal areas, no evidence of predation pressure was noticed. As far as the local breeding species are concerned, they are facing one more anthropogenic factor i.e. the destruction of their breeding and nesting ground through the elimination of forest and over-cutting of trees. The impact of predation on particular population of birds varies and is not considerable, while the physical factors of the environment, such as shortages of food, act directly as well as more definitely on bird populations. As a result of environmental deterioration due to the pollution and interaction of the human activity, the gastropods and bivalves are fast disappearing and the population of shorebirds, like oystercatcher (*Haematopus ostralegus*), is also affected.

REFERENCES

Ali, S.A. and S.D. Ripley (1987). Compact handbook of the birds of India and Pakistan. Oxford University Press, Delhi, Oxford, New York, pp 737.

Banse, K. (1984). Overview of the hydrography and associated biological phenomena in the Arabian Sea off Pakistan. pp. 271-303. In: Marine Geology and Oceanography of the Arabian Sea and coastal Pakistan (B.U. Haq and J.D. Milliman eds.). Van Norstand Reinhold, New York.

Beg, M.A.A., S.N. Mahmood and A.H.K. Yousufzai (1992). Land based pollution of the marine environment of Karachi. *Pakistan J. Mar. Sci.*, 2: 112-116

Bibby, C.J. and R.E. Green (1980). Foraging behaviour of migrant pied flycatchers (*Ficedula hypoleuca*) on temporary territories. *J. Anim. Ecol*., 49: 507-521.

Butler, R.W., N.C. Davidson and R.I.G. Morrison (2001). Global state shorebirds distribution in relation to productivity of nearshore ocean waters. *Waterbirds*, 24(2): 224-232.

Davies, N.B. (1977). Prey selection and social behavior in wagtails (Aves: Matacillidae). *J. Anim. Ecol*., 46: 37-57.

Ghalib, S.A., S.A. Hasnain and M.F. Ahmad (1993). The Waterfowl of Karachi coast. *Rec. Zool. Surv. Deptt*., Vol. XII: 39-62.

Howes, J.R. (1987). Rapid assessment techniques for coastal wetland evaluation. Interwader Publ. No. 24, Kuala Lumpur.

Khurshid, S.N., S. Barkati and S. Rahman (In press). Seasonal changes in waterfowl community of Hawkesbay, Karachi coast, based on guild structure. *Records, Zoological Survey of Pakistan*.

Moazzam, M. and S.H.N. Rizvi (1979). An overview of oil pollution along the coast of Pakistan. pp. 33-39. In: *Protection of Marine Environment* (A.A. Baig ed.). Proceedings of National and Regional Seminar for the protection of marine environment and related ecosystems, PCSIR, Karachi.

Nooruddin (1967a). An account of the phytoplankton of Karachi with a note on their seasonal variation, fluctuation and distribution. *Agric. Pakistan*, 13: 51-83.

Nooruddin (1967b). An account of the zooplankton of Karachi with a note on their seasonal variation, fluctuation and distribution. *Agric. Pakistan*, 18: 197-224.

Piersma, T., J.H. Klaassen, A.M. Bruggeman, A.G. Blomert, N. Matiomoa-Baidu and N.E. Van Brederode (1990). Seasonal timing of spring departure of waders from the bank of d'Arguin, Mauritania. *Ardea*, 78: 123-134.

Roberts, T.J. (1991). The birds of Pakistan, Vol. 1. Oxford University Press, Oxford, New York, Karachi, 598 pp.

Root, R.B. (1967). The niche exploitation of the blue-gray gnatcatcher. *Ecol. Monogr*., 37: 317-50.

Scott, D.A. and C.M. Poole (1989). A status overview of Asian wetlands. Asian Wetland Bureau, Publication No. 53.Kaula Lumpur, Malaysia.

Saifullah, S.M. and M. Moazzam (1978). Species composition and seasonal occurrence of centric diatoms in a polluted marine environment. *Pakistan J. Bot*., 10: 53-64.

Vannucci, M. (1988). Overall productivity of mangroves with special reference to the Indus delta. pp. 401-405. In: *Proc. Intern. Conf. Mar. Sci. Arabian Sea* (M.F. Thompson and N.M. Tirmizi, eds.). American Institute of Biological Sciences, Washington, D.C.

(*Accepted for publication January 2010*)