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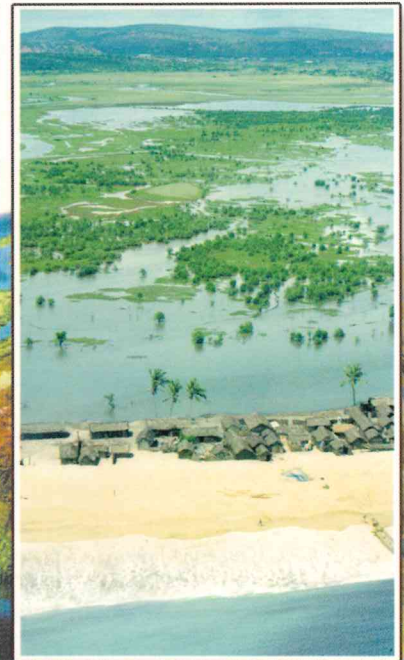


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WATERBIRD ECOLOGY AND THE MANAGEMENT OF COASTAL WETLANDS IN GHANA

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Theunis Piersma & Yaa Ntiamoah-Baidu



Ghana Coastal Wetlands Management Project

Netherlands Institute for Sea Research(NIOZ) / Ghana Wildlife Society

The cover shows a global perspective of Africa in the south (the position of Ghana is indicated by a rectangle) and Europe in the north, with emphasis on the eastern shores of the Atlantic Ocean. The inset at right shows an aerial photograph of one of the lagoons along the Ghanaian coastline, with the sandy barrier and its fishing village in the front, and flooded marshland of the lagoon and higher countryside in the back (Densu Delta, just west of Accra). The insets at left show a group of fisherfolk catching tilapia (top) and a mixed aggregate of waders, herons and terns fishing for tilapia as well (bottom). Note that fishermen and birds fish for very different size classes (see elsewhere in this report).

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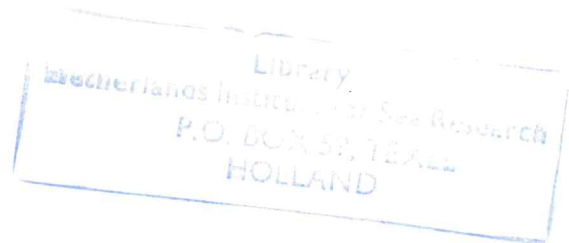
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WATERBIRD ECOLOGY AND THE MANAGEMENT OF COASTAL WETLANDS IN GHANA

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1. SYNOPSIS

1. The Ghana Coastal Wetlands Management Project (CWMP), which is implemented by the Wildlife Department, aims at preserving the ecological integrity of the ecologically most important coastal wetlands of Ghana, while at the same time enhancing the socio-economic benefits of the wetlands to local communities. CWMP recognises the need for a technical information base, for example on biological productivity and the interactions between the biotic and physical elements of the systems. Although the ornithological importance of the Ghana coast is well documented, the role of individual bird species in the wetland ecosystem had not been studied. Ornithological studies for the Songor and Keta Lagoons, the largest two of the proposed Ramsar sites, were therefore commissioned by the Wildlife Department, as part of the environmental baseline studies initiated to provide scientific data to guide management decisions and actions, and to provide a basis for monitoring of the wetland ecosystems and evaluation of the CWMP.

2. The specific objective of the study was to provide more complete data on the use of Songor and Keta Lagoons by waterbirds. The key components of the work were: waterbird surveys, detailed studies on the spatial patterns of wetland use by individual waterbird species for roosting and feeding, assessment of waterbird prey and their availability and determining the factors that are likely to affect the food resource, identification of the most important areas for birds within the two sites, suggesting measures to maintain the value of the wetlands for waterbirds, and defining parameters and a regime for monitoring the use of the two sites by waterbirds.

3. During a seven week study in October-November 1994 our team worked in the Songor-Keta area, the two large lagoon complexes in Ghana found at either side of the delta of the Volta River. This report covers our findings. It provides a snapshot at the life-style and the annual cycle of the waterbirds in Songor and Keta Lagoons, a glimpse at the ever changing ecology of the lagoons. It has

allowed us to describe general behaviour, water depth selection, daily feeding rhythms and diets of about 36 waterbird species. We have also been able to describe the waterbirds' distribution during the study period, and to analyse the food resources underlying these particular distributions.

4. To structure our thoughts and to help the analysis of the results, we put together, from first principles, a conceptual model incorporating the basic ecological factors affecting the functioning of the lagoons. This model gives an outline of the seasonality of the ecological conditions and the consequences for food availability for waterbirds

5. Rainfall in Ghana generally is very seasonal and shows great variability from year to year. The monthly distribution of rain in the Keta and Songor Lagoon area has a bimodal pattern with two distinct rainy seasons. Normally, the main rains fall from March/April to July with maximum precipitation in June, followed by a short period of dry weather in August/September. A minor rainy season runs from September to November. The mean monthly rainfall values during 1994 were generally higher than the average over the last 30 years. Flow from the Volta River has become less important in the recent past owing to the regulation of flow of the Volta River by the Akosombo Dam. 1994 had a comparatively high flow. Despite this, the water levels in the lagoon were very low during the study period, most areas were less than 30 cm and the deepest section was 1.5 m. The main source of fresh water to the lagoon may be run off from the catchment and direct rainfall on the lagoon.

6. During the comprehensive ground count on 14 October, a total of 38,073 waterbirds, comprising 32 species, was recorded in Songor Lagoon. Of this, 84.3% was contributed by terns, while waders and herons/egrets accounted for 23.9% and 1.7% respectively. At Keta Lagoon a total of 37,519 waterbirds belonging to 46 species were recorded. This comprised 92 % waders, 7.2 % herons and egrets and 3.7 % terns. Curlew Sandpiper contributed 54.5% of the total count. Other wader species which

occurred in significant numbers included Black-winged Stilt (15.1%), Greenshank (5.3%), Little Stint (4.7%) and Ringed Plover (4.5%). Whiskered Terns were present in relatively large numbers (261) compared with the small numbers (under 10) previously recorded at any time.

7. Thus, almost 76,000 waterbirds were counted during a single day in October, thereby unambiguously establishing the large total populations counted previously on separate days. Some species were observed in larger numbers than ever before, amongst which was the observation of 650 individuals of the endangered Roseate Tern and the count of 21,000 Curlew Sandpipers on 14 October and over 31,000 at Woe-Tegbi only, on 25 October. These numbers of Curlew Sandpipers are much higher than the previously published maximum of 15,250 for the whole of Ghana (NTIAMOA-BAIDU 1991a).

8. The aerial survey was most useful for providing a general overview of the habitats and the distribution of birds. The aircraft disturbed the birds and this made the counting very difficult. For censusing, ground counts, though more tedious, provide of much better population estimates.

9. Activity (feed, preen/bath or roost) of a total of 3,199 flocks containing 118,648 individuals of 36 different waterbird species was scored during the study period.

10. To structure our information on the foraging habits, diurnal rhythms and diets of 36 waterbird species, we defined seven "guilds" on the basis of our information on the sensory mechanism used to detect food and on individual feeding style: (1) *Herbivorous ducks* (comprising the Fulvous Tree Duck and the White-faced Tree Duck), (2) *Visual surface foraging waders* (comprising Kittlitz's Plover, White-fronted Plover, Ringed Plover, Grey Plover, Common Sandpiper, Whimbrel, Turnstone, Wood Sandpiper and Redshank), (3) *Tactile surface foraging waders* (comprising Black-tailed Godwit, Bar-tailed Godwit, Curlew, Knot, Sanderling, Little Stint and Curlew

Sandpiper), (4) *Pelagic foraging waders* (comprising Marsh Sandpiper, Greenshank, Spotted Redshank, Black-winged Stilt and Avocet), (5) *Stalking herons* (comprising Little Egret, Reef Heron, Great White Egret and Grey Heron), (6) *Fishing pelicans* (comprising the White Pelican and the Pink-backed Pelican) and (7) *Fishing terns* (comprising Little Tern, Common Tern, Roseate Tern, Sandwich Tern, Royal Tern, Caspian Tern, Whiskered Tern and Black Tern).

11. Ringed Plovers, Kittlitz's Plovers, White-fronted Plovers, Little Stints, Turnstones, Grey Plovers, and Common Sandpipers (guilds 2 and 3) feed on the outer edges and wet mudbanks, followed by such species as Curlew Sandpipers, Sanderlings and Knots (guild 3) in the shallow water margins, Greenshanks, Spotted Redshanks, Black-winged Stilts (guild 4) in the deeper water, with the Reef Herons and Little Egrets (guild 5) in the inner layer. The choice of feeding habitats depended on leg length and food availability. Deeper areas of the lagoon and recently flooded areas devoid of prey items were not used by the birds. Most of the terns went feeding out to feed at sea, using Songor Lagoon as a night- and day-time roost. Little Terns, Black Terns, Whiskered Tern and the Caspian Tern sometimes foraged also on the lagoons. White Pelicans fed at dawn and dusk and perhaps during the night in the deeper parts of the lagoon.

12. Most of the waders observed in the Ghana lagoons fed and roosted in mixed species flocks. Flock sizes ranged from one to 600 birds, with most individual birds feeding in flocks of 50 or larger. Dense flocks of waterbirds that were all frantically foraging at the same time, giving some sort of organized impression, were classified as "social foraging" flocks. These were particularly common in the Greenshank, Spotted Redshanks, Marsh Sandpipers, Avocets and White Pelicans.

13. Prey items ranged from seeds of widgeon-grass *Ruppia maritima*, to various invertebrates (mainly polychaetes, molluscs and crabs) and fish, mainly juvenile tilapia. All the species in guilds 2 and 3 (plovers and sandpipers) fed on

invertebrates and seeds and either pecked from the surface or probed in the mud for prey. Species in guilds 4-7, comprising the shanks, stilts, herons and terns, fed mainly on fish.

14. Fourteen of the 26 species showed a circadian activity pattern, feeding day and night, while the remaining 12 were diurnal, with no purely nocturnal species. The herons and egrets (guild 5) who fed on fish and used visual means for prey detection, fed only during the day, while all the species in guild 4, the pelagic foraging species which fed mainly on fish using a combination of visual and tactile clues for prey detection, fed both day and night. In addition to the pelagic foragers, nocturnal foraging was observed also in three of the nine visual surface foragers, Ringed Plover, Grey Plover and Redshank; in three of the tactile surface foragers, Black-tailed Godwit, Little Stint and Curlew Sandpiper and in the White Pelican which also uses both tactile and visual means to detect prey. Night feeding therefore was common in many of the waterbird groups that use the lagoons in Ghana irrespective of the sensory mechanism they used to detect prey, but appeared to be more predominant in the species which detect their prey by touch.

15. Most species spent at least two thirds of the daytime feeding. Species which spent the greatest proportion of the day time foraging (over 75%) were Wood Sandpiper, Kittlitz's Plover, Common Sandpiper, Turnstone, Ringed Plover and White-fronted Plover, all belonging to guild 2 (the visual surface foragers) which also fed on small prey. Species which spent the least proportion of the day time foraging (less than 40%) included Grey Plover, Curlew, Black-tailed Godwit, Greenshank, Avocet, Grey heron and White Pelican. All these species, apart from the Grey Heron, were observed to also forage at night, and it could therefore be argued that they spend the day time roosting and on comfort activities, because they get most of their food requirement at night. Species feeding on small prey spent a lot more of the daytime feeding (67%) than the fish-eating species (36%). Time spent foraging was also related to the size of the bird species, with small waders

spending far more time feeding than bigger birds.

16. Songor and Keta Lagoons have large standing stocks of invertebrates and fish. Seeds of widgeongrass *Ruppia maritima* are present at 90 g/m², macro-invertebrates at 26 g/m² and fish at least at 0.35 g/m² (all figures in ash-free dry mass). The question remains how much of this biomass is available to birds. We identify water depth, salinity, water temperature, and sediment texture as the important factors controlling availability.

17. In Keta Lagoon the standing stocks of invertebrates and *Ruppia*-seeds are high and the sediments are unsorted, with many shell fragments. These fragments may provide obstacles for prey detection in some of the tactile surface foraging waders probing in the sediment.

18. We summarize the scarce information about human disturbance, trapping and competitive interactions between humans and waterbirds. The fish-eating habits of the large numbers of waterbirds are probably not negatively affecting human fisheries. Indeed, it is more likely that the presence of waterbirds, due to their size-selective predation on smaller fish, turnover of nutrients and indicator roles, may have a positive effect on fisheries.

19. We identify one key area in Songor Lagoon (the lagoon and mudflats between Totokpoe and Vunya camp), and three key areas in Keta Lagoon (the southwestern part of the lagoon bordered by Anloga, Woe, Tegbi and Dudu Island; an area south of Afiadenyigba; and the lagoons close to Adina) as crucial for waterbirds during most of times. These areas should receive special status and protection with respect to habitat changes and human disturbance.

20. The crucial issue which determines whether or not the waterbirds will continue to use the coastal lagoons, is that their food resources must be available. The presence and accessibility of the prey items is linked with the environ-

mental conditions in the lagoon such as water depth, salinity and sediment texture. Other secondary factors which will influence the value of the coastal lagoons as waterbird habitat are human disturbance, availability of roosting and nesting sites. These, therefore, are the key parameters which should be of management concern in the efforts to maintain the value of the wetlands as waterbird habitat.

21. Recommendations for long-term research work in the future include:

- (1) To keep up the waterbird counts;
- (2) To collect data on water levels and extent of flooded area at each of the counting dates;
- (3) To monitor benthos and fish populations;
- (4) To embark on an analysis of past environments by satellite image analyses of water coverage in relation to waterbird counts to understand long-term changes in the ecology of the lagoons.



Starting the fieldwork near Anloga, Keta Lagoon (Photo: T. Piersma).

2. INTRODUCTION

Ghana is on the boundary of two flyways of waterbirds, the East Atlantic Flyway and the Mediterranean Flyway (SMIT & PIERSMA 1989). The coastal wetlands of Ghana, therefore, receive significant numbers of waterbirds from a greater breeding range than most wetland sites in West Africa (Fig. 1). At least 15 species of waterbirds occur in internationally important populations (NTIAMOA-BAIDU 1991, pers. obs.). Ghana's coastal wetlands are better charted for birds (NTIAMOA-BAIDU & GRIEVE 1987, GRIMES 1987, NTIAMOA-BAIDU 1991A, NTIAMOA-BAIDU & GORDON 1991, NTIAMOA-BAIDU & HOLLIS 1992, and see VAN GAALEN & VAN GELDEREN 1995), than those in the other countries along the Gulf of Guinea (ALTENBURG *et al.* 1983, ALTENBURG 1987, TYE & TYE 1987, ZWARTS 1988, SCHEPERS & MARTEIJN 1993, NICOLE *et al.* 1994). Their value as staging areas and wintering grounds for migratory waterbird species is also much better known (e.g., NTIAMOA-BAIDU 1993). The long series of monthly waterbird counts (running since 1986), which was established under the Save the Seashore Birds Project (SSBP-G) (NTIAMOA-BAIDU & HEPBURN 1988, NTIAMOA-BAIDU 1991b) and is now continued by the Ghana Wildlife Society, is a unique data set for Africa. Such long-term data are essential for better understanding of both the ecology of these coastal wetlands and their importance in the life cycles of the migrant waterbirds.

Eight wetland sites along the Ghana coast (Fig. 2, Esiama, Elmina, Muni, Densu delta, Korle, Sakumo, Songor and Keta) qualify as internationally important wetlands on the basis of the total populations and species of waterbirds they support (NTIAMOA-BAIDU 1991a, NTIAMOA-BAIDU & GORDON 1991). In 1992, five of these sites, Muni, Densu delta, Sakumo, Songor and Keta, were proposed as Ramsar sites and received support from the Global Environment Facility (GEF) for their protection under the Ghana Coastal Wetlands Management Project (CWMP), which is implemented by the Wildlife Department. The CWMP aims at preserving the ecological integrity of the selected coastal wetlands, while at the same time enhancing the socio-economic benefits of

the wetlands to local communities. The management strategy advocated is therefore based on the "wise-use" concept of the Convention on Wetlands of International Importance (Ramsar Convention). The CWMP recognises the need for a technical information base on the physical parameters of the coastal wetlands ecosystem. This information comprises the status of the biotic components and the biological productivity; interactions between the biotic and physical elements of the system; factors affecting the long-term integrity of the system and the influences of human interventions; as well as the socio-economic situation of the people living within and around the sites.

Although the ornithological importance of the Ghana coast is well documented, the role of individual bird species in the wetland ecosystem had not been studied. The ornitho-

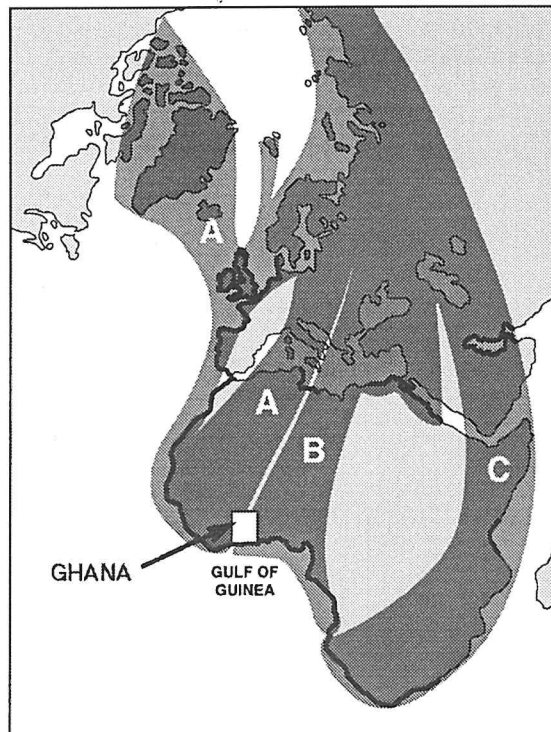


Fig. 1. "Catchment area" and migration corridors of migratory waterbirds that spend part of their annual cycle in Ghana: a map summarizing the East Atlantic, Mediterranean and East African Flyways. Ghana, on the transition between the East Atlantic and Mediterranean Flyways, is indicated with a rectangle. Adapted from SMIT & PIERSMA (1989).

logical studies for the Songor and Keta Lagoons, the largest two of the proposed Ramsar sites, was therefore commissioned by the Wildlife Department, as part of the environmental baseline studies initiated to provide scientific data to guide management decisions and actions; and to provide a basis for monitoring of the wetland ecosystem and evaluation of the CWMP.

The fact that waterbirds are conspicuous and easy to observe and count, has often made them into a tool for the identification of ecologically important areas. The fact that they are also beautiful to look at provides incentives and support for the protection and ecological management of important sites. In this report, we shall argue for the great importance of waterbirds as useful and sensitive indicators of the ecological state of wetlands. Indeed, waterbirds as a group could be put to much greater use for the management and the evaluation of management practices than is

common usage in Africa. The current relative non-appreciation of waterbirds may stem from a lack of knowledge about the role of waterbirds in the wetland ecosystem. In this study, we aim to ameliorate the situation for the coastal wetlands of Ghana by establishing the ecological characteristics and requirements of 36 main waterbird species that occur in the Volta lagoons, Keta and Songor. Although this report is based on a short-term study carried out in October-November 1994, a period during which the ecological conditions in the lagoons may have been far from average for the time of the year, we were able to derive sufficient insights from long-term field observations by informed observers to outline which aspects of the ecosystem each of the waterbird species is likely to stand for.

The specific objective of the study as outlined in the **terms of reference** was to provide more complete data on the use of the proposed Ramsar sites along the Ghana coast by

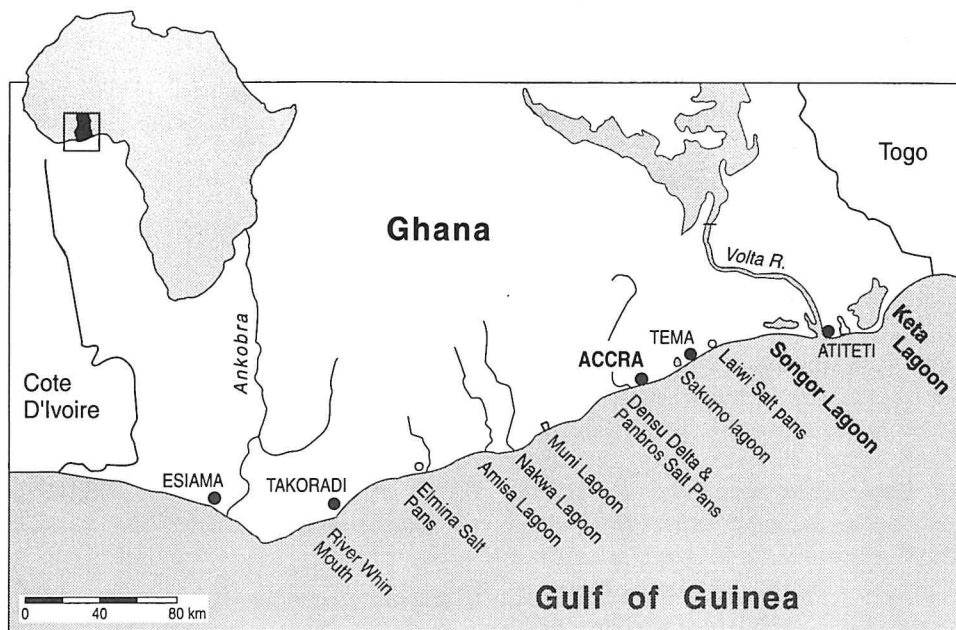


Fig. 2. Map indicating the major wetlands of coastal Ghana. The lagoons in the east of Ghana (Songor and Keta Lagoon) where this study was carried out are indicated. Adapted from NTIAMOA-BAIDU (1993).

waterbirds. Such data were required for the definition of key areas/bird sanctuaries within the sites and the development of an effective strategy for maintaining the value of the wetlands for waterbirds. The key components of the scope of work were as follows:

- Undertake aerial and ground surveys of the Keta and Songor Lagoon sites to provide data on total waterbird populations and spatial distribution of birds on the sites.
- Undertake detailed studies to determine spatial patterns of wetland use by individual waterbird species for roosting, feeding and nesting.
- Assess waterbird prey availability and determine the factors that are likely to affect the food resource base on the sites.
- Identify the most important areas for birds within the two sites and define provisional boundaries for the establishment of core areas/bird sanctuaries within the sites.
- Suggest measures to maintain the value of the wetlands for waterbirds.
- Define parameters and a regime for monitoring use of the two sites by waterbirds.

During October-November 1994 our team worked in the Songor-Keta area, the large lagoon complexes at either side of the delta of the Volta River (Fig. 3), to establish the current distribution, habitat characteristics and diets of the majority of waterbird species occurring there. We carried out ground and aerial counts, visual observations of waterbird behaviour, working throughout the 24 hr period using a light-intensifier at night, and we characterised diets from detailed visual observations and faecal pellet analyses. Observations on food abundance, both in areas where waterbirds occurred and in areas where they did not, were also made. The detailed quantification of the ecological requirements of waterbird species, linked with appropriate large-scale descriptions of relevant ecological parameters, can be profitably used for large-scale assessments of the ecological value of the lagoons. Using the reverse reasoning, the counts of waterbirds might be profitably used to evaluate ecological conditions in seasons past, and provide a basis for monitoring the state of the wetland ecosystems.

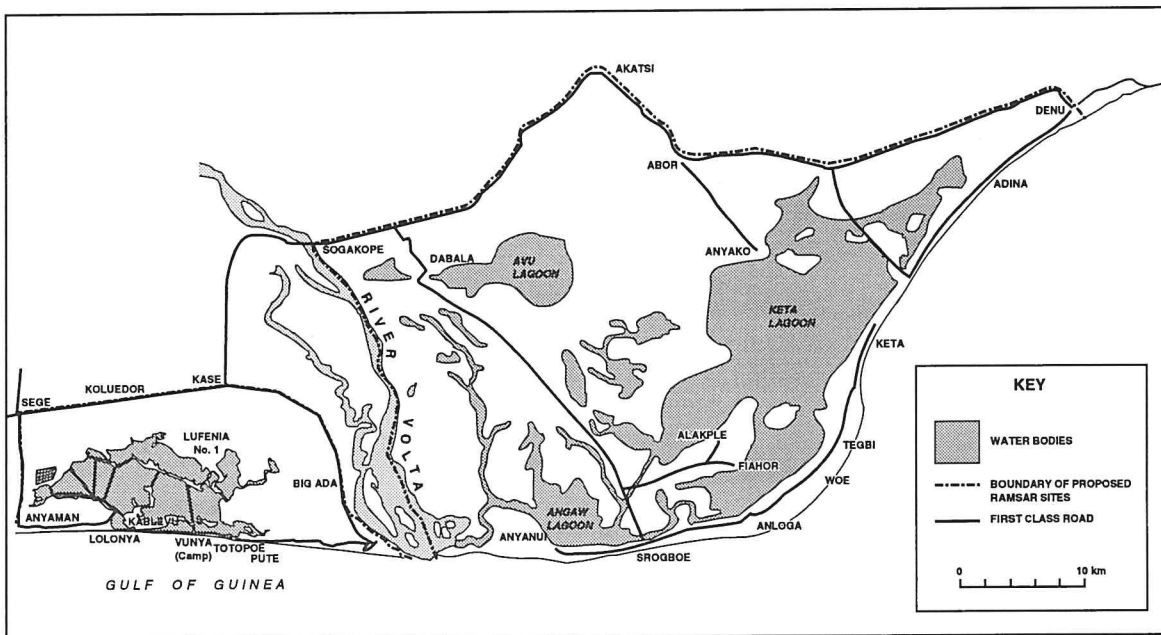


Fig. 3. Overview of the study areas (the Songor Lagoon complex west of the Volta and the Keta Lagoon complex east of the Volta River). The main roads and villages are indicated. The outlines of the two management areas are indicated by dotted lines. Adapted from NTIAMOA-BAIDU & GORDON (1991).



Dried out *Ruppia*-bed with *Tympanotonus*, Keta Lagoon (Photo: P. Battley).

3. CHARACTERISTICS OF GHANAIAN COASTAL WETLANDS AND THEIR USAGE BY WATERBIRDS

In order to address the problem of how to manage the coastal wetlands from the viewpoint of use by waterbirds, it is helpful to consider the basic ecological factors that may be important from a first principles approach as a means of outlining our way of thinking and how we intend to tackle the problem. We make several basic assumptions, some rooted in factual knowledge and others in how we would expect the systems under review to function.

The first assumption is that Ghana's coastal wetlands are effectively not tidal systems, but rather lagoons with surrounding flood plains. Of these lagoons, two types can be distinguished: the open lagoons which are associated with large rivers and have a connection to the sea, and the closed lagoons formed behind a sand bar, with no permanent connection to the sea (BOUGHEY 1957, KWEI 1977, MENSAH 1979, GORDON 1987). Ecologically, open lagoon systems are much more stable due to the tempering influence of the sea. The closed lagoons are functionally much more unpredictable, with conditions changing very rapidly from one point in time to another. The Songor and Keta Lagoons can be considered to be effectively closed lagoons.

The second assumption is that for both the closed and open lagoons, the freshwater inflow during the major and minor rainy seasons is the proximate factor driving the life cycles of the food organisms for waterbirds using the coast of Ghana (e.g., SANDISON 1966). The reason why we believe this to be so is that fresh water inflows ensure an annual supply of nutrients in a labile form. The fresh water also dilutes the hypersaline waters that may have accumulated in the wetlands providing more favourable conditions for both plant and animal growth.

For the closed lagoons, water surface area and salinity are very variable and to an extent, vary unpredictably. We also assume that water surface area and salinity are generally negatively correlated (larger surface, more fresh-water, lower salinity). This is not always true as salt water seepage passing under the dunes can be a significant source of water in some

cases. We anticipate that with falling levels of water and increases in salinity many organisms present in the lagoons will reach the limit of their tolerance and suffer mass mortality (e.g., KENSLEY 1978).

The fourth assumption is that in certain years, after high levels of rainfall, temporary connections with the open sea result from breaches in the sand bar. This results in temporary tidal systems which are very productive due to an influx of marine organisms into the sheltered waters of the lagoon. The length of time the lagoon is open to the sea determines the extent of recolonisation by marine organisms.

The final assumption is that food abundance for waterbirds is a function of the immediate past history, that is, the extent of recolonisation of fresh water and marine resource organisms during the rainy season, and the presence of water of the 'right' depth which would enable the wading water birds access to the food resources. Past bird records should enable us to comment on the recent history of the coastal wetland systems.

From the above we are now in the position to present a **conceptual model** of the sequence of events that may pertain in the annual cycle of a coastal lagoon in Ghana (Fig. 4) and how those events may affect the availability of food for the shorebirds.

1. The main food available for birds between the period January to March (end of the dry season) are seeds. This is due to the hypersaline conditions that occur in the lagoons at this time. In the extreme case the whole lagoon may dry up leaving seeds as the only source of food, apart from terrestrial insects. Under the normal hypersaline conditions, large schools of several species of fish persist in areas where salinity is below 50‰. In the main body of the lagoons, the falling water levels serve to concentrate the fish into a smaller area which may increase feeding success by the waterbirds. Benthic invertebrates are virtually non-existent at this time.
2. April and May can be typified by moderate water levels caused by the inflow of fresh-water from the northern part of the catchment. The salinity falls to levels approaching that of sea water, allowing the fish to

reproduce giving rise to fish fry which are of the right size for most of the smaller waders. Seeds are less abundant as they have started to germinate and the growth of the sea grass on the lagoon bottom reduces their availability. The reduced salinities allows the recolonisation of the lagoon by benthos, the main groups being amphipods, polychaetes and molluscs.

3a. The period June to October is characterised by very high water levels and salinities much lower than sea water. Fish are abundant but not available to the birds due to three factors. The first is that water levels are in the main part too deep for the majority of the wading birds to exploit the resource. The second reason is that the sea grass in the lagoon grows much faster at reduced

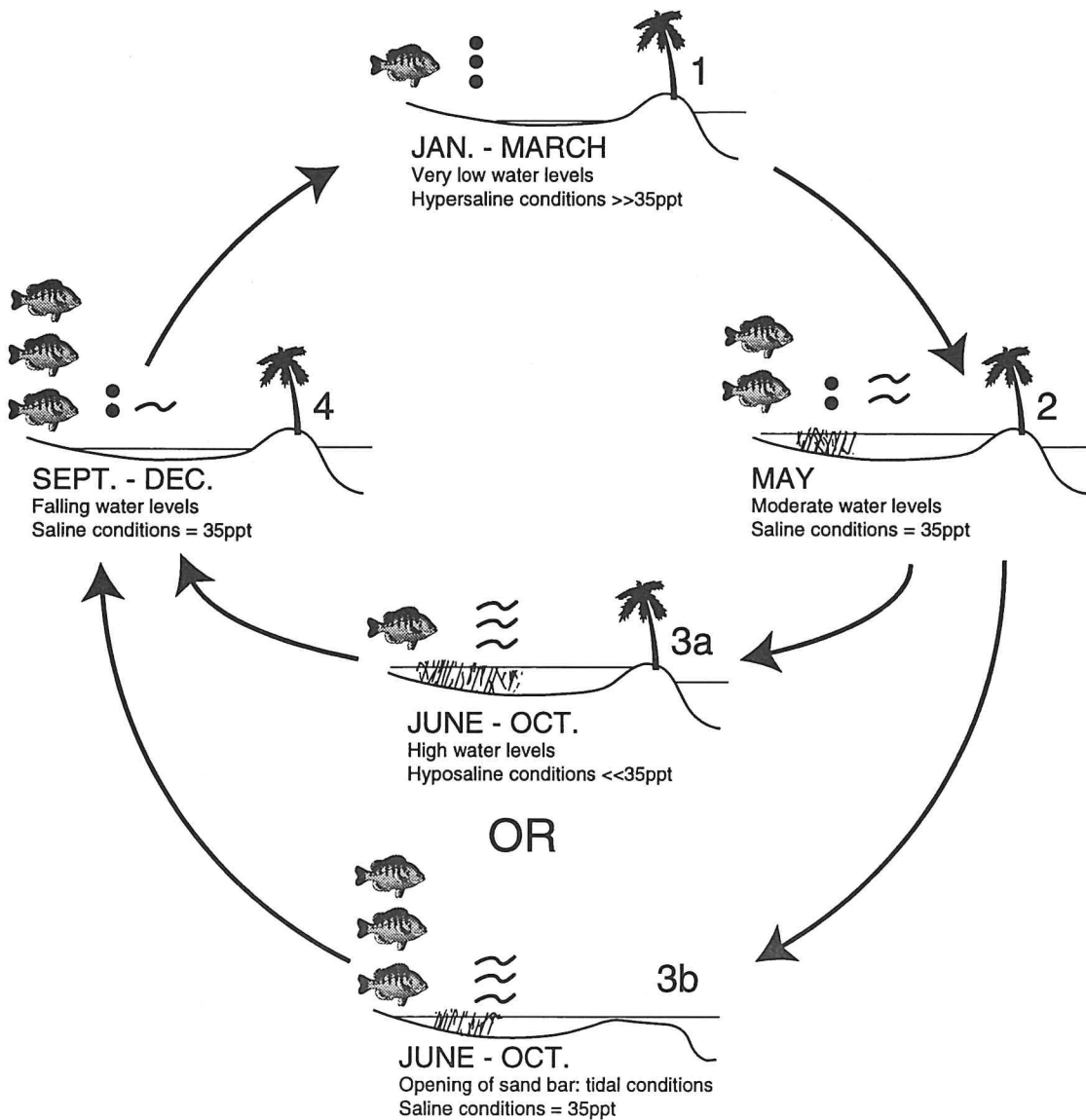


Fig. 4. Schematized outline of the seasonal changes in water level, salinity and the availability of benthic (seeds and invertebrates respectively) and pelagic prey (fish) in coastal lagoons in Ghana (the *a priori* conceptual model). See text for discussion.

salinities, providing cover for the fish. Finally, some of the fish species present in the lagoon prefer to move to the margins of the lagoon into areas of newly flooded terrestrial vegetation in order to take advantage of food resources such as drowned insects and rotting vegetation. The flooded vegetation, mostly the sedge *Paspalum*, provides cover for the fish and waders tend to avoid such areas. Seeds are not available at this time as they have either germinated or are too deep for the birds to reach.

3b. In cases of exceptionally high water the lagoon water breaks the coastal sand bar and the lagoon system becomes tidal. The relatively narrow opening as compared to the vast expanse of the lagoon means that true tidal conditions are manifested only in the immediate vicinity of the opening. More importantly however, the opening to the sea allows marine fauna, especially euryhaline fish and crustacea, to enter the lagoon. Fish

and benthos become available to the birds as depressions in the lagoon bottom trap fish at low tide and exposed mudflats provide feeding grounds for waders.

4. The period September to December is characterised by falling water levels and increasing salinity. In the case of situation 3b (where there is a breach in the coastal sand bar), long shore drift carries sand to close off the lagoon again. Fish are available for birds as the fish are trapped in pools of water left by the shrinking lagoon, seeds are again available as they are exposed as the water recedes, as are benthic organisms especially sessile molluscs such as mussels. By the middle of the dry season water levels have fallen even further, the lagoon water starts to become hypersaline. The majority of the lagoon at this time would have water depths of less than 50 cm and vast expanses are between 1-10 cm in depth, ideal for small waders.



Flock of Black-tailed Godwits and Black-winged Stilts near Anloga, Keta Lagoon (Photo: P. Battley).

4. DESCRIPTION OF STUDY AREAS

4.1. SONGOR LAGOON

Songor Lagoon (Fig. 5) is one of the two major lagoon systems associated with the Volta river estuary. The lagoon is closed off from the sea (KWEI 1977, MENSAH 1979) and is situated to the west of the Volta estuary (05°49' N, 00°28' E; see Fig. 3). Songor Lagoon can be approached by road from three directions: from Ada Foah in the east along the coast to the villages of Pute and Totokpoe which are situated on the edge of the lagoon; from the west through Sege, Anyaman to Lolonya village and from the north through Koluedor and Bonikope. Open water can cover an area of ca. 115 km² and extends ca. 20 km along the coast and ca. 8 km inland behind a narrow sand dune on which villages like Pute and Totokpoe are situated.

The Songor wetland comprises a brackish water lagoon with extensive mudflats and islands, a broad sandy beach in the south and flood plains with degraded mangroves and

coastal savannah vegetation. The lagoon is shallow, the deepest part in October 1994 was about 50 cm and most areas were less than 10 cm. The land around the lagoon is low-lying, with the highest point less than 10 m above sea level. A number of small streams including the Sege and Zano, drain directly into the Songor although several small dams have been constructed on the streams for water supply. Channels which in the past provided direct connection with the Volta river are effectively blocked. The lagoon has no direct access to the sea and sea water replenishment results from seepage through the sand dunes.

Five main vegetation types are identifiable in the Songor wetland: saline marshes on parts of the mud and salt flats; low degraded mangroves, mainly *Avicennia africana*, along the margins of the lagoon; waterlogged grassland; riverine woodland and scattered thickets of shrubs, climbers and small trees on higher ground. The vegetation is largely degraded and the terrain is characterised by farms, secondary

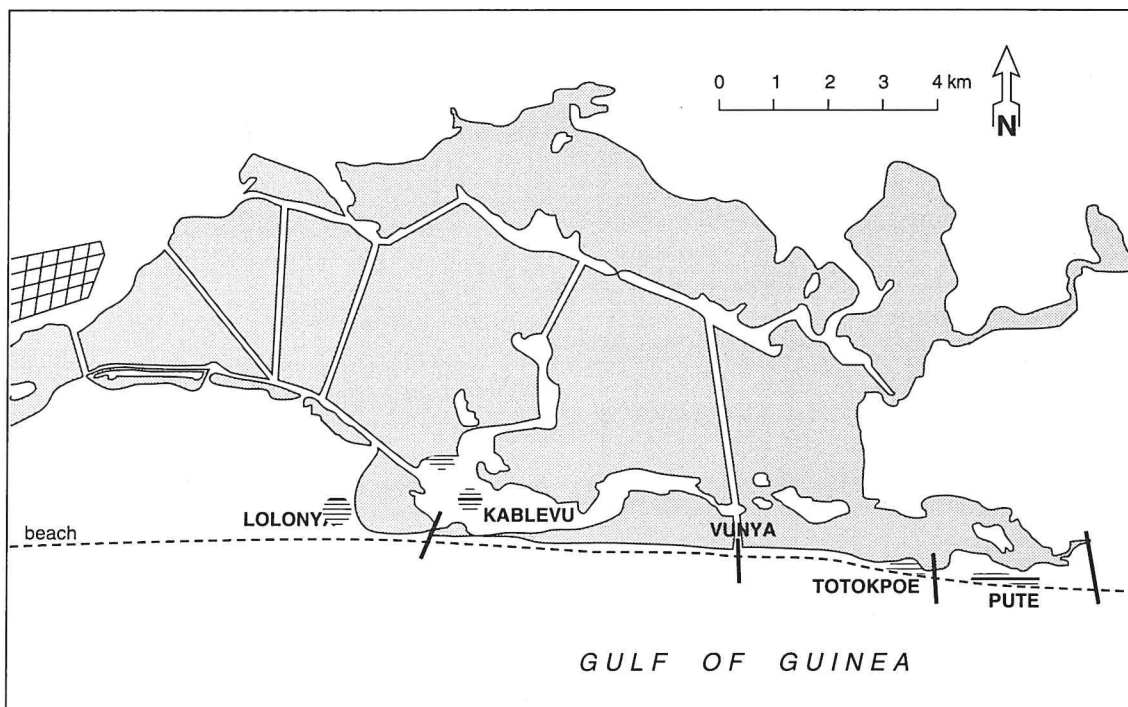


Fig. 5. Map of Songor Lagoon, showing the villages (horizontal hatching), the basins (shaded), and the borders of the bird counting areas (indicated with lines perpendicular to the coast).

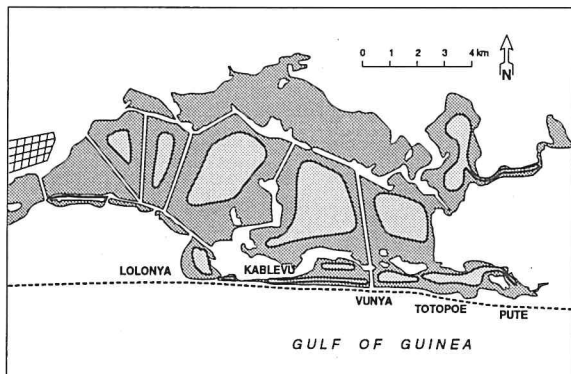


Fig. 6. Map of Songor Lagoon showing the approximate extent of open water (lightly shaded) as estimated from a continuous video-recording taken during the aerial survey on 14 October 1994.

vegetation on abandoned farms, wastelands and eroded lands invaded by Neem (*Azadirachta indica*), and isolated trees like Fan Palm (*Borassus aethiopum*), Mango (*Mangifera indica*), Silk Cotton Tree (*Ceiba pentandra*) and Baobab (*Adansonia digitata*).

Human settlements are concentrated along the coast and around the northern edges of the lagoon. The indigenous people in the area are the Ningos in the west and the Adas in the east. Land is owned by kingship groups or families and held in custody by the elders of each group. Land use in the Songor area includes farming, animal rearing, fishing, salt collection, recreation, settlement and associated constructions such as roads. Farming, fishing and salt winning are the main occupation of the people.

Main crops cultivated include cassava, maize and vegetables (particularly okra, pepper and tomatoes). Small scale livestock production is common in all the villages, with pigs being the most popular in the coastal villages, although small numbers of chicken, goats, ducks and sheep are also kept. All these are reared free range. Cattle are grazed extensively on the grasslands in the north. Fishing is undertaken in both the lagoon and the sea, the latter being a major commercial activity. The main species caught in the lagoon are tilapia and lagoon crabs.

The Songor area is traditionally known for salt production. Salt winning using both traditional

and modern methods is a major commercial activity in the villages around the lagoon and a majority of the people derive their livelihood from salt collection. In the dry season, extensive parts of the lagoon dry up, leaving large deposits of salt, which is then collected by the people. Proposals by the Minerals Commission advocates the conversion of Songor Lagoon into a large scale industrial salt complex, with estimated production level of 1.2 million tons/year. This proposed development could be a major threat to the wetland ecosystem since it would, no doubt, cause major changes in the ecological integrity of the lagoon.

For convenience in the shorebird monitoring studies, the lagoon had been divided into four sectors, named after the main village along the particular stretch of shore: Lolonya, Kablevu, Totokpoe and Pute. The greater part of the lagoon, however, was dry in October-November 1994 (see Fig. 6 for extent of water coverage in that period) and the detailed waterbird studies had to be concentrated at two sites, Vunya camp (eastern end of the Kablevu sector) and Totokpoe, which had standing water at the time.

Vunya - A small water body maintained by seawater seepage through the dunes was present east of Vunya camp (Vunya Old). The water was very shallow (maximum depth 5-7 cm), and consequently, the water temperatures were frequently high. A layer of semi-liquid mud overlay dark grey clay, which was somewhat firmer than more eastward at Totokpoe. The extensive saltpan areas north and west of Vunya were mostly dry during our visit, and contained no birds nor salt workers. The rains in October and early November filled a small basin just west of Vunya camp (Vunya New), which was rather sterile and attracted no birds during the time of our study. Human activity was low during the study period. There were some cattle herds along the lagoon edge, and a few people fished in a small ditch well away from the main water body.

Totokpoe - Water depth in the lagoon did not exceed 50 cm. The mud in the lagoon was very soft and had a high coverage of *Ruppia maritima* in areas with standing water. Much of

the lagoon near Totokpoe had dried up, although a continuous seepage of seawater through the dune ridge wetted the seaward edges. Due to the high evaporation during the day, the seepage areas were much wetter in the early morning than later in the day. The volume of water seeping through the dune is affected by the stage and size of tide (e.g., more flow at high tide). At the western limit of standing water, a small corridor of mangrove trees (*Rhizophora* sp.) bordered the dune ridge in the seepage areas. This corridor continued west to Vunya and beyond. The substrate between the mangroves was a soft and sticky grey mud.

The people of Totokpoe made channels from the lagoon's main water body towards the dune ridge in which they set cane-traps to catch fish. The salinity of the main lagoon water body was very high (>100 ppt) while that of the seepage

water was 27 ppt, rising to 31 ppt halfway down the channels (Fig. 7). Cast-net fishing also occurred in the main water body. Other human activities on the lagoon were the drying of fish on exposed flats near the village. As a result of these activities, the soft mud bottom of the deepest part of the lagoon was heavily reworked by human trampling, making the water very muddy and turbid.

4.2. KETA LAGOON

Keta Lagoon (Fig. 8) is an extensive brackish water body situated to the east of the Volta river estuary (05°55' N, 00°59' E; see Fig. 3). The lagoon is an open lagoon but was effectively closed in October/November 1994 when the study was carried out. The only small outlet into the sea for the entire Keta Lagoon complex was at Atiteti, but this was more linked

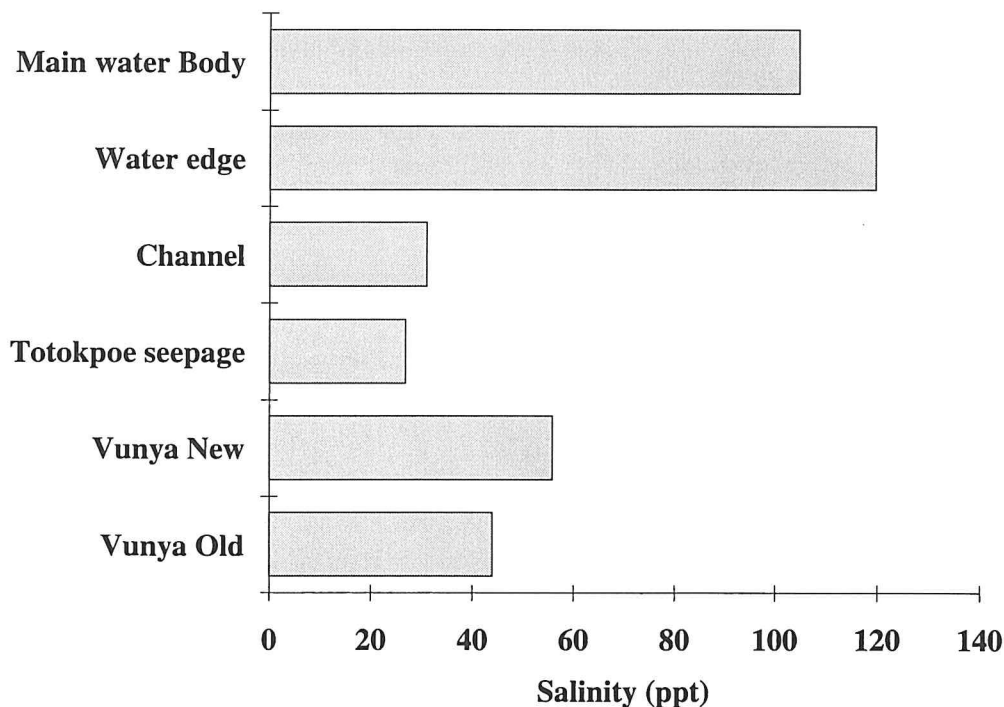


Fig. 7. Salinities at selected sites in Songor Lagoon in late October 1994. The main water body refers to the lagoon holding 50 cm deep water near the village of Totokpoe, and the edge of this part of the lagoon is referred to as the water edge. The channel refers to the small man-made fishing channels running perpendicular to the seashore (but not reaching it) from the lagoon at Totokpoe. This channel is filled with seepage, which has approximately the same salinity. The new water at Vunya is found west of the dike, the old is just east of it.

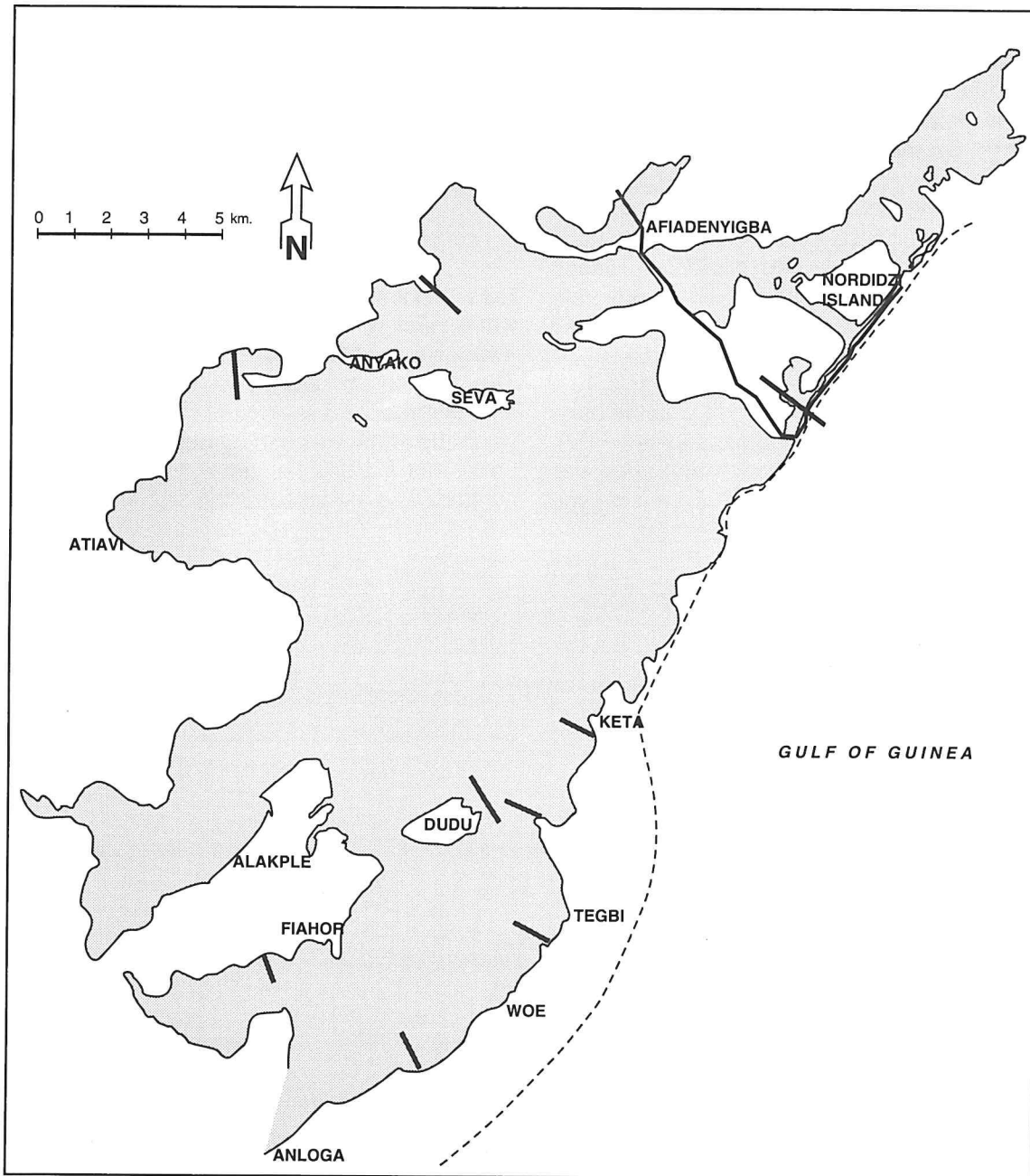


Fig. 8. Map of Keta Lagoon, in which the towns and main villages are indicated by their names, the basins are shaded, the borders of the bird counting areas are indicated with lines perpendicular to the coast, and the benthic sampling transects are indicated with thicker lines projecting from the shore at Anloga, Fiahof and Tegbi in the lagoon.

with the Angaw Lagoon than with the main Keta Lagoon. The open water of Keta Lagoon is estimated to cover an area of 300 km² which varies with the season. The proposed Keta Ramsar Site itself covers ca. 530 km² and comprises the open water, the surrounding flood plains and the mangrove swamps east of the Volta River (Fig. 3). The Keta Lagoon stretches for ca. 40 km along the coast and is separated from the sea by a narrow coastal ridge which is only ca. 2.5 km at its widest point and ca. 0.92 km at the narrowest portion

Keta Lagoon can be approached through several points along the main Accra-Aflao road: to the south from the Anlo-Keta junction where starting from Srogboe, the coastal road runs more or less parallel to the lagoon; to the north through the junctions to Anyako and Afiadenyigba; and to the east through Denu. The lagoon is surrounded by numerous settlements and the surrounding flood plains consists of marsh, scrub and farm lands and substantial mangrove stands which are heavily exploited for fuelwood. The vegetation of the Keta Lagoon wetland is very much the same as the Songora area.

Inflow into the Keta Lagoon is from three main sources: run-off from the Todzie River which enters and fills the Avu lagoon in wet years and overflows into the Keta lagoon via several small tributaries; run-off from Aka and Belikpa streams which enter Keta lagoon directly from the north; and to a limited extent, from the Volta River itself. Records of stream flows of the Todzi river are incomplete and in some years inconsistent, therefore the data are not presented here. Records from the Water Resources Research Institute, however, indicate that the annual mean run off from the basin is about 1.4×10^6 m³ per day and the mean monthly run off ranges from a maximum of 155.52×10^6 m³ to a minimum of 0.09×10^6 m³.

Flow from the Volta River has become less important in the recent past owing to the regulation of the river flow by the Akosombo dam. Before the construction of the dam, stream flows were much more variable ranging from 11,050 m³/s at times of peak flows to 30 m³/s at times of low flows (PETR 1986). This large amount of water contributed to the water balance of the Keta Lagoon till 1966. Stream flows in the lower Volta show far less variation

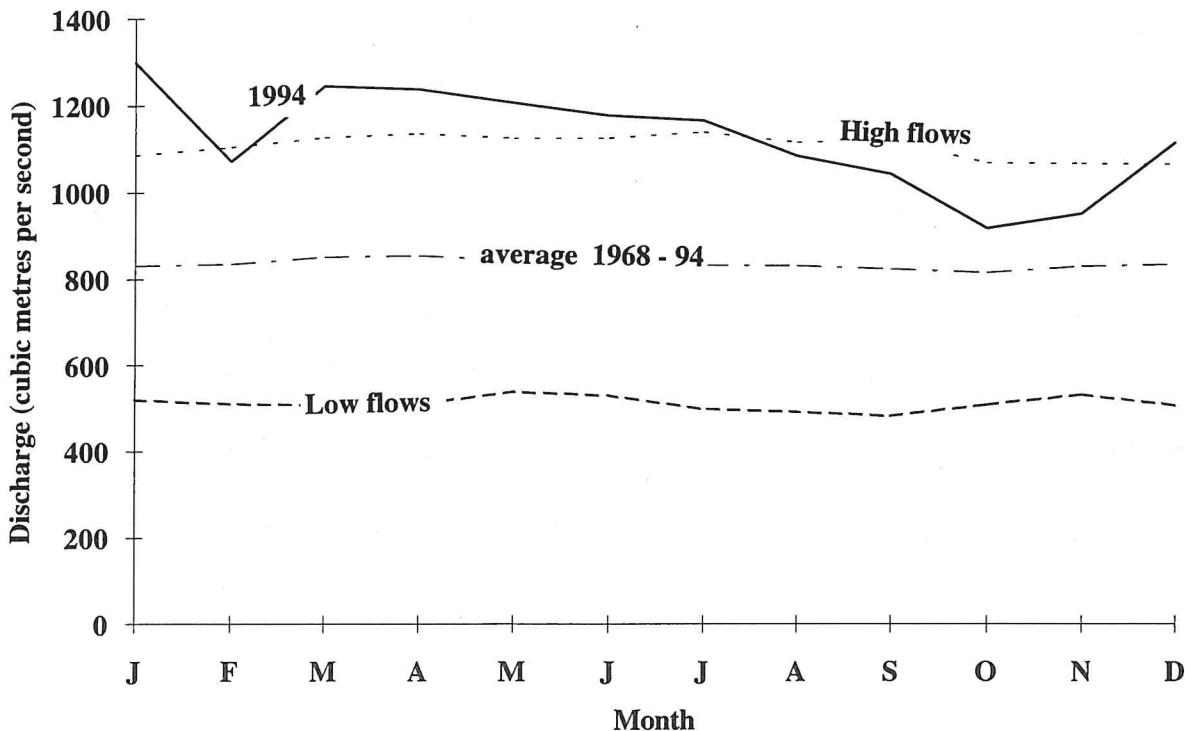


Fig. 9. Mean monthly water discharge from the Volta River catchment in 1994 and the previous 26 years. The averages for years with typical high flows and low flows are indicated as well.

in the post impoundment period with flow rates averaging 900 m³/s. Figure 9 shows a comparison of the flows in 1994 with the average for the 26 years that data were available, as well as the minimum ('low flow curve', average of the 5 years with lowest flows: 1968, 1969, 1983, 1984, 1985), and the peak flows ('high flow curve', average of the 5 years with highest flows, 1980, 1981, 1991, 1992, 1993). It can be seen that 1994 had a comparatively high flow. Despite this, the water levels in the lagoon were very low during the study period, most areas were less than 30 cm and the deepest section was 1.5 m. This would imply that the main source of fresh water to the lagoon is run off from the catchment and direct rainfall on the lagoon. The only significant outlet of water from the lagoon is by evaporation, estimated at 1,500 mm annually (TAHAL CONSULTING ENGINEERS 1986).

The construction of the Akosombo dam has been blamed for a number of ecological changes which have occurred within Keta wetland in the recent past. This includes silting and blockage of the channels inter connecting the

lagoons which is said to have affected the direct and natural drainage system that used to regulate the lagoon water levels. The result is that in the dry season, large areas of the lagoon and marshlands dry up, leaving small pools of hyper-saline water (see Figs. 10 and 11 for extent of water coverage in October 1994 and salinities at selected sites, respectively). In the wet season and during heavy rains, the water level in the lagoon becomes so high that houses and crops around the periphery of the lagoon become inundated.

The indigenous people within the Keta wetland are the Anlos in the south, the Ewes in the north and the Tongus in the north-west. Fishing (both marine and lagoon), salt mining and vegetable farming are the main occupations of the people in the south, while those in the northern sectors are mainly farmers with some fresh water fishing in the areas along the rivers and channels. The southern part is famous for its shallots and market gardening, and produces large quantities of onion and okra. Other crops grown include pepper, tomatoes, cassava and maize. Lagoon fisheries is a major source of livelihood for many people in the area, the species caught being tilapias which are sold in the region and as far as Accra. Salt mining is a substantial industry, particularly during the drier periods of the year, November - March. Mangrove exploitation for fuelwood is another important source of income in the area; stacks of mangrove wood were sold all along the main road from the Anlo-Keta junction to Keta and a major fuelwood market thrives in the village of Anyanui, where the wood is transported in canoes from the mangrove stands.

Three major socio-ecological problems are apparent in the Keta wetland:

- severe coastal erosion: over the past 50 years, the coastline in the area is reported to have receded by some 500 m (DORBU, 1985) and the ruins of eroded houses are a common sight in Keta and the other settlements along the coast.
- periodic flooding of the lagoon and its surroundings which happen rapidly with the onset of the rains leading to destruction of farms, houses and property.

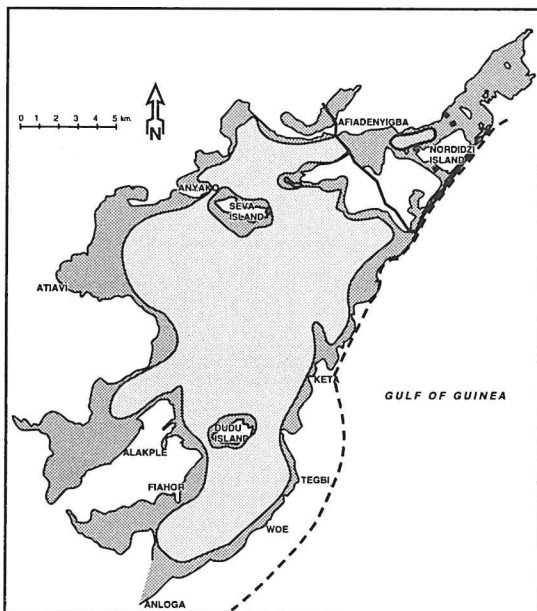


Fig. 10. Map of Keta Lagoon showing the approximate extent of open water as estimated from a continuous video-recording taken during the aerial survey on 14 October 1994.

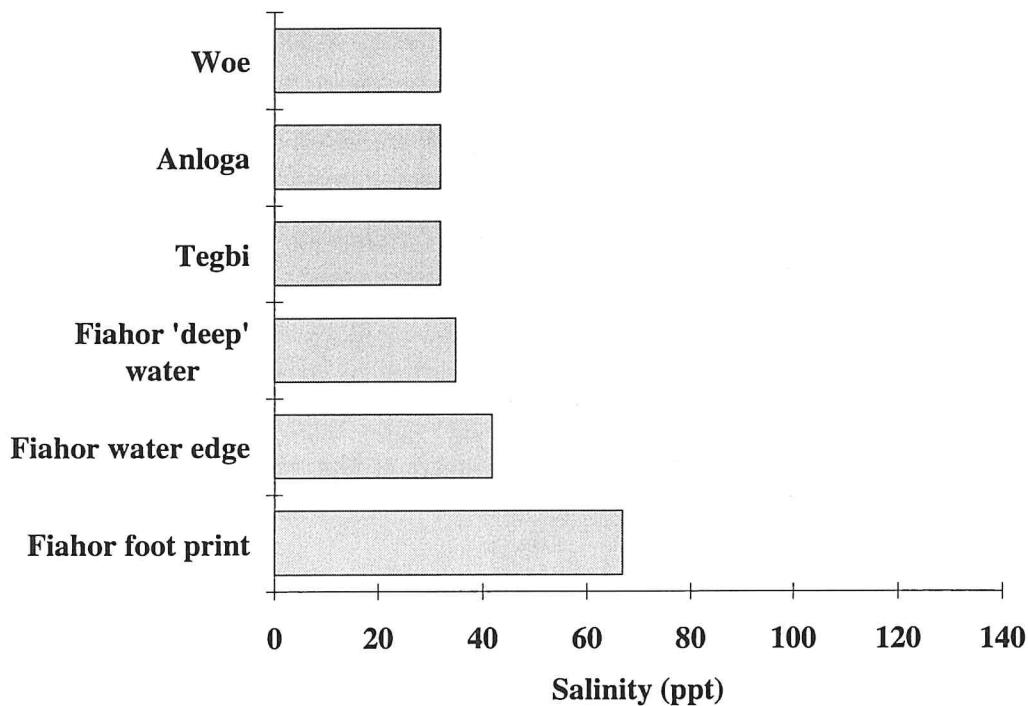


Fig. 11. Salinities at the study sites in Keta Lagoon in late October 1994. The foot print refers to a water-filled print in an otherwise dried out flat not very far from the retreating waterline.

- insufficient land, suitable for both farming and human settlement leading to high human population densities.

The intensive waterbird studies in October-November 1994 concentrated on three of the sections of the lagoon included in the routine waterbird monitoring programme: Fiahor, Anloga and Tegbi.

Fiahor - Due to the drought, the main water body immediately south of the Fiahor, village was about 500 m from the normal high water mark, but eastward a large dry mudbank extended approximately 1500 m into the lagoon (see Fig. 12 for bottom profile of the Fiahor part of the lagoon). Maximum water depth near-shore was never more than 30 cm. Water levels were higher in early November than in mid October. In this part of the lagoon, the flooded substrate was softer than the dried up sediment. The substrate consisted of clay and was covered with extensive beds of *Ruppia maritima*.

Human activity levels were low. Fishermen were active with cast-nets and with canoes. In early November local fishermen were building a fish fence offshore on the mudflat where the bird observations were being made.

Anloga - The Anloga area differed from the other sites in that it had a freshwater inflow (from the Volta River in the west). Two habitat types were recognisable in the study site: (1) Along the outflow stream of the Volta an extensive *Typha*-marsh existed. Within this habitat there was a complex network of channels and pools. Water depth here was 10-40 cm deep with very soft mud substrate. Submerged macrophytes were abundant in the stagnant waters. (2) Adjacent to the marshes were large exposed mudflats which continued along the southern and eastern shores of Keta Lagoon. They were prone to drying out during periods of low water levels, as it was in the period preceding the study. After the heavy showers experienced in southern Ghana in the second half of October 1994, large areas of the

mudflats were flooded. The recently flooded areas were obvious from the hard cracked surface of the mud, which contained no live invertebrates.

Tegbi - A continuous stretch of mudflats extended all the way from Fiahor via Anloga and Woe to the Tegbi village. Although the extent of water coverage in the Keta Lagoon was rather low during the study period (see Fig. 10), at Tegbi the water reached within 200-500 m of the permanent higher shore (cf. Fig. 12). In addition, afternoon breezes pushed the water temporarily over parts of the dry flats. The probable great interchange of birds between Tegbi and Woe might relate to wind effects on

relative water levels and mudflat exposure. The sediment was quite sandy and firm, although in a few places a layer of foul smelling mud occurred on the surface. At the north-eastern end of the study area, the flats had been partitioned by small embankments for fishing. Fish-attracting devices, acadjas, made of heaps of twigs surrounded by a circle of vertical sticks, were widespread and frequently used by herons to roost on during the day.

Human activity was very prominent, with sometimes a constant stream of fisherfolk walking to and from canoes at the water's edge. While most human activity involved the transport of fish from the canoes, fishing in shallow water with cast nets also occurred.

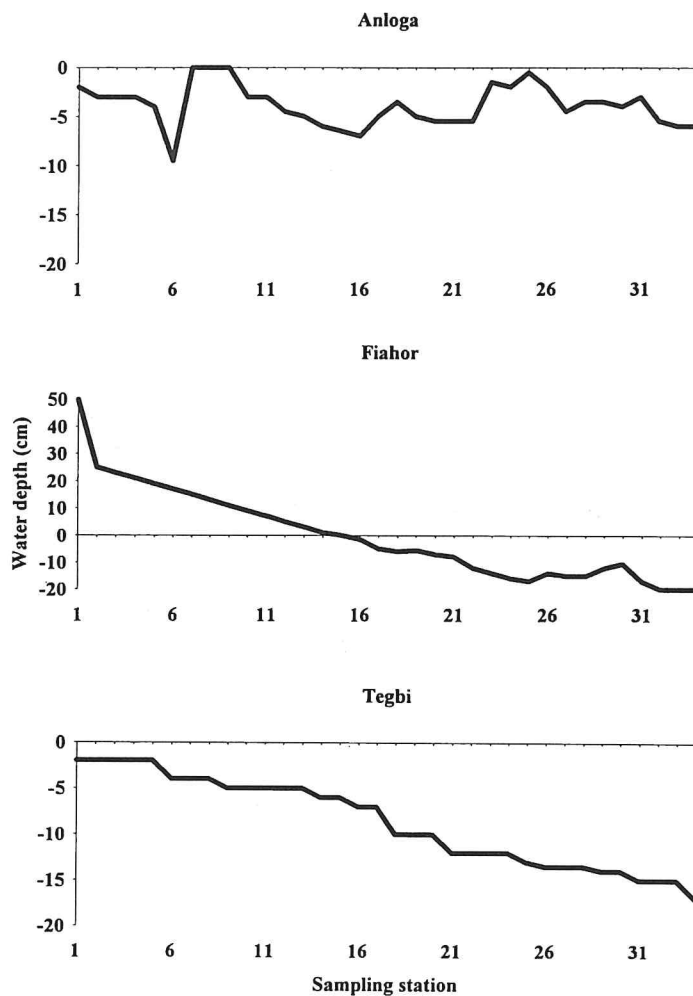


Fig. 12. Bottom profiles relative to water surface (0 cm) of the three benthic sampling transects in Keta Lagoon, the positions of which were indicated in Fig. 9. The sampling stations along these transects are 30 m apart and run from the shore into the lagoon.

5. CLIMATIC AND WEATHER CONDITIONS IN 1994

General - The Keta and Songor lagoon area has an equatorial climate with high temperatures, high humidity and medium to low rainfall. The climate is dependent on the movement of two air masses. The first is the moist monsoon from the southwest with a long sea track over the Gulf of Guinea, the second is the dry Harmattan wind from the northwest over the Sahara desert. The contact band between these two air masses is known as the Inter Tropical Convergence Zone (ITCZ). The ITCZ oscillates seasonally north and south of the equator each year in phase with the sun, moving to its northern-most point in mid-September and farthest south in December. As a result of this movement and in the absence of any marked temperature changes in the area, rain or absence of rain becomes the principal determinant of season. Due to the flatness of the terrain, rainfall is usually of the convective type. During the field work we experienced several line squalls. The description of weather components that follow are based on records from the Meteorological Services Department of Ghana and unless otherwise stated are for the period 1963 to 1994.

Rainfall - Rainfall in Ghana generally is very seasonal and shows great variability from year to year. The monthly distribution of rain in the Keta and Songor lagoon area has a bimodal pattern with two distinct rainy seasons. Normally the main rains fall from March/April to July with maximum precipitation in June. Approximately 60% to 75% of the annual rainfall occurs during the main rainy season. This is followed by a short period of dry weather in August-September. A minor rainy season runs from September to November. The 30-year mean monthly rainfall distributions for Ada, Keta and Akatsi are shown in Figs. 13A-C. The mean annual rainfall increases from the coast inland, (783 mm at Keta in the south to 948 mm at Akatsi). Ada, located on the west bank of the Volta estuary has a synoptic meteorological station approximately 3 km from the coast and its rainfall pattern can be taken as representative of coastal rainfall trends. There was a

period of greater than normal rainfall between 1960 to 1977, followed by reduced rainfall in subsequent years. A drought prevailed over the years 1983 to 1986 and this is confirmed by the drying of the lagoons during 1985/86. The drier than normal conditions at coastal locations are not necessarily related to flood levels since runoff to the lagoons is largely determined by rainfall at the upper elevations of the drainage area. The mean monthly rainfall values during 1994 were generally higher than the 30 year average.

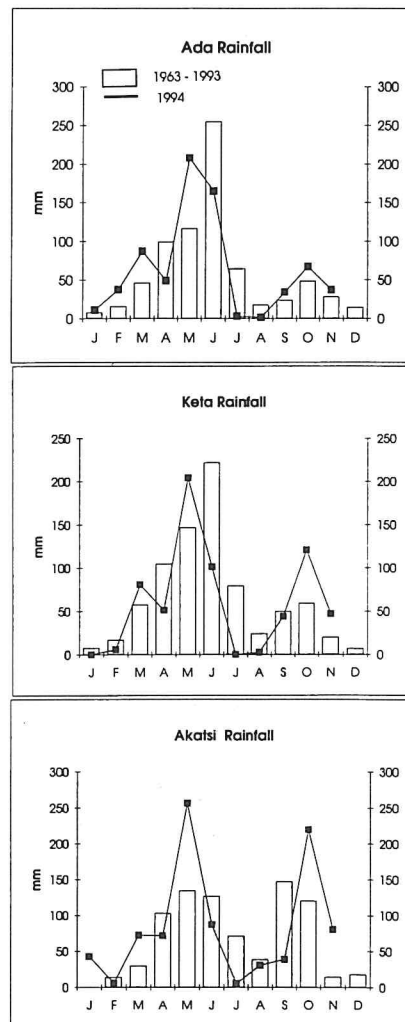


Fig. 13. Rainfall data for three stations within the study area. A: Ada (Songor Lagoon), B: Keta (southern half of Keta Lagoon), and C: Akatsi (just north of Keta Lagoon). The histograms give the average for the period 1963-1993; the filled squares the values for 1994.

Air temperature - Air temperature of the coastal savanna zone is high with relatively minor seasonal variations (about 3°C). The hottest months of the year are February and March, just before the rainy season. The coolest month is August. In the coastal strip, the modifying influence of the sea reduces the diurnal temperature range as well as its seasonal variation. The mean annual temperature of Ada is 27.9°C and that of Keta is 27.5°C (see Figs. 14A and 15A).

Relative humidity - Relative humidity (RH) in the area is usually over 90% during the night and early morning, reaching 95% to 100% on the coast. RH decreases during the day with a minimum in the late afternoon. Along the coastal strip at Keta lagoon, the humidity can drop to about 75% in the southwest and 65% in the southeast with a seasonal variation of about 15%. Due to the Harmattan, extremely low relative humidities may occur for a few days during December, January or February. Details of variations in the relative humidities for Ada and Keta are given in Figs. 14B and 15B.

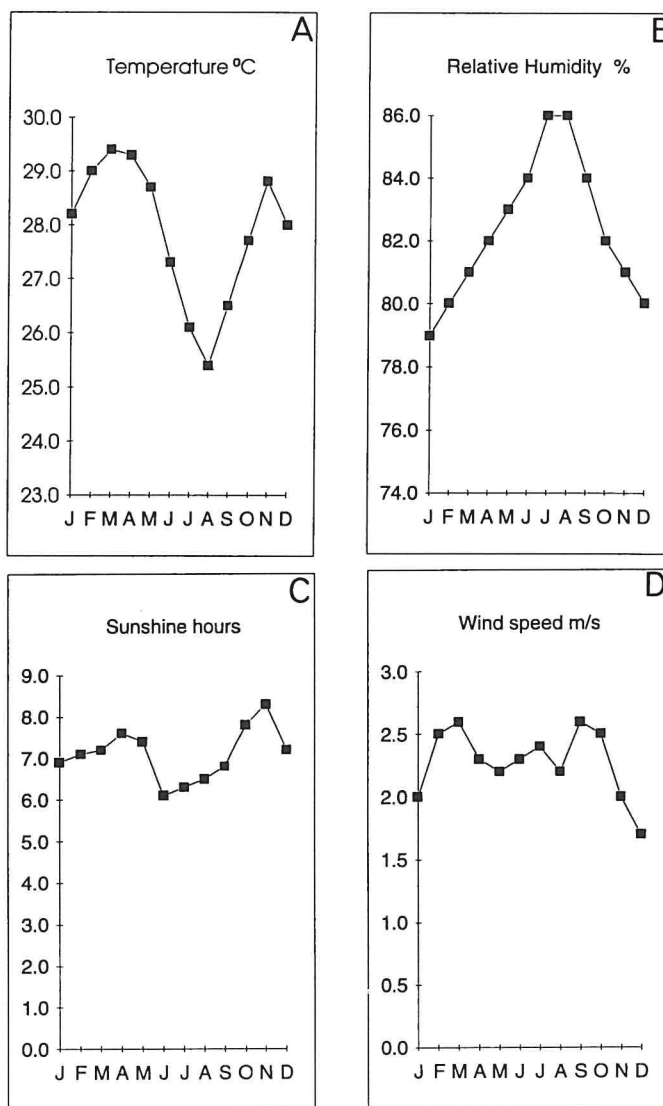


Fig. 14. Climatological conditions for Ada, close to Songor Lagoon. A: air temperature (°C), B: relative humidity (%), C: sunshine hours per day, and D: wind speed (m/s). Source: Meteorological Services Department of Ghana.

Hours of sunshine - The number of hours of sunshine ranges between 4 and 8 in the two study sites. Sunshine exhibits a bimodal pattern with peaks in April - March and October - November. The hours of sunshine at Ada shows less variation than at Keta (Figs. 14C and 15C).

Wind speed and direction - Winds are dominated by the southwesterlies, and for the period 1963 to 1994, only thirteen months had prevailing winds in any other direction. Wind speeds at Ada were generally higher than at Keta (Figs. 14D and 15D). Mean monthly wind speeds in m/s ranged from 1.6 to 2.6 at Ada and 0.6 to 1.8 at Keta.

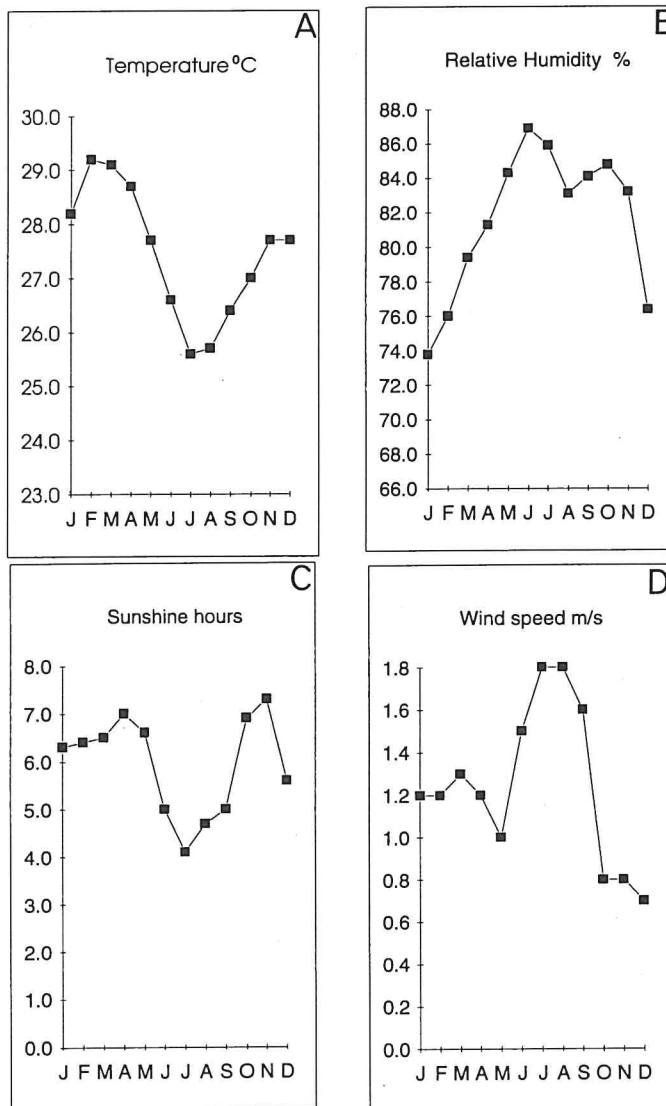
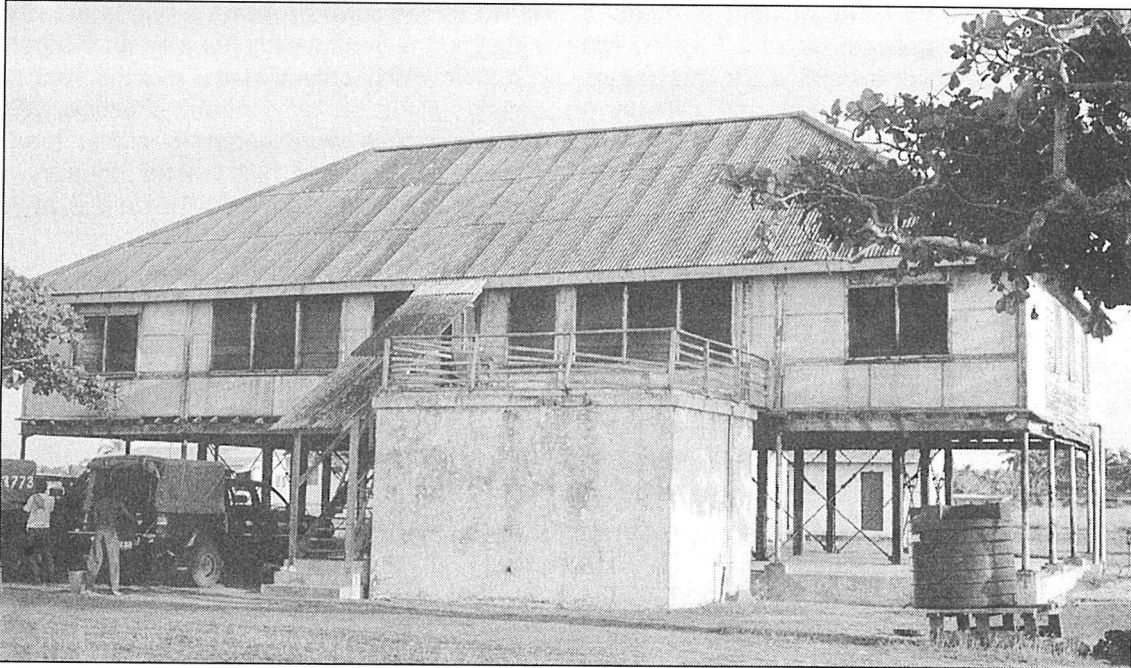


Fig. 15. Climatological conditions for Keta, the town at Keta Lagoon. A: air temperature (°C), B: relative humidity (%), C: sunshine hours per day, and D: wind speed (m/s). Source: Meteorological Services Department of Ghana.



Temporary field research (Godwits) station at Ada Foah (Photo: P. Battley).



Fieldwork preparations at Fiahor, Keta Lagoon (Photo: T. Piersma).

6. FIELD METHODS

6.1. MEASUREMENTS OF PHYSICAL AND CHEMICAL HABITAT CHARACTERISTICS

Water parameters - Measurements of basic physico-chemical characteristics were taken at all the sites visited. Dissolved oxygen, read as both percentage saturation and as concentration, as well as temperature were measured by probes attached to a portable Jenway® oxygen meter. Both air and water temperatures were taken. The oxygen probe was calibrated in the laboratory before use in the field by cross checks with samples analysed by the Azide modification of the Winkler method (APHA 1984). In the field, the instrument was recalibrated by fixing the internal 100% saturation level with the probe a few millimetres from the water surface. Due to the very shallow water present at the sites, water was collected in a small beaker and the reading for oxygen taken after emersion of the probe for about 1 minute. Salinity was measured by a direct reading refractometer manufactured by Atraco® which read to 100‰. At most of the sites one or two measurements were taken (see Figs. 5 and 7 for sampling sites). At Fiahor, measurements were taken at two hourly intervals at 15 stations over a 24 hour period on 7 October. This exercise was undertaken to provide some idea of the diurnal variations in temperature and dissolved oxygen.

Sediment - At each site, samples of the sediment were taken for particle size analysis which was undertaken by dry sieving through a graded set of stainless steel sieves for the sand fractions and by timed decantation for the clay fraction. In addition to this, samples were washed through a 1 mm sieve and the residue separated into three size classes of < 2 mm, 2 to 4 mm and > 4 mm to estimate the amount of large particles present in the sediment that could present problems to probing waders.

Submerged vegetation - At Fiahor and Tegbi, the presence and absence of submerged vegetation was noted and the extent of coverage of any sea grasses present was estimated as percent cover of a 0.1 m² quadrant.

6.2. BENTHIC FAUNAL SURVEYS

Between three to five core samples were taken at each sampling site using a corer with an area of 0.00196 m². Core depths ranged from 5 -15 cm depending on substrate type. In areas of unconsolidated sediment where samples could not be retained by the corer, a stainless steel sieve (mesh 250 microns) was used to scoop up bottom material. All samples were washed through a sieve (300 micron mesh size) and material retained on the sieve removed. Samples were fixed in the field with 4% formalin and taken to the base camp for identification and counting. After counting, a selection of the invertebrates found in the samples were dried at 60°C for 48 hours, weighed and then ashed at 600°C for 1 hour and 20 minutes to obtain ash-free dry masses (AFDM)

6.3. FISH SURVEY

The purpose of the fish survey was to find out the species present and to establish the fish size spectrum. Three methods were used, all relying on active gear. These were:

Trawling - A bottom drag from NIOZ, designed to catch bottom-dwelling fish, was used at Fiahor. The net which had an opening of 1 metre and stretched mesh of 1 cm was pulled along the lagoon bottom for a distance of approximately 80 m. Three replicates were made. The net however was very heavy to pull and collected, in addition to fish, many old shells and other debris.

Liftnets - Five liftnets, each with an area of 0.1 m², were constructed using 1 mm mosquito netting. They were deployed at Fiahor, two within an area of open water, two in an area with sea grass and one in an area where a scum of decaying algae was found. The nets were initially lifted every 30 minutes but due to poor fish catch, were later lifted whenever fish were present over them.

'Sweep net' - A net was constructed in the field based on local design. Basically the net consisted of three metres of 1 mm mesh polythene mosquito net strung between two broom

sticks. The net was operated by two people, one on each stick 'sweeping the water' in a rapid movement for a distance of between 3 to 10 m. This net was used at Fiahor and at Tegbi.

Fishermen - In addition to the above, the catches of Tegbi and Fiahor based fishermen were examined and a sample of fish taken from a fisherman at Fiahor. They used cast nets of 4 m diameter and 2.5 cm stretched mesh.

6.4. WATERBIRD COUNTS ON THE GROUND

The two sites, Keta and Songor, had been regularly counted every month since 1986 under the SSBP-G. The counting was done from the ground, mainly on foot, by trained teams of two or three persons using binoculars and 20-60 x telescopes. Each site was divided into sectors, four for Songor: Lolonya, Kablevu to Vunya camp, Totokpoe and Pute (Fig. 5) and eight for Keta Lagoon: Alakple to Fiahor, Fiahor to Dudu island, Anloga to Woe, Tegbi, Keta, Adina, Afiadeniyigba and Anyako (Fig. 8). Coverage of the Songor sectors normally started around 7:00 hr from the Lolonya end and was completed by late afternoon. Coverage of the Keta sectors, however, took two days using a single team. All birds seen were counted and recorded in field sheets and the data was transferred on to species and site sheets in the laboratory.

On 14 October, simultaneous ground counts were undertaken in all the sectors to provide ground truthing for the aerial survey which was carried out on the same day. Four teams of two persons, each team with at least one experienced counter, were used for the exercise. Counting was done on foot, starting around 6.30 hr and finishing at dusk. The Keta site was covered in the morning with one team covering Srogboe through Fiahor to Dudu island, the second team Anloga, the third team Woe through Tegbi to Keta and the fourth team counting Adina, Anyako and Afideniyigba. Songor was covered in the afternoon with one team starting at the Lolonya end and working towards a second team which started from the Pute end (Fig. 5). The advantage of the simultaneous count over the monthly counts was that most of the different sectors were

covered during the same period in a day and this reduced the possibility of double counts. This, however, was only possible because of the availability of the required human resources, i.e. experienced counters at the time of the study.

Counts were also taken of birds on the sites where the detailed studies were made at each visit during the study period, October to November 1994. This was done to provide an indication of the bird population changes that occurred on the sites during the period.

6.5. AERIAL SURVEY

On 14 October an aerial survey was carried out from Kotoka Airport, Accra, by three observers and a pilot in a Cessna single engine four-seater airplane. We were in the air from 11:27 hr to 13:36 hr, spending 45 min above Keta Lagoon and 35 min above Songor Lagoon. On the way back, we spent about 10 min above Sakumo Lagoon and 15 min above the Densu Delta. During the flight one observer counted the birds and gave directions to the pilot. Bird observations were spoken into a tape-recorder with approximate positions noted on a map. A second observer documented the areas by making still photographs and a third observer made a continuous video-recording during the flight. We used the video-recording to make a detailed reconstruction of the flights paths, presented for Songor Lagoon in Fig. 16, and for Keta Lagoon in Fig. 17. Flight speeds varied between 95 and 110 mph (153-177 km/hr). Flight altitude varied between 150 and 250 m.

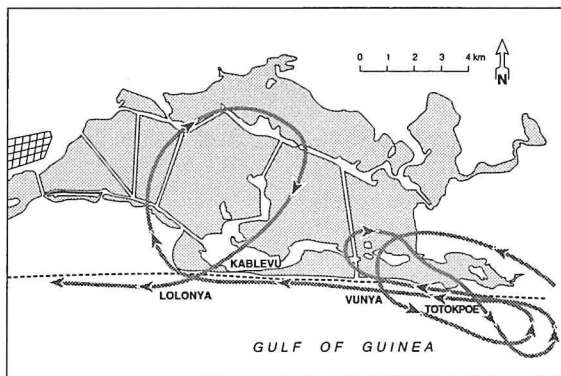


Fig. 16. Map showing the flight path of the aerial survey over Songor Lagoon.

During the night and early morning of 14 October, very heavy rain showers occurred in southern Ghana, which added some fresh water to the rainfall of 9 October, and flooded large expanses of previously dried out areas in both Keta and Songor Lagoon. This feature, along with the absence of recent maps, made it quite hard to navigate, and especially to determine the extent of long-flooded, and hence productive water bodies and their edges. Large waterbird species, such as herons, pelicans and the whitish terns and gulls, were easily discovered and counted. Waders were apparently easily disturbed by the Cessna, and although their whirling flocks were easy to spot, counting them was problematic. Any waders remaining on the ground were likely to be missed by aerial observers because of the small size and the relatively non-distinct colouration in comparison with the background.

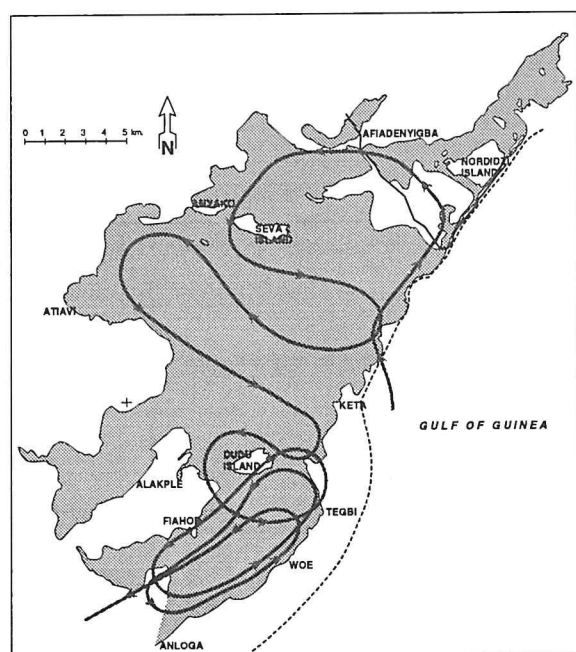


Fig. 17. Map showing the flight path of the aerial survey over Keta Lagoon.

6.6. BEHAVIOUR, WATER DEPTH SELECTION & TIME-ACTIVITY BUDGETS

The bulk of the data on the time-activity budget of the ground-based waterbirds were collected systematically during 24 hours observation pro-

grammes, carried out five times at Keta Lagoon (16 October and 7 November at Fiahor, 24 October and 11 November at Tegbi and 31 October at Anloga). Since it was not profitable to do night observations at Songor, three all day observations were carried out near Totokpoe (19, 20, 21 October). Additional information was, however, collected opportunistically as we visited the different parts of the two lagoons on other days.

Observations were made by zoom-telescopes (magnification 15-60 x) during daylight, and during dusk and dawn, and with a Delnocta night-scope (magnification 5 x) during the hours of darkness. A small infrared beam was used to enhance the clarity of the light-intensified image on the Delnocta night-scope. At night, flocks turned to be often too distant for the equipment used to yield reliable species identification and foraging observations, and only few quantitative observations could be collected.

The following three behavioural categories were discerned: (1) feeding, (2) comfort behaviour (preening, bathing), and (3) roosting (sleeping, standing). We made our observations on the basis of flocks, considering that a distance of about 20 bird lengths between the nearest birds indicated a break between two separate flocks. Each flock was instantaneously scanned, and the overall average nearest neighbour distance was recorded in bird lengths. Scanning usually demanded rapid assessments on the part of the observers since, especially in foraging flocks, the waders and other waterbirds were engaged in erratic and rapid movements, the detailed situation thus changing every few seconds. For each species in a flock, water depth was estimated by estimating the water level relative to exposed vertical leg length (in 10% intervals relative to a total of 100% when birds were standing belly deep in water). These relative leg lengths were converted to depth from scale drawings or photographs of the waterbirds concerned. Table 1 summarizes the lengths of exposed legs as used in this study.

To describe the feeding areas and foraging rhythms of the terns roosting in Songor Lagoon near Totokpoe, we established an observation post for three days on the dune ridge a few 100 m west of the village of Totokpoe. On 8

October we tried out the methodology of counting terns flying in and out of the lagoon. We managed to make a good description of the daily changes in numbers of roosting terns. On 22 October and 6 November observations covering entire days were again made with three and four observer-teams, starting before dawn and ending after nightfall. During intervals of 10 min we recorded the number of terns flying out of the lagoon to sea, and those returning from sea over the dune ridge into the lagoon. The majority of birds in the lagoon were roosting on wet mud. It proved impossible to separate Common and Black Terns in flight during these intense observations (note that terns came in over a long stretch of coastline, thus requiring at least two observers, one looking west, the other east), although the simultaneous counts on the roost suggested that the majority of these terns were Black Terns.

6.7. FEEDING STYLE AND DIET OF WATERBIRDS

Whenever we carried out activity and water depth scans, we also made detailed observations on the style of feeding (how prey items were hunted or searched for and methods used for catching/obtaining the prey) of the different waterbird species comprising the flocks under observation. Prey items and intake rates were also recorded through direct observations using telescopes. A total of about 25 minutes of close-up video-recordings of different dense feeding aggregations of waterbirds were made at Fiahor and Tegbi on 17 and 25 October respectively. These records helped us to check and sharpen our field observations. Data on prey items obtained through the direct visual observations were further supplemented by collecting and analysing the contents of faecal droppings of birds wherever possible.

TABLE 1.
Exposed leg lengths (as used in this study) of the different waterbird species that forage upright in shallow water.

Species	Exposed leg length (mm)
Kittlitz's Plover	30
White-fronted Plover	31
Ringed Plover	35
Grey Plover	71
Common Sandpiper	31
Whimbrel	86
Turnstone	34
Wood Sandpiper	46
Redshank	68
Black-tailed Godwit	123
Bar-tailed Godwit	84
Curlew	111
Knot	42
Sanderling	33
Little Stint	33
Curlew Sandpiper	45
Marsh Sandpiper	74
Greenshank	75
Spotted Redshank	86
Black-winged Stilt	174
Avocet	143
Little Egret	135
Reef Heron	135
Grey Heron	208

7. OCCURRENCE OF WATERBIRDS IN OCTOBER-NOVEMBER 1994

7.1. RESULTS OF THE GROUND COUNTS

Songor - Table 2 gives the results of the ground counts undertaken in October in the different sections of Songor lagoons. A total of 38,073 waterbirds, comprising 32 species, was recorded for Songor. Of this, 84.3% was contributed by terns, while waders and herons/egrets accounted for 23.9% and 1.7% respectively. Of the terns, two species, Black and Common Terns, were the most abundant accounting for 56% and 25.7% of the total bird population at the Songor site during that period. The most common wader species were Greenshank, Curlew Sandpiper, Little Stint, Black-winged Stilt and Avocet, each of which accounted for over 1% of the total Songor count. For comparison, the maximum counts recorded at Songor for the different species over the past nine years are also given in Table 2. The maximum total number of birds recorded on anyone day over the past nine years is 50,500 in October 1989.

Of the four sectors of the Songor Lagoon, Totokpoe was the most productive in terms of bird numbers, contributing 87.8% of the total Songor count. This, however, comprised mainly roosting terns. A concentration of terns, (comprising over 20,000 birds) roosted regularly on the edge of the lagoon next to the Totokpoe village. These were mainly Black Terns and Common Terns, but also of special interest is the large numbers of Roseate Terns present at this site during the period. Up to 650 Roseates were counted at one time in this roost (building up from 56 on the first visit on 8 October to the peak on 22 October). The peak count recorded for Roseate Terns on this site is equivalent to over 50% of the European breeding population of the threatened species which is known to spend the winter months on the Gulf of Guinea coast. Substantial numbers of Greenshanks and Avocets were also present in the area of the tern roost. Other wader species occurred in small numbers. On the exposed mud between the mangroves west of Totokpoe, Common Sandpipers, Grey Plovers, Curlew Sandpipers and Marsh Sandpipers were regularly seen feeding. Ringed Plovers frequently foraged in

slightly drier areas along the lagoon edges. Herons were present in moderate numbers.

Keta - A total of 37,519 waterbirds belonging to 46 species were recorded in the ground count at Keta Lagoon (Table 3). This comprised 92% waders, 7.2 % herons and egrets and 3.7 % terns. A single wader species, the Curlew Sandpiper, contributed 54.5 % to the total count. Other wader species which occurred in significant numbers included Black-winged Stilt (15.1 %), Greenshank (5.3 %), Little Stint (4.7 %) and Ringed Plover (4.5 %). Numbers of tern species at the Keta site were low, with total populations under 300. Of significance is the relatively large numbers of Whiskered Terns (261) present on the site during the study period, as compared with the small numbers (under 10) previously recorded at any time.

The Anloga section of the lagoon was by far the most important both in terms of species counts (32) and total populations (over 40% of the count) followed by the Woe and Tegbi sections. Although the entire population of ducks encountered were found at Anloga, the numbers were very low compared with the several thousands (up to 50,000) regularly recorded in the routine monitoring. Common species in the marshes at Anloga were Black-winged Stilts and Black-tailed Godwits. The dry extensive flats nevertheless attracted significant numbers of Ringed Plovers and Little Stints, which concentrated their feeding efforts on the dry flats around old puddles. The only birds present on the mudflats along the main waterbody were fish-eaters such as herons, terns and Avocets.

Large concentrations of birds, particularly small waders, were present at the Woe and Tegbi sections of the lagoon throughout October, despite the relatively low record during the ground count on 14 October. Over 40,000 birds, two-thirds of which were Curlew Sandpipers, were present on this site in the last week of October (Table 3). Significant numbers of Marsh Sandpipers, Greenshanks, Ringed Plovers and Little Stints were also present. Moderate numbers of all five species were also present at the Fiahor site. Large areas of the Keta Lagoon, particularly the eastern and northern sections including the Adina, Afiaden-

TABLE 2.
Numbers recorded in ground counts at Songor Lagoon on 14 October 1994.

Species	Songor Lagoon					Maximum recorded 1986-94
	Pute	Totokpoe	Kablevu	Lolonya	Total	
Kittlitz's Plover	12	7	1	0	20	141
White-fronted Plover	0	6	4	0	10	79
Ringed Plover	63	136	124	4	327	3009
Grey Plover	15	48	38	0	101	981
Common Sandpiper	20	11	9	4	44	90
Whimbrel	0	2	2	0	4	32
Turnstone	0	8	0	0	8	30
Wood Sandpiper	6	7	0	0	13	66
Redshank	4	4	0	0	8	47
Bar-tailed Godwit	0	3	3	0	6	133
Knot	0	0	44	0	44	1486
Sanderling	0	48	100	6	154	700
Little Stint	73	110	737	0	920	3121
Curlew Sandpiper	116	274	595	64	1049	6916
Marsh Sandpiper	0	8	0	0	8	184
Greenshank	47	602	402	23	1074	5066
Spotted Redshank	0	102	0	0	102	10060
Black-winged Stilt	149	161	29	403	742	4391
Avocet	0	660	0	0	660	3740
Little Egret	45	138	13	21	217	4461
Reef Heron	27	142	164	39	372	1022
Great White Egret	0	22	0	0	22	235
Grey Heron	0	34	3	1	38	458
Little Tern	116	82	0	250	448	2740
Common Tern	220	9560	0	0	9780	9479
Roseate Tern	10	411	0	0	421	190
Sandwich Tern	44	30	0	0	74	5119
Royal Tern	7	18	0	15	40	2569
Caspian Tern	0	8	0	0	8	109
Black Tern	474	20800	0	67	21341	18065
Lesser Black-backed Gull	0	2	0	15	17	538
African Jacana	0	0	1	0	1	8
Totals	1448	33444	2269	912	38073	

TABLE 3.
Numbers recorded in ground counts at Keta Lagoon on 14 October 1994.

Species	Keta Lagoon						Total	Maximum recorded 1986-94
	Fiahor	Anloga	Woe	Tegbi	Keta	Adina		
Fulvous Tree Duck	0	327	0	0	0	0	327	7207
White-faced Tree Duck	0	591	0	0	0	0	591	53050
Kittlitz's Plover	0	36	0	10	6	86	138	1811
White-fronted Plover	0	7	2	0	6	1	16	54
Ringed Plover	204	757	301	252	74	111	1699	5953
Grey Plover	1	81	138	4	16	1	241	1386
Common Sandpiper	5	15	2	0	1	12	35	296
Whimbrel	0	15	0	0	0	0	15	56
Turnstone	0	35	8	3	0	0	46	141
Wood Sandpiper	5	69	3	19	0	2	98	955
Redshank	0	0	70	61	5	1	137	169
Black-tailed Godwit	0	600	0	0	0	0	600	4166
Bar-tailed Godwit	0	21	13	64	0	0	98	383
Curlew	2	130	33	6	0	0	171	333
Knot	0	20	0	58	0	0	78	2342
Sanderling	0	18	6	69	18	32	143	658
Little Stint	35	873	421	127	107	193	1756	18381
Curlew Sandpiper	572	4299	9964	5163	168	283	20449	28748
Marsh Sandpiper	0	49	139	159	220	2	569	1737
Greenshank	268	738	22	3	417	536	1984	6906
Spotted Redshank	12	356	0	1	0	0	369	12602
Black-winged Stilt	11	5177	126	214	27	120	5675	12077
Avocet	0	198	0	1	0	0	199	1559
Little Egret	177	190	18	9	8	382	784	7168
Reef Heron	55	111	14	2	14	90	286	1418
Great White Egret	0	35	0	0	0	0	35	1648
Grey Heron	81	430	0	0	0	115	626	1285
White Pelican	250	0	240	0	0	0	490	-
Little Tern	0	90	0	0	30	117	237	929
Common Tern	83	12	0	0	0	72	167	2768
Sandwich Tern	0	52	0	0	0	8	60	1900
Royal Tern	14	48	0	0	0	2	64	1269
Caspian Tern	0	119	2	0	1	0	122	442
Whiskered Tern	0	54	205	0	2	0	261	998
Black Tern	55	89	24	0	0	130	298	3354
Gull-billed Tern	0	131	47	0	0	0	178	448
Lesser Black-backed Gull	85	100	0	0	0	5	190	778
Collared Pratincole	0	3	0	0	0	0	3	1009
Ruff	0	54	0	0	0	0	54	273
African Jacana	0	6	0	0	0	0	6	604
Glossy Ibis	0	17	0	0	0	0	17	119
Senegal Wattled Plover	0	2	0	0	0	0	2	5
Purple Heron	0	4	0	0	0	0	4	100
Black Heron	0	14	0	0	0	0	14	57
Squacco Heron	0	26	0	0	0	0	26	574
Long-tailed Cormorant	0	22	16	6	0	32	76	3045
Totals	1915	16021	11814	6231	1120	2333	39434	

yigba and Anyako areas were completely dry and very few birds were found there.

The total count of 37,519 waterbirds recorded during the ground count approximates the average for that time of year. Peak counts of over 100,000 birds have frequently been made at Keta Lagoon during the northern autumn passage (October-December) and also during spring passage (February-March) on a number of occasions over the past nine years.

7.2. RESULTS OF AERIAL SURVEY

Figures 18-21 show the concentrations of waterbirds recorded at Keta Lagoon during the aerial surveys. Although the total numbers were underestimated, particularly for the small waders, the general distribution patterns agree with the records obtained from the ground truthing (Table 3). At Keta Lagoon, the highest

concentrations of waterbirds were found in the Anloga through Woe to Tegbi sections of the lagoon. Small numbers of Little Egret (Fig. 19), Reef Heron (Fig. 20) and Grey Heron (Fig.21) were seen between Seva Island and also around Kedzi. Whereas the waders concentrated mainly in areas with large expanse of shallow water, the herons and egrets were much more widespread and exploited the small pockets of standing water in the dried up parts of the lagoon. At Songor, the highest concentrations of birds were found around Vunya and the Totokpoe village. On the whole the aerial survey was most useful for providing a general overview of the habitat characteristics and distribution of birds. The aircraft disturbed the birds and made them wheel round and round. This made counting very difficult. For censusing, the ground counts, though more tedious, provides a much better population estimate.

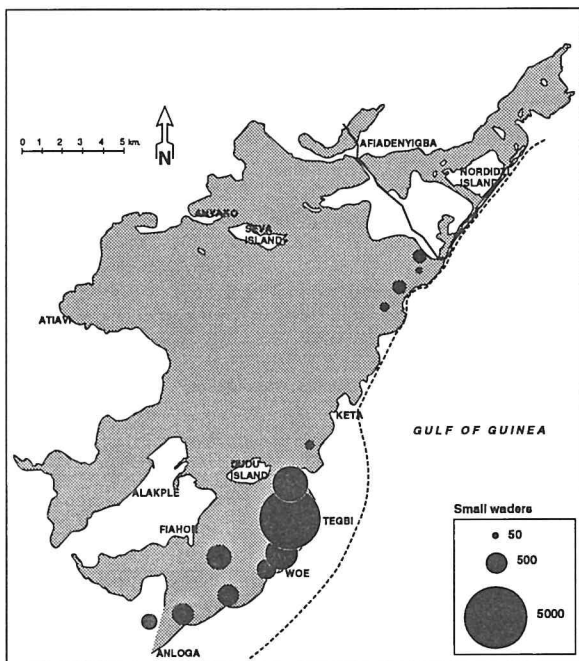


Fig. 18. The approximate numerical distribution of small waders (most of them Curlew Sandpipers) in Keta Lagoon as registered during the aerial survey on 14 October 1994.

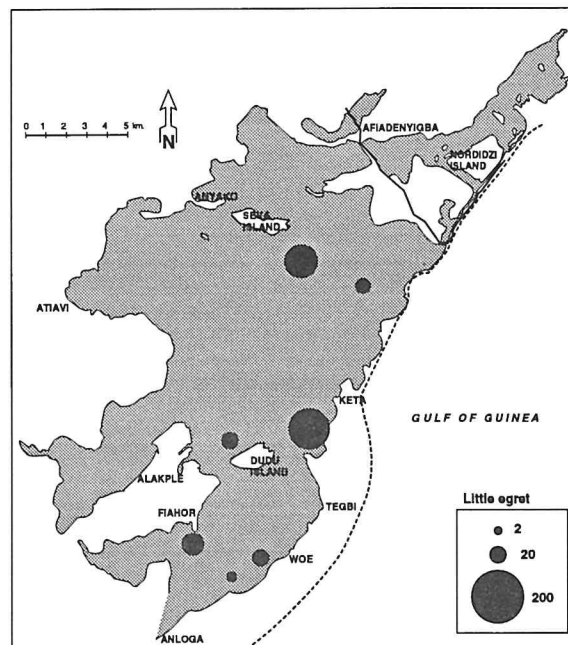


Fig. 19. The approximate numerical distribution of Little Egrets in Keta Lagoon as registered during the aerial survey on 14 October 1994.

7.3. TEMPORAL CHANGES IN ABUNDANCE OF WATERBIRDS

The numbers of birds on the sites varied between visits and a marked decrease in total bird numbers was observed on all sites in early November. This is illustrated by the counts at two of the study sites, Totokpoe and Woe-Tegbi, during the study period (Table 4). The pattern of change in numbers of individual species, however, varied. In most cases numbers declined. For example, numbers of Ringed Plover, Grey Plover, Curlew Sandpiper, Wood Sandpiper, Sanderling and Little Stint left at Tegbi in November were 10-50% of the peaks recorded in October. Populations of other species, e.g. Marsh Sandpiper, Greenshank and Bar-tailed Godwit, remained relatively stable, while increases were observed in numbers of species like Spotted Redshank, Black-winged Stilt, the herons and the egrets. Although it is not possible to make any conclu-

sive statements about the patterns of change in bird numbers on the sites from the short period of study, it is known that the highest concentrations of migrant waterbirds occur on the Ghana coast during September to December (the northern autumn-early winter). By January, the populations of most species have declined to less than 50% of the autumn peak (NTIAMOA-BAIDU 1988, 1991, NTIAMOA-BAIDU & HEPBURN 1988)

There was evidence of regular movement of birds between the sites. Local conditions in terms of food availability and changes due to water levels and flooding regimes probably affects usage of the sites by the birds and accounted for the short term changes in local populations. Bird numbers also varied greatly in the course of the day at some sites. At Fiahor, for example, highest numbers occurred in the early morning. A few hours later most birds had left, sometimes returning in the late afternoon or just before dusk to the night roosts.

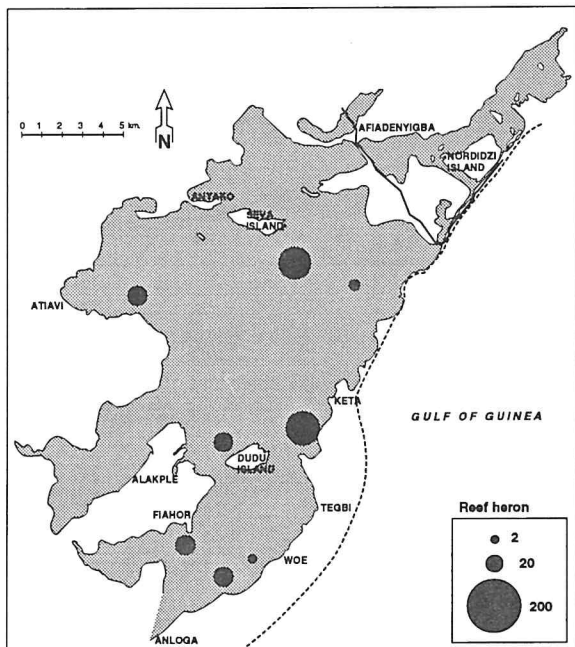


Fig. 20. The approximate numerical distribution of Reef Herons in Keta Lagoon as registered during the aerial survey on 14 October 1994.

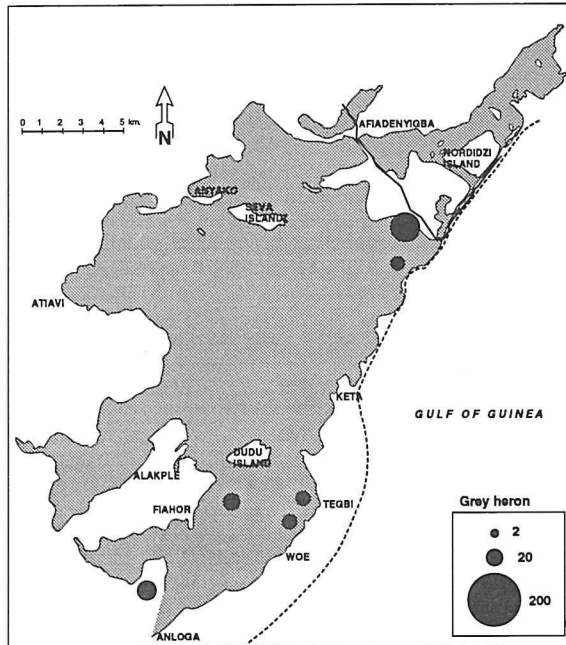


Fig. 21. The approximate numerical distribution of Grey Herons in Keta Lagoon as registered during the aerial survey on 14 October 1994.

TABLE 4.
Temporal changes in bird numbers on repeatedly counted sites in Songor Lagoon (Totokpoe) and Keta Lagoon (Woe-Tegbi) in October-November 1994.

Species	Songor Lagoon (Totokpoe)					Keta Lagoon (Woe-Tegbi)		
	8 Oct. 17-18 hr	10 Oct. 10-14 hr	14 Oct.	15 Oct. 17-18 hr	5 Nov.	14 Oct. 09-12 hr	25 Oct. 07-11 hr	7 Nov.
Kittlitz's Plover	1	8	7	0	13	10	70	38
White-fronted Plover	0	1	6	0	5	2	13	4
Ringed Plover	0	234	136	208	194	553	2006	455
Grey Plover	2	86	48	42	56	142	814	82
Common Sandpiper	0	0	11	3	14	2	2	7
Whimbrel	2	2	2	1	2	0	4	2
Turnstone	0	0	8	2	11	11	19	26
Wood Sandpiper	21	0	7	3	4	22	113	63
Redshank	4	0	4	5	5	131	114	44
Black-tailed Godwit	0	0	0	0	0	0	48	27
Bar-tailed Godwit	0	3	3	7	9	77	240	271
Curlew	0	0	0	0	0	39	38	7
Knot	0	44	0	13	43	58	71	84
Sanderling	34	142	48	157	257	75	385	163
Little Stint	0	723	110	579	355	548	1723	802
Curlew Sandpiper	20	405	274	668	1152	15127	31258	13374
Marsh Sandpiper	115	3	8	0	74	298	1461	1499
Greenshank	130	255	602	327	295	25	2685	2145
Spotted Redshank	2		102	686	50	1	280	1195
Black-winged Stilt	140	188	161	177	23	340	410	1306
Avocet	349	305	660	597	156	1	26	68
Little Egret	15	76	138	89	58	27	426	563
Reef Heron	17	263	142	117	41	16	48	220
Great White Egret	0	17	22	30	0	0	0	8
Grey Heron	0	0	34	35	6	0	77	212
White Pelican	0	0	0	0	0	240	234	575
Little Tern	10	50	82	365	94	0	27	22
Common Tern	8500	2090	9560	7400	234	0	0	10
Roseate Tern	56	415	411	422	26	0	0	0
Sandwich Tern	10	0	30	56	16	0	3	6
Royal Tern	8	0	18	26	7	0	0	0
Caspian Tern	0	0	8	3	0	2	0	19
Whiskered Tern	0	0	0	0	0	205	346	375
Black Tern	22500	13000	20800	12100	406	24	13	39
Gull-billed Tern	0	0	0	0	0	47	0	137
Black Noddy	0	1	0	3	0	0	0	0
Lesser Black-backed Gull	0	70	2	11	10	0	0	62
Glossy Ibis	19	0	0	0	0	0	0	0
Long-tailed Cormorant	0	0	0	0	0	22	148	158
Totals	31955	18381	33444	24132	3616	18045	43102	24068

8. FORAGING HABITS, DIURNAL RHYTHMS AND DIETS

8.1. DEFINING THE WATERBIRD GROUPINGS

The Volta lagoons were inhabited by almost 50 waterbird species (Tables 2 and 3) in October-November 1994. Thirty-six of these, were observed in sufficient numbers and frequently enough during the study period to allow brief descriptions of their ecology (Table 5); but even 36 species is too large a number to easily and comprehensively come to grips with in ecological terms. We therefore use the concept of "guild" to structure our information on waterbirds' foraging habits, diurnal rhythms and diets. ROOT (1967) introduced the concept of functional species groups or "guilds" indicating species assemblies that exploit the same class of resources in a similar way (see discussion by JAKSIC 1981). Guilds can be defined *a posteriori* on the basis of (subjective or more objective) clustering based on the descriptions of foraging habits, habitat choice and diets (see discussion by HOLMES & RECHER 1986). Guild can also be derived *a priori*, for example on the basis of morphological characters (RICKLEFS & TRAVIS

1980). We have defined guilds *a posteriori* on the basis of our information on the sensory mechanism used to detect food (a major determinant of the feeding niche, see discussion by PIERSMA 1994, pp. 32-33) and on individual feeding style (MYERS 1984). Information on diet, degree of social foraging, diurnal habits and habitat characteristics are projected on this guild structure to describe the waterbird community in Ghana's coastal lagoons.

Our fairly objective structuring of the waterbird community yielded 7 guilds (Fig. 22), four of which consist of tight taxonomic groupings: the herbivorous tree ducks (Guild 1), the (stalking) herons (Guild 5), the (fishing) pelicans (Guild 6) and the (fishing) terns (Guild 7). Although herons, pelicans and terns all feed on fish, they obtain them in very different ways. Herons walk and wait, and surprise their prey by well-directed jabs. Pelicans usually engage in social fishing with birds swimming in a tight flock simultaneously opening their large beaks and pouches thus driving pelagic fish together before scooping them up out of the water (see SAINO *et al.* 1995). Terns fish by diving from the

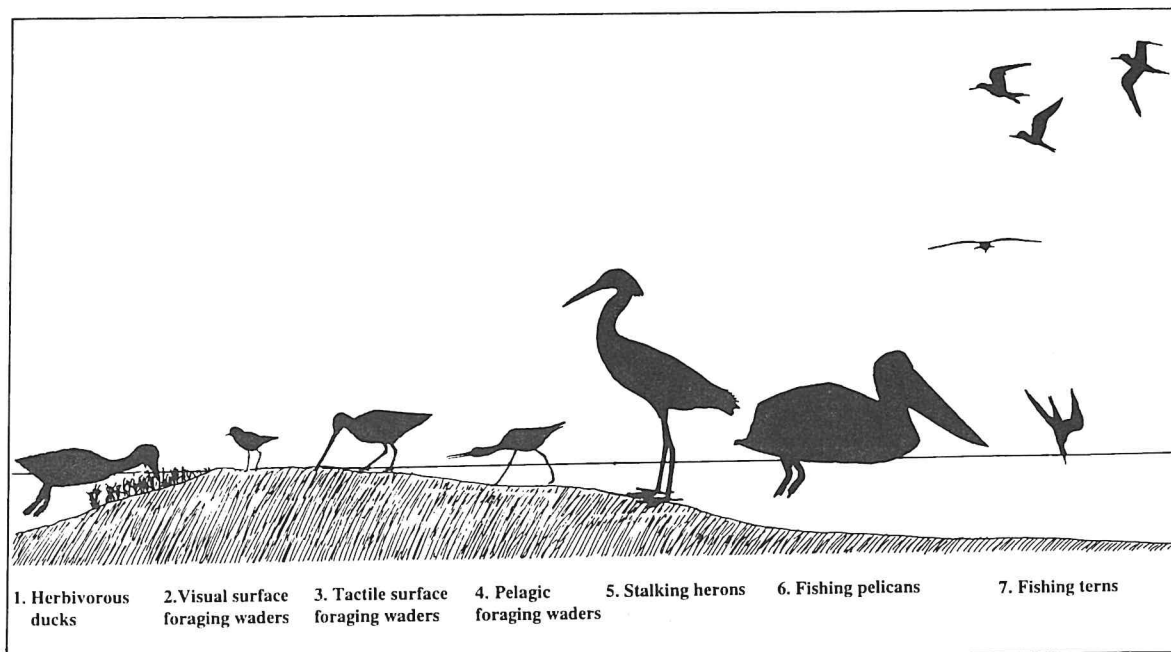


Fig. 22. Pictorial representation of the seven waterbird guilds of the coastal lagoons of Ghana. See text for explanations.

TABLE 5.
 Characteristics of feeding habitat, feeding style and diet of the waterbirds using Songor and Keta Lagoons on October-November 1994. The bird species are arranged in the order of seven guilds: 1. Herbivorous ducks, 2. Visual surface foraging waders, 3. Tactile surface foraging waders, 4. Pelagic foraging waders, 5. Herons, 6. Pelicans, and 7. Terns.

Species	Feeding style	Guild	Feeding habitat (water depth)	Degree of flocking during foraging	Incidence of organized social foraging	Diet	Diurnal feeding rhythm	Use of separate roost?
Fulvous Tree Duck	grazing	1	?	strong	always	weeds & seeds	?	yes
White-faced Tr. Duck	grazing	1	?	strong	always	weeds & seeds	?	yes
Kittlitz's Plover	pecking	2	0-1 cm	weak	never	invertebrates	24 hrs	no
White-fronted Plover	pecking	2	0-2 cm	weak	never	invertebrates	24 hrs	no
Ringed Plover	pecking	2	0-3 cm	weak	never	invertebrates	24 hrs	no
Grey Plover	pecking	2	0-5 cm	none	never	mainly worms	24 hrs	no
Common Sandpiper	pecking	2	0-1 cm	none	never	arthropods	day	yes
Whimbrel	pecking	2	0 cm	none	never	crabs	day	yes
Turnstone	pecking	2	0-2 cm	weak	never	invertebrates	day	yes?
Wood Sandpiper	pecking	2	0-4 cm	weak	never	invertebrates	24 hrs	no
Redshank	pecking	2	0-6 cm	weak	sometimes	inverts., fish	24 hrs	no
Black-tailed Godwit	probing	3	5-10 cm	strong	never	molluscs	24 hrs	no
Bar-tailed Godwit	probing	3	0-7 cm	strong	never	worms	24 hrs	no
Curlew	probing	3	0-12 cm	weak	never	crabs, worms	24 hrs	no
Knot	probing	3	0-3 cm	strong	never	molluscs, seeds	24 hrs	no
Sanderling	peck, probing	3	0-2 cm	strong	never	invertebrates	24 hrs	no
Little Stint	peck, probing	3	0-2 cm	strong	never	invertebrates	24 hrs	no
Curlew Sandpiper	peck, probing	3	0-3 cm	strong	never	invertebrates	24 hrs	no
Marsh Sandpiper	peck & ploughing	4	1-7 cm	strong	often	inverts., seeds	24 hrs	no
Greenshank	peck & ploughing	4	1-7 cm	strong	usually	fish	24 hrs	no
Spotted Redshank	peck & ploughing	4	1-7 cm	strong	usually	fish	24 hrs	no
Black-winged Stilt	probe, peck, sweep	4	0-14 cm	variable	sometimes	fish, inverts.	24 hrs	no
Avocet	sweeping	4	2-11 cm	strong	always	fish	24 hrs	no
Little Egret	stabbing	5	2-15 cm	weak	-	fish	day	yes
Reef Heron	stabbing	5	2-15 cm	weak	-	fish	day	yes
Great White Egret	stabbing	5	2-15 cm	weak	-	fish	day	yes
Grey Heron	stabbing	5	2-17 cm	weak	rarely	fish	day	no
White Pelican	scooping	6	>30 cm	strong	always	fish	crepuscular	yes
Little Tern	diving	7	lagoon	-	-	fish	day	yes
Common Tern	diving	7	sea	-	-	fish	day	yes
Roseate Tern	diving	7	sea	-	-	fish	day	yes
Sandwich Tern	diving	7	sea	-	-	fish	day	yes
Royal Tern	diving	7	sea	-	-	fish	day	yes
Caspian Tern	diving	7	lagoon	-	-	fish	day	yes
Whiskered Tern	diving	7	lagoon	-	-	fish	day	yes
Black Tern	diving	7	sea	-	-	fish	day	yes

air to pick individual fish out of surface swimming schools. The remaining species are all ground-feeding waders, which were split up into three guilds (2, 3 & 4) on the basis of their sensory mechanism of food detection and feeding style. These contain two groups of surface foragers, one of which predominantly uses visual detection of prey (Guild 2, consisting of the plovers and a few scolopacids/sandpiper-like birds), and another which predominantly uses tactile means to find their prey (Guild 3, all sandpipers). The third group (Guild 4, consisting of tringid sandpipers and stilt-like birds) consists of pelagic foragers, fishing in the water layer. These species use visual as well as tactile senses to detect the prey. In the coastal lagoons of Ghana many of the fish-eating waterbirds (the waders, herons and terns) were often found together in areas of shallow water, especially when hectic feeding is going on in schools of small tilapia. In such cases, the waders were frantically running around, the herons were walking, running and flying about to grab the confused fish and the terns "splashed" in from the air.

In summary, the seven guilds are:

- (1) **Herbivorous ducks** (comprising the Fulvous Tree Duck and the White-faced Tree Duck),
- (2) **Visual surface foraging waders** (comprising Kittlitz's Plover, White-fronted Plover, Ringed Plover, Grey Plover, Common Sandpiper, Whimbrel, Turnstone, Wood Sandpiper and Redshank),
- (3) **Tactile surface foraging waders** (comprising Black-tailed Godwit, Bar-tailed Godwit, Curlew, Knot, Sanderling, Little Stint and Curlew Sandpiper),
- (4) **Pelagic foraging waders** (comprising Marsh Sandpiper, Greenshank, Spotted Redshank, Black-winged Stilt and Avocet),
- (5) **Stalking herons** (comprising Little Egret, Reef Heron, Great White Egret and Grey Heron),
- (6) **Fishing pelicans** (comprising the White Pelican and the Pink-backed Pelican) and
- (7) **Fishing terns** (comprising Little Tern, Common Tern, Roseate Tern, Sandwich Tern, Royal Tern, Caspian Tern, Whiskered Tern and Black Tern).

In the subsequent paragraphs, species accounts are provided first, outlining habitat (especially water depth) selection and providing notes on feeding style, daily rhythms in foraging and comfort behaviour and diet. Data on water depth selection (see Fig. 23 for foraging and Fig. 24 for roosting birds) and daily activity rhythms (Figs. 25-28) are presented guild by guild. After the species accounts, foraging is discussed and a summary is then given of our findings on habitat selection, diel rhythmicity and diet, again taking the guilds as common denominator for grouping the waterbird species.

8.2. SPECIES ACCOUNTS

Fulvous Tree Duck - *Dendrocygna bicolor* (Guild 1) - Fulvous Tree Ducks were seen only in the freshwater marshes near Anloga. They fed in shallow water, with submerged head and neck, regularly coming up with a dabbling bill. At the feeding sites, a slightly spiked macrophyte with lots of *Hydrobia accrens* (small snails) on the plants was present. The birds could have been feeding on either the plant, or the snails or both.

White-faced Tree Duck - *Dendrocygna viduata* (Guild 1) - White-faced Tree Ducks occurred in the freshwater swamp near Anloga. On 10 November a huge flock was seen in the haze far off on Keta Lagoon. At least 2600 ducks were counted in the air. We were unable to collect detailed feeding and diet observations on this species during this study but previous observations indicate that they fed on various aquatic plants in the lagoon. In the deeper parts of Keta Lagoon extensive fields of *Ruppia* occurred, and this is likely to have been the main food source of White-Faced Tree Ducks.

Kittlitz's Plover - *Charadrius pecuarius* (Guild 2) - These plovers foraged on dry and wet mud and they mostly avoided a layer of water (foraging water depth ranged from 0-3.2 cm, median 0 cm, n=62 flocks). Tegbi was the only place where Kittlitz's Plovers were seen feeding in very shallow standing water in a mixed flock with many other species. On this occasion they were picking small flies and beetles floating on the water surface. On wet

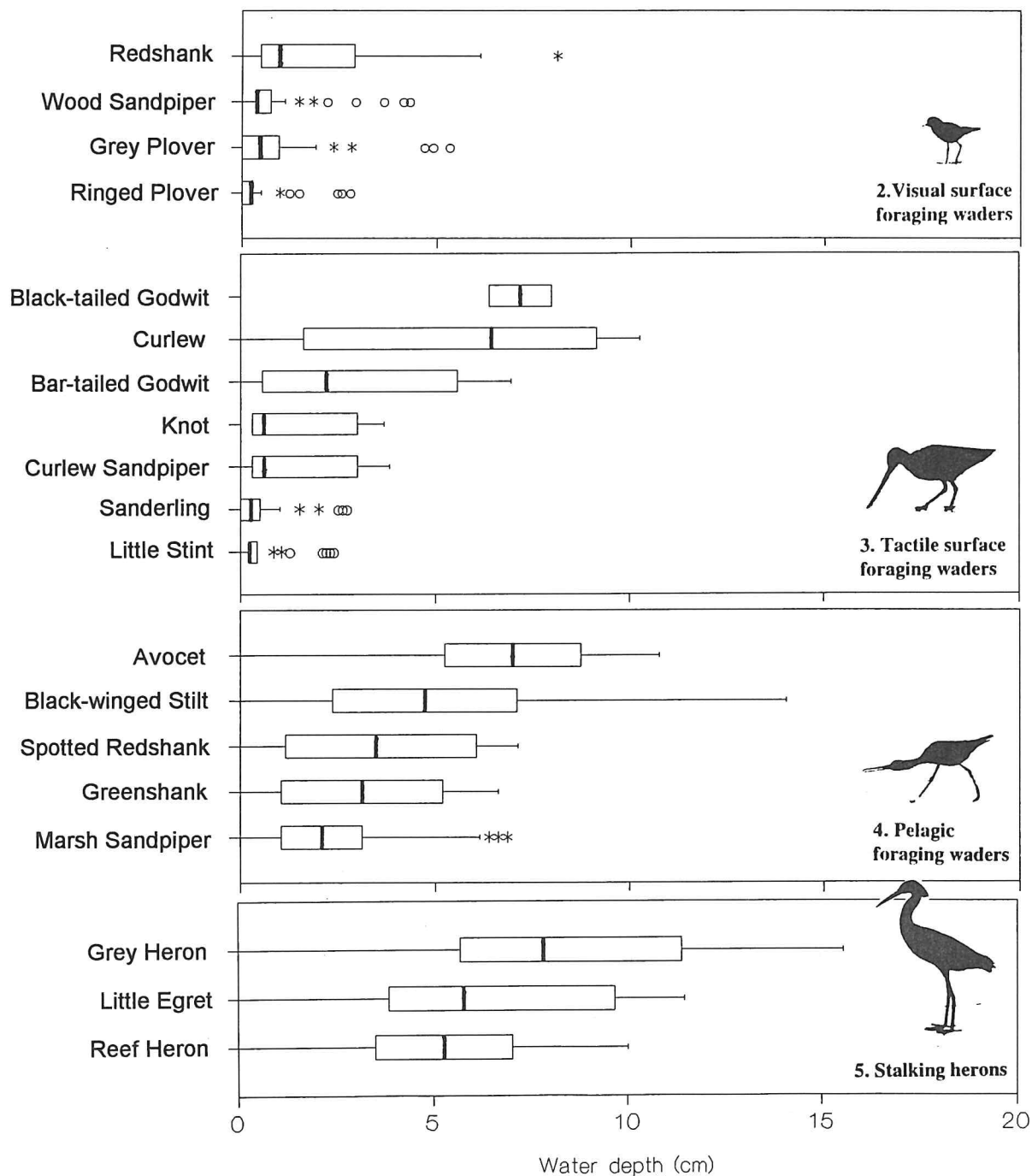


Fig. 23. Breakdown of water depths of sites used by foraging flocks of representative species of four of the seven waterbird guild in Songor and Keta Lagoon in October-November 1994. The data are presented as box-plots, giving the median, the two central quartiles and the range (plus outliers indicated with asterisks) of estimated (from exposed leg length) values.

mudflats the plovers probably fed on small worms. On one occasion (6 November at Totokpoe) a Kittlitz's Plover was dominated by Ringed Plover and White-fronted Plovers in territorial disputes.

White-fronted Plover - *Charadrius marginatus* (Guild 2) - White-fronted Plovers also foraged on dry and wet mudflats (foraging water depth ranged from 0-2.4 cm, median 0.24 cm, n=25 flocks). The only prey types that were observed to be ingested were worms (lengths of up to three times bill length). Under similar circumstances, they seemed to peck at faster rates than Ringed Plovers. White-fronted Plovers occasionally maintained feeding territories, dominating Kittlitz's Plovers but always being displaced by Ringed Plovers. On one occasion, a White-fronted Plover with a long worm in its bill was chased by a Curlew Sandpiper.

Ringed Plover - *Charadrius hiaticula* (Guild 2) - Ringed Plovers usually fed on wet and dry mud and only rarely in a layer of water (foraging water depth ranged from 0-3.1 cm, median 0.25 cm, n=436 flocks). They also fed on exposed mats of *Ruppia maritima*, where they obtained high pecking rates. At all sites they fed on polychaete worms, but in the shallow water layer near Tegbi they also picked small flies and beetles floating on the water surface. Here also, they had a high pecking rate, but a low rate of swallowing. The worms ingested were sometimes large, up to more than 10 times bill length. Ringed Plovers fed throughout the day and also at night with only a slight dip in feeding activity during the late morning and early afternoon, which is also the peak period for roosting and comfort activities (Fig. 25). At several sites (Totokpoe, Tegbi), Ringed Plovers appeared to maintain feeding territories (intra- and interspecific). They dominated both Kittlitz's and White-fronted Plovers.

Grey Plover - *Pluvialis squatarola* (Guild 2) - Grey Plovers fed on dry and wet mud, and sometimes in shallow water (foraging water depth ranged from 0-6.1 cm, median 0.47 cm, n=126 flocks). They used a wider variety of habitats than the *Charadrius*-plovers, also feeding on soft mud between the mangroves at

Totokpoe and close to the fishing villages. Grey Plovers were seen feeding in the day time and at night, with peak feeding period occurring at dawn and around mid-day (Fig 25). On the wet mud near the dune ridge west of Totokpoe, they fed on polychaete worms with a high success rate (27 worms in 10 min, worm size up to 2.4 times bill length, average 1.9 times bill length). At Tegbi, three worms were taken in 5 min. One long worm measured 8 times bill length and took more than half a minute to handle. Some night-time observations with the light-intensifier indicated that they also fed on polychaete worms at night, perhaps even catching larger worms than during daylight (7-15 times bill length) at lower pecking rates. One Grey Plover lost a long worm to a kleptoparasitic Redshank. Although Grey Plovers usually roosted in small flocks, they were mostly territorial in feeding areas. A territorial fight (including biting each other in the wing) observed near Totokpoe lasted for more than 10 min. Grey Plovers also scavenged for tilapia (the size range 10-20 mm) near the villages.

Common Sandpiper - *Actitis hypoleucos* (Guild 2) - Common Sandpipers fed in dry habitats, often feeding in marsh or dune vegetation, and only on mudflats between mangroves (foraging water depth ranged from 0-2.4 cm, median 0.00 cm, n = 46 cases). Common Sandpipers were usually single. Common Sandpipers roosted on prominent habitat features such as a largish mangrove tree or a canoe. Some birds appeared to maintain feeding territories and engaged in prolonged ritualised fights, behaving much like lekking male Ruffs. Their diet was very variable but probably consisted mainly of arthropods: insects, small marine crabs and small ghost crabs were all part of the diet. One bird scavenged on dead fish near a fishing village.

Whimbrel - *Numenius phaeopus* (Guild 2) - Whimbrels occurred in dry habitats such as the beach and the dunes and grassy patches adjacent to the beach and only one case of a Whimbrel feeding in water was observed (foraging water depth ranged from 0-11.1 cm, median 0.00 cm, n=8 cases). Their diet appeared to consist of crabs (ghost crabs on

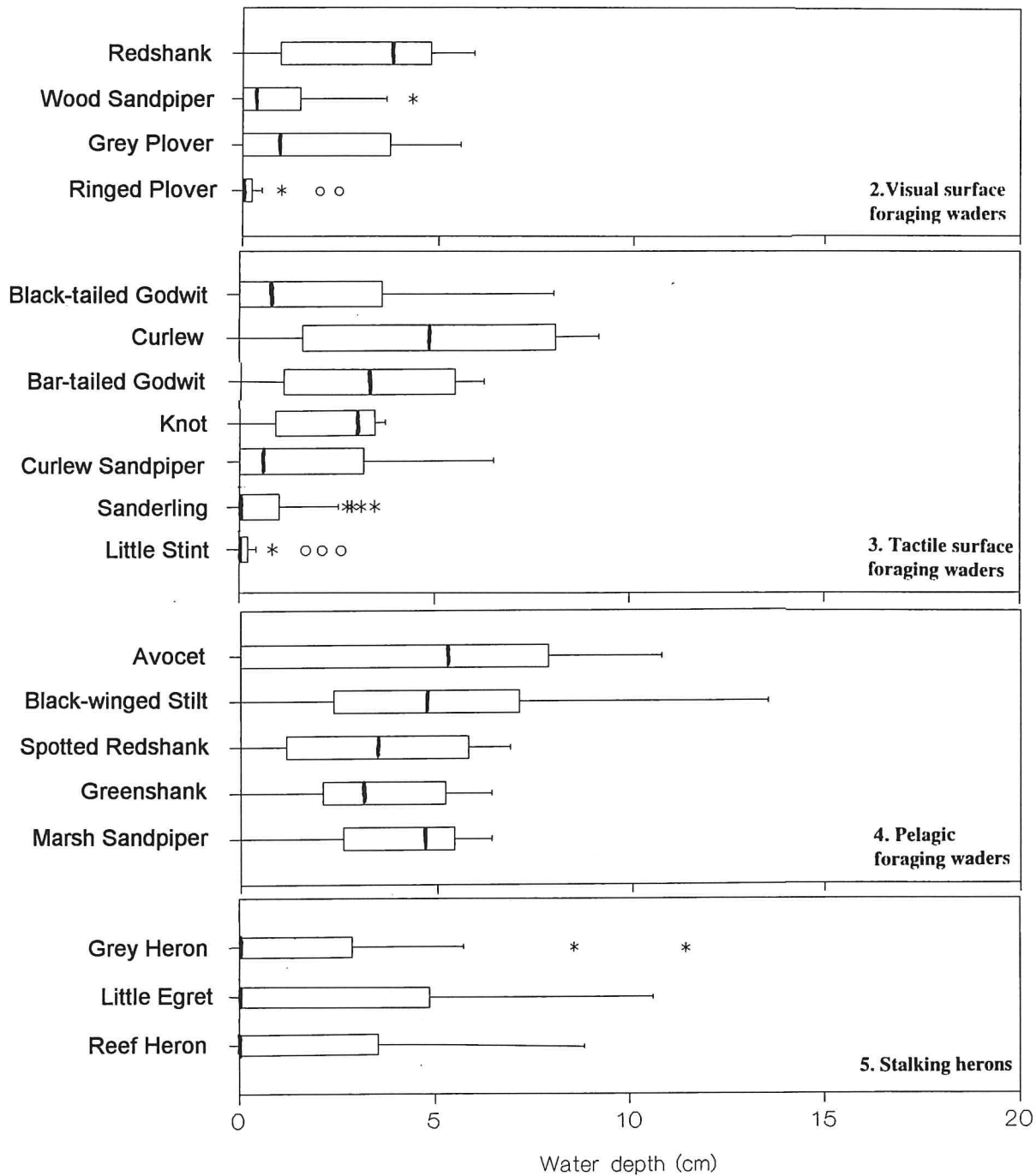


Fig. 24. Breakdown of water depths of sites used by roosting flocks (the percentage of birds feeding in a flock being smaller than 25%) of representative species of four of the seven waterbird guild in Songor and Keta Lagoon in October-November 1994. See caption to Fig. 23 for explanations.

the beach). The handling times of some crabs were long. Near Tegbi, a Whimbrel took 12 min to handle and ingest a large crab (carapace width 0.8 times bill length). At Totokpoe, three birds were engaged in a severe territorial dispute. The Whimbrels chased each other on foot and in the air over the sea to beyond the ocean surf. At night Whimbrels appeared to assemble in small communal roosts on the beaches, such as near Ada Foah.

Turnstone - *Arenaria interpres* (Guild 2) - Turnstones fed on wet and dry mud (foraging water depth ranged from 0-3.4 cm, median 0.00 cm, n=27 flocks) and on exposed mats of *Ruppia maritima*. They also scavenged for fish remains and fish spread out to dry near the villages. A Turnstone feeding on exposed *Ruppia* mats obtained a high pecking rate of 440 pecks in 5 min; probably feeding on the small seeds. They also foraged by flicking over mats of dry algae on mudbanks.

Wood Sandpiper - *Tringa glareola* (Guild 2) - Wood Sandpipers fed on wet mud, exposed beds of *Ruppia maritima* and in shallow water (foraging water depth ranged from 0-4.4 cm, median 0.73 cm, n=172 cases) mostly pecking prey from the surface or the subsurface. Wood Sandpipers were active throughout the day, feeding during the day and at night and spent very little time on either roosting or comfort activities (Fig. 25). Most foraging was visual, but at night some ploughing also occurred. Birds pecked for moving prey, probably fish, and also probed, perhaps for small fish buried in mud. Near Anloga, Wood Sandpipers fed on wet mud around and in puddles in the freshwater marsh, mostly gleaning prey items from weeds, presumably *Hydrobia accrensis*-snails. They usually foraged solitarily, but they nevertheless formed the occasional loose feeding flock on *Ruppia*-beds. At Tegbi, a scattered flock fed on larval fish with high success rate. Territorial interactions were regularly seen, but these may represent temporary territories rather than fixed ones, given that flock feeding occurred in areas where territorial interactions were seen at other times.

Redshank - *Tringa totanus* (Guild 2) - Redshanks fed on wet mud, exposed weed and *Ruppia*-beds and in shallow to deep water (foraging water depth ranged from 0-10.8 cm, median 0.96 cm, n=154 flocks). Redshanks also fed throughout the day, but were more active in the early part of the day and again before dusk (Fig. 25). In a *Ruppia*-bed near Totokpoe, a Redshank attained a peck rate of 400 pecks in 5 min, presumably ingesting the small seeds. Near Anloga, Redshanks fed in a similar manner on what were likely to be *Hydrobia accrensis*-snails. At other sites, Redshanks sometimes joined socially foraging shank flocks chasing small fish in shallow water, but also in own-species flocks. At Tegbi, a Redshank was seen capturing a worm of 10 times bill length, and subsequently being chased by a Bar-tailed Godwit which stole the worm. A single Redshank was observed foraging in a flock of Black-winged Stilts which fed on small prey floating on the water surface. This bird was swimming in belly deep water and had a pecking rate of 325 pecks per 2.5 min (the stilts had a lower peck rate of 229 pecks in 2.5 min). A Redshank feeding in the edge of a pool rich in algae showed 155 pecks in 10 min, out of which 24 swallows were observed.

Black-tailed Godwit - *Limosa limosa* (Guild 3) - Black-tailed Godwits were only encountered in the freshwater marshes near Anloga in early November. They fed on the mudflats and roosted in shallow water. Four cases of foraging in water were observed and the water depth ranged from 6.4-8.0 cm. On the flats they fed in soft mud (birds could be seen sinking into the mud with each step) adjacent to reeds, probing to half bill length in water of 0.5 times leg length. They swallowed prey of ca. 15 mm, after rolling them up in the bill. These prey were possibly juvenile *Tympanotonus*-snails, which were the only benthic animals recorded in that area of sediment from the manual digging and core sampling. Faecal samples collected there contained masses of mollusc fragments, but the vast majority was small white bivalve shells, with only small amounts of gastropod-remains. It may be that godwits were indeed feeding on

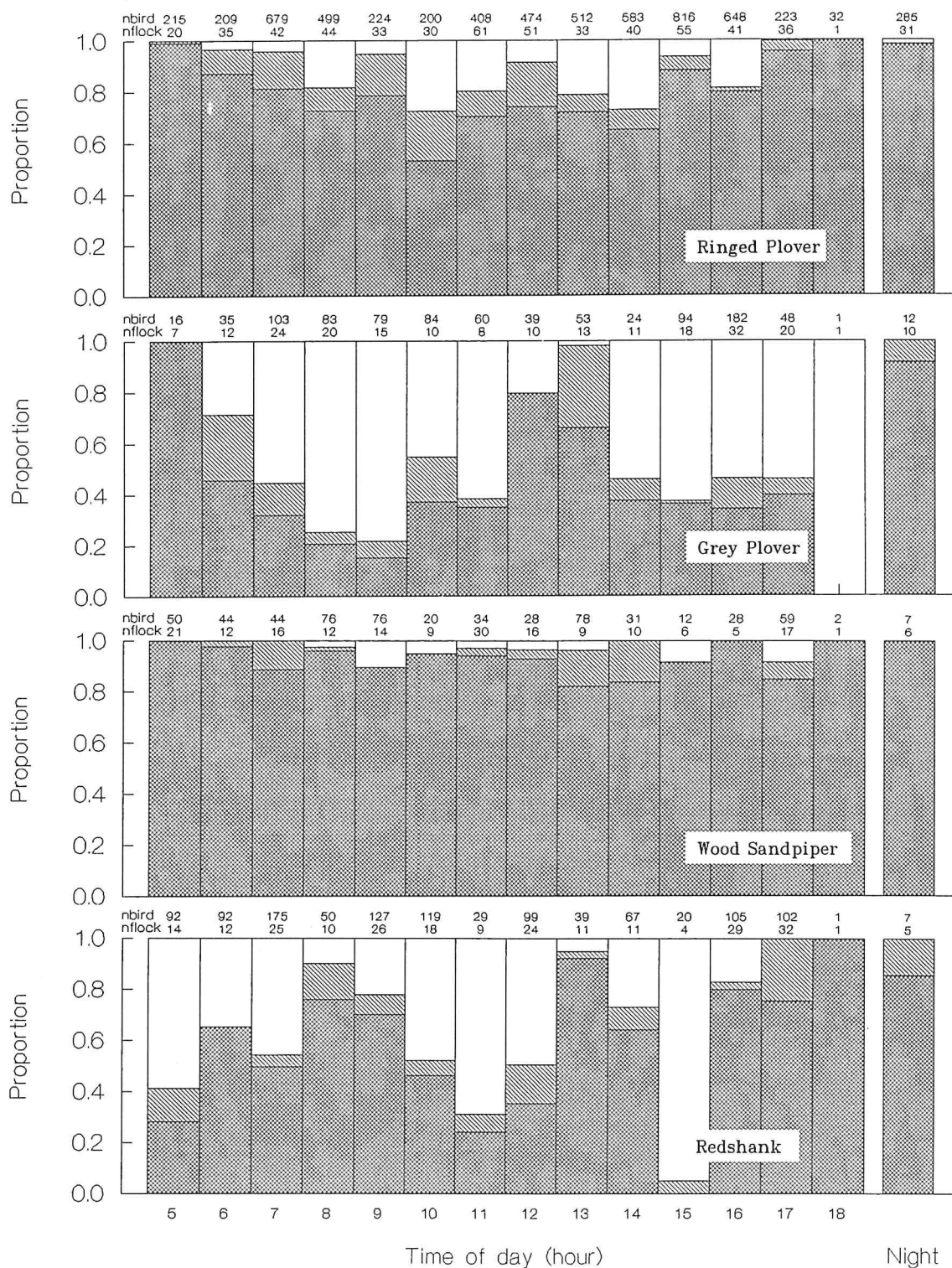


Fig. 25. Time-budgets of visual surface foraging waders in Songor and Keta Lagoon in October-November 1994. Foraging is indicated by dark shading, comfort behaviour by light shading and roosting by open parts in the histograms. Although the time-budgets are based on the counts of individual birds, the n-values for both the number of recorded birds and the number of recorded flocks are given.

Tympanotonus in that part of the swamp (seen on two days by two independent observers), but that the droppings were the result of feeding elsewhere.

Bar-tailed Godwit - *Limosa lapponica* (Guild 3) - Although Bar-tailed Godwits often roosted in small flocks on dry mudbanks, they always foraged on wet mud and usually in shallow water up to belly deep (foraging water depth ranged from 0-9 cm, median 2.2 cm, n=92 flocks). Bar-tailed Godwits foraged throughout the day and at night, but showed a clear peak of foraging activity from dawn till about 08:00 hr and again from late afternoon to dusk, spending the greater part of the mid-day period roosting (Fig. 26). They foraged both singly and in loose, usually monospecific, flocks. At all sites polychaete worms were the main prey, and the birds usually probed from half to full bill length into mud (head deep into water). Birds frequently tried to steal prey from each other. At Totokpoe, they attained intake rates of 13 and 6 worms in 4.5 and 3 min respectively. At Tegbi, the godwits were observed probing as well as pecking at night during half moon. 84 pecks were recorded in 3 min, two of which yielded large worms (many more small ones may have been missed).

Curlew - *Numenius arquata* (Guild 3) - The largest numbers of Curlews were observed at Fiahor, where they used dry mudbanks as night-time roosting sites. The birds congregated in several spread out flocks in the late afternoon, and they may have had a communal roost near Anloga. Curlews always foraged in shallow to belly deep water (foraging water depth ranged from 0-11.7 cm, median 6.44 cm, n=46 cases), where they were seen probing, probably mainly for crabs. On one occasion, a bird was seen with an eel-like fish (probably *Pisodonophis semicinctis*), which took a long handling time and was eventually stolen by a Grey Heron. On another occasion, a Curlew was seen probing in wet mud, from which it extracted whitish morsels of food (possibly crab). At Tegbi crabs were also eaten, but on a few occasions large worms were spotted in the bills of Curlews.

Knot - *Calidris canutus* (Guild 3) - Knots roosted in shallow water or on dry mudbanks (such as near Anloga in the company of Grey Plovers). They always foraged on wet mud or in shallow water (foraging water depth ranged from 0.3-4.1 cm, median 0.60 cm, n=22 flocks), searching their food with half to full bill length deep, rapidly repeated, probes. Knots foraged mainly at dawn and late evening, spending the greater portion of the morning roosting (Fig. 26). They were not observed at night. Some Knots also searched for food by surface-pecking. Prey items taken were too small to be seen, but an analysis of their droppings indicated that seeds of *Ruppia maritima* was the main ingested item at Vunya and Totokpoe. However, amphipods and small polychaete worms are less likely to end up in the droppings and cannot be completely excluded as additional prey at some sites. At Tegbi, Knot droppings contained some mollusc remains, mainly of the small rounded green striped snail (Neritidae).

Sanderling - *Calidris alba* (Guild 3) - Sanderlings foraged on the beaches and on wet exposed mud and very shallow water in the lagoons (foraging water depth ranged from 0-2.7 cm, median 0.25 cm, n=116 flocks). Sanderlings started feeding at first light and showed three peaks of feeding activity: early morning, midday and just before dusk (Fig.26). No observations were obtained for the species at night. At Vunya, their droppings contained many seeds of *Ruppia maritima*. They also scavenged on dried fish remains. On wet sediments near the dune ridge, Sanderlings made very deep probes, almost ploughing, and had many aggressive interactions (likely prey here would be amphipods). At Tegbi, a flock of 100 birds were seen feeding on larval fish in beds of *Ruppia maritima*, the birds engaging in many aggressive interactions. A widely dispersed flock of Sanderlings on bare mud was seen taking worms, and had aggressive interactions with Ringed Plovers. Sanderlings feeding in shallow water in a mixed wader flock were seen to be picking small flies and small beetles from the water surface.

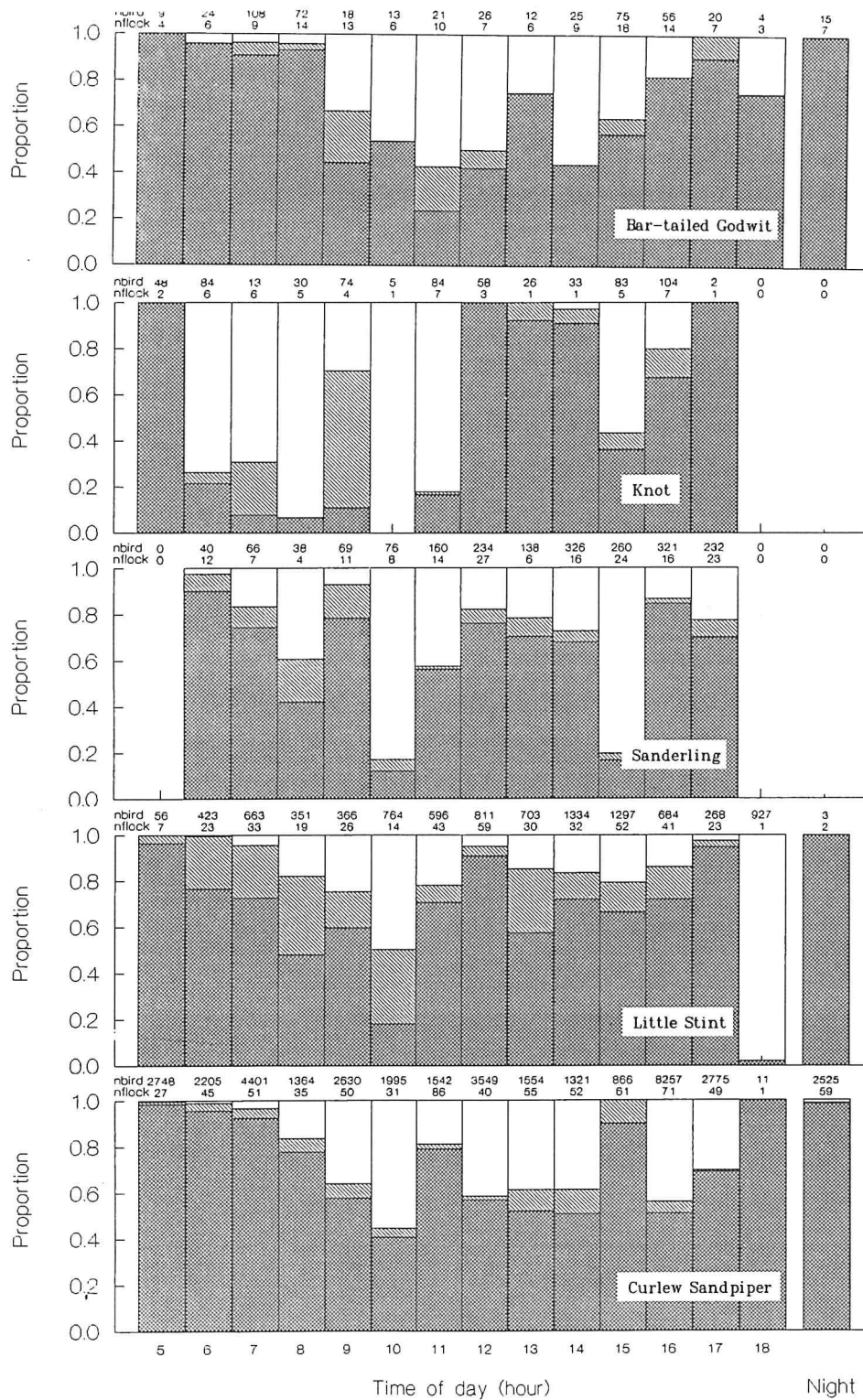


Fig. 26. Time-budgets of tactile surface foraging waders in Songor and Keta Lagoon in October-November 1994. See Fig. 25 for legend and explanation.

Little Stint - *Calidris minuta* (Guild 3) - Little Stints were strongly associated with Curlew Sandpipers, Ringed Plovers and Sanderlings, both when feeding and when roosting. Little Stints roosted at the edges of the water in small (mixed) flocks. They fed on dry and wet mud, exposed beds of *Ruppia maritima* and in shallow water, sometimes with a tendency to concentrate at the water's edge (foraging water depth 0-2.8 cm, median 0.21 cm, n=334 flocks). Little Stints fed throughout the day and at night, foraging activity was low around mid morning, and no birds were observed feeding just before dusk. They spent a considerable amount of the day time on comfort activities (Fig. 26). Birds at Vunya fed in a pecking manner and their droppings contained many *Ruppia*-seeds. At Totokpoe, Little Stints feeding along the edges of a pool had very high pecking rates (250 pecks per min), and could have been picking *Ruppia*-seeds. There were aggressive interaction between individuals, but no signs of territoriality. Birds also fed in mixed flocks in shallow water near Tegbi where they fed on floating flies and small beetles. Some of the birds made multiple probes (sewing) and may have been feeding on small worms.

Curlew Sandpiper - *Calidris ferruginea* (Guild 3) - Curlew Sandpipers roosted in dense flocks on or around mud islands as well as in shallow water, often adjacent to shanks. They foraged on dry and wet mud, exposed beds of *Ruppia maritima* and in shallow water (foraging water depth 0-4.8 cm, median 0.60 cm, n=586 flocks), taking a variety of "not-to-identify, small" prey types. They fed throughout the day and at night but foraging activity was lowest around the late morning-early afternoon period, when the highest proportion of roosting birds were recorded (Fig. 26). At Vunya, surface pecking was the major feeding method, but some birds also made multiple-probes. At Totokpoe, Curlew Sandpipers used probing as the main method of feeding, up to a variety of bill depths. Amphipods and *Ruppia*-seeds may have been the major food items, but deep probing birds were almost certainly catching polychaete worms. Curlew Sandpipers always foraged in scattered flocks, and sometimes displaced each other, as well as other species (such as a

White-fronted Plover from which a worm was stolen). Near Anloga the birds fed on dry and wet mud in the freshwater marsh, presumably pecking for *Hydrobia accrensis*-snails living on the exposed weeds. Here they were also observed to be sewing in mud, getting tiny prey every 2-3 s (probably also *Hydrobia accrensis*). At Tegbi, where Curlew Sandpipers were very abundant, polychaete worms may have contributed most to the diet. Although most of the prey were too small to be seen, birds that were pecking with occasional deep probes in shallow water took worms from 1.5 to 10 times bill length. The polychaetes were sometimes too large to be ingested. Birds in a mixed flock feeding in shallow water picked small flies and small beetles from the water surface. Aggressive interactions were seen quite regularly.

Marsh Sandpiper - *Tringa stagnatilis* (Guild 4) - Marsh Sandpipers fed in shallow to belly deep water in the main lagoons (foraging water depth 0-9.2 cm, median 2.1 cm, n=318 flocks), and also roosted in flocks in similar areas. Marsh Sandpipers foraged throughout the day (Fig. 27) and also exhibited very active social foraging activity at night, ploughing synchronized *en masse*, or singly, for small fish. At Tegbi, they also fed in scattered flocks on larval fish in *Ruppia*-beds with high success rate. Sometimes birds were found swimming, up-ending in water. Occasionally, Marsh Sandpipers were seen scything (sweeping from side to side, see PIERCE 1985). During the night, they showed characteristic ploughing in small flocks comprised of synchronized running birds, which now and then switched to sweeping at a spot.

Greenshank - *Tringa nebularia* (Guild 4) - Greenshanks also fed in shallow to belly deep water in the main lagoons (foraging water depth 0-6.6 cm, median 3.1 cm, n=320 flocks), and also roosted in flocks in similar areas. They were often inactive for most of the daylight period (Fig. 27), sometimes roosting near to Avocets (Totokpoe). Greenshanks formed large social feeding flocks, regularly mixing with Spotted Redshanks, Redshanks and Marsh Sandpiper. These flocks sometimes contained only a few Marsh Sandpipers, but at other times

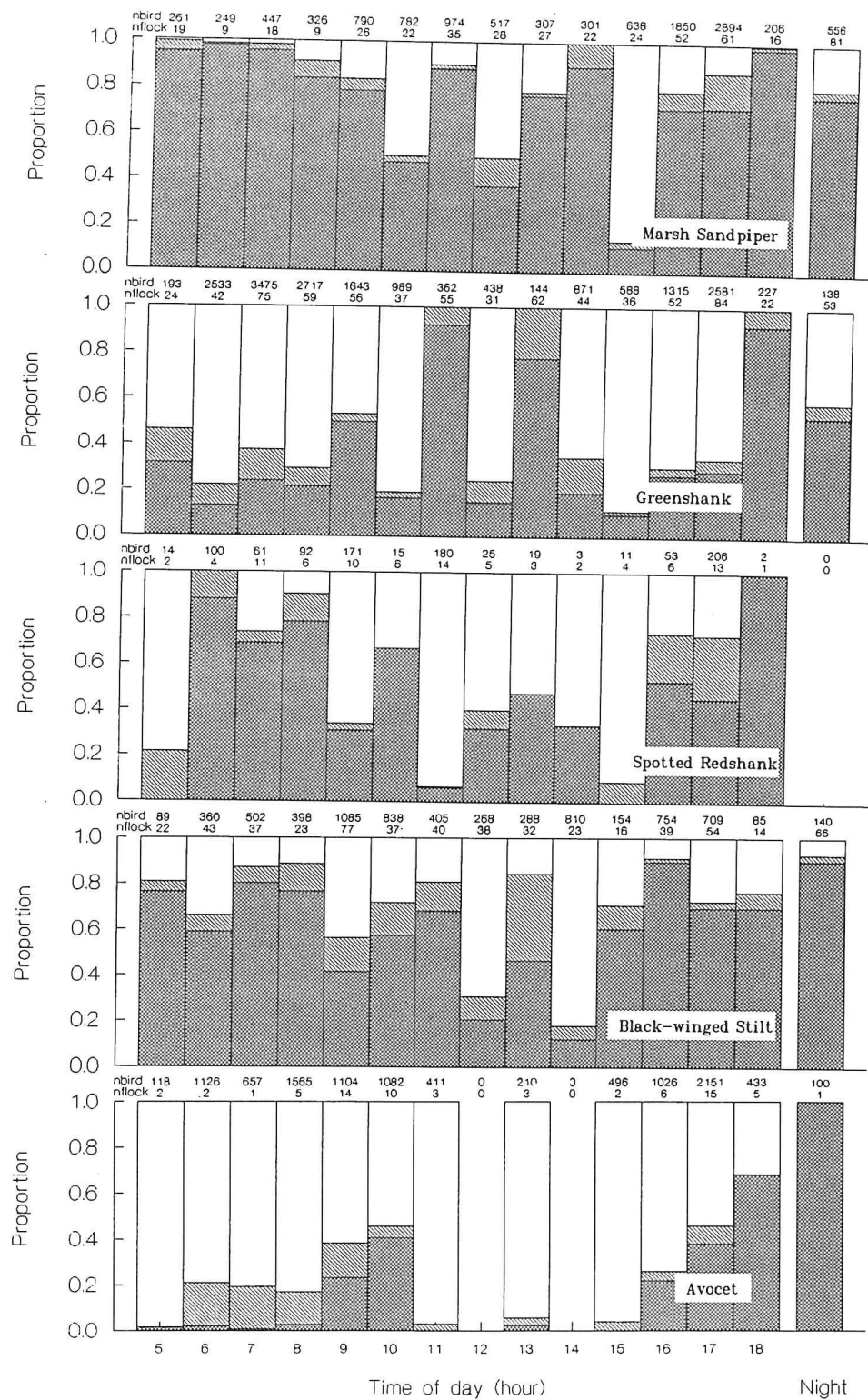


Fig. 27. Time-budgets of pelagic foraging waders in Songor and Keta Lagoon in October-November 1994. See Fig. 25 for legend and explanation.

the two species were totally mixed. Greenshanks fed predominantly on small fish. On a few occasions we saw them probing half-bill-length deep in the mud. Possibly they were searching for fish hiding in mud. In deeper water, Greenshanks pecked for prey, sometimes with their heads completely immersed, and sometimes sideways bill sweeping. Recorded fish prey sizes (probably biased upwards) were 0.1, 0.2, 0.6 and 1.0 times bill length. A fish of 1.5 times bill length proved hard to ingest, but on one occasion, a worm of 1.5 times bill length was taken from the sediment surface.

Some detailed observations on birds feeding in dense social feeding flocks showed that birds took 2 to 3 fish within a few seconds. High feeding rates occurred both in synchronized ploughing sessions as well as in non-synchronized pecking gatherings. In contrast, birds feeding solitary or in pairs ("tandem-walking") walked long distances, pecked only occasionally (pecking rate of 5-11 pecks per 5 minutes) and had low success rate (up to 1 prey per 5 minutes). The experimental fishing showed that schools of small tilapia, when encountered, have the tendency to escape from a flock of predators by swimming to the sides. The somewhat circular pattern of movement within the foraging flock may be linked to the behaviour of the fish-schools. By forming a social feeding flock of birds, the fish's only possibility to escape is by swimming away from the birds. The ploughing technique would ensure that fast swimming fish are overtaken by the bird flock. Although the effort to catch the fish is high, the reward can also be high over short periods of time.

Spotted Redshank - *Tringa erythropus* (Guild 4) - Although Spotted Redshanks roosted in shallow water or dry mudbanks, they always foraged in fairly deep water, often up to belly deep (Figs. 23 and 24). Most Spotted Redshanks were observed foraging near Tegbi, where they fed in large mixed social flocks of shanks. They were seen foraging throughout the day-time, with three peaks around early morning, mid-day and two to three hours before dusk (Fig. 27). No observations were made of night foraging activity. When feeding in dense

social flocks, Spotted Redshank often used the (sideways) sweeping foraging method, in contrast to Greenshanks or Marsh Sandpipers who also used pecking and forward ploughing through the water layer. Spotted Redshank took mostly fish.

Black-winged Stilt - *Himantopus himantopus* (Guild 4) - Black-winged Stilts foraged on wet mud and in a large variety of water depths (foraging in 0-16.3 cm deep water, median 4.7 cm, n=411 flocks). They fed throughout the day and at night, but foraging activity was lowest during the mid-part of the day (Fig. 27). They showed very variable feeding behaviours and fed on a wide variety of prey types. At Totokpoe, they were seen taking fish (of 0.1, 0.3, 0.15, 0.2 and 0.6 times bill length) from the water layer, but some birds pecked in the mud, perhaps searching for hidden fish. At Fiahor, they showed a very plover-like feeding behaviour at night, alternating series of steps with careful spotting of the surroundings when standing still. At Anloga, stilts fed in the freshwater marsh, pecking prey from the water bottom (probably *Hydrobia accrens* which were very abundant there). At Tegbi, Black-winged Stilts fed in shallow to deep water in loose flocks, sometimes peripherally to social flocks of shanks in low numbers. They fed frequently on fish (29 pecks with no success in 5 min in one individual, in same flock another bird was successful with a fish of 0.2 times bill length). The largest fish which was seen to be ingested was 1.25 times bill length. Some birds were pecking seeds from the water bottom and direct from exposed *Ruppia*-beds. On one occasion we saw a flock of 10 Black-winged Stilt feeding on small prey floating on the water surface. In this flock a stilt had a lower peck rate than a Redshank.

Avocet - *Recuvirostra avosetta* (Guild 4) - Avocets were always encountered in flocks, and spent the greater part of the day time roosting along the edges of the lagoons (Fig. 27). They fed socially in flocks in shallow to deeper than belly-deep water (foraging water depth 0-14.2 cm, median 7.0 cm, n=32 flocks), taking fish (lengths recorded on two occasions were 0.4 and 0.3 times their bill length). Although some

feeding was observed during the early morning and in the evening, this species probably feeds predominantly at night. This is supported by observations at Tegbi where Avocets were encountered in very noisy feeding flocks at night.

Little Egret - *Egretta garzetta garzetta* (Guild 5) - Little Egrets fed communally, particularly with Reef Herons and Greenshanks in shallow to relatively deep water (foraging water depth 0-13.1 cm, median 5.8 cm, n=201 flocks) and also took advantage of socially foraging shanks.

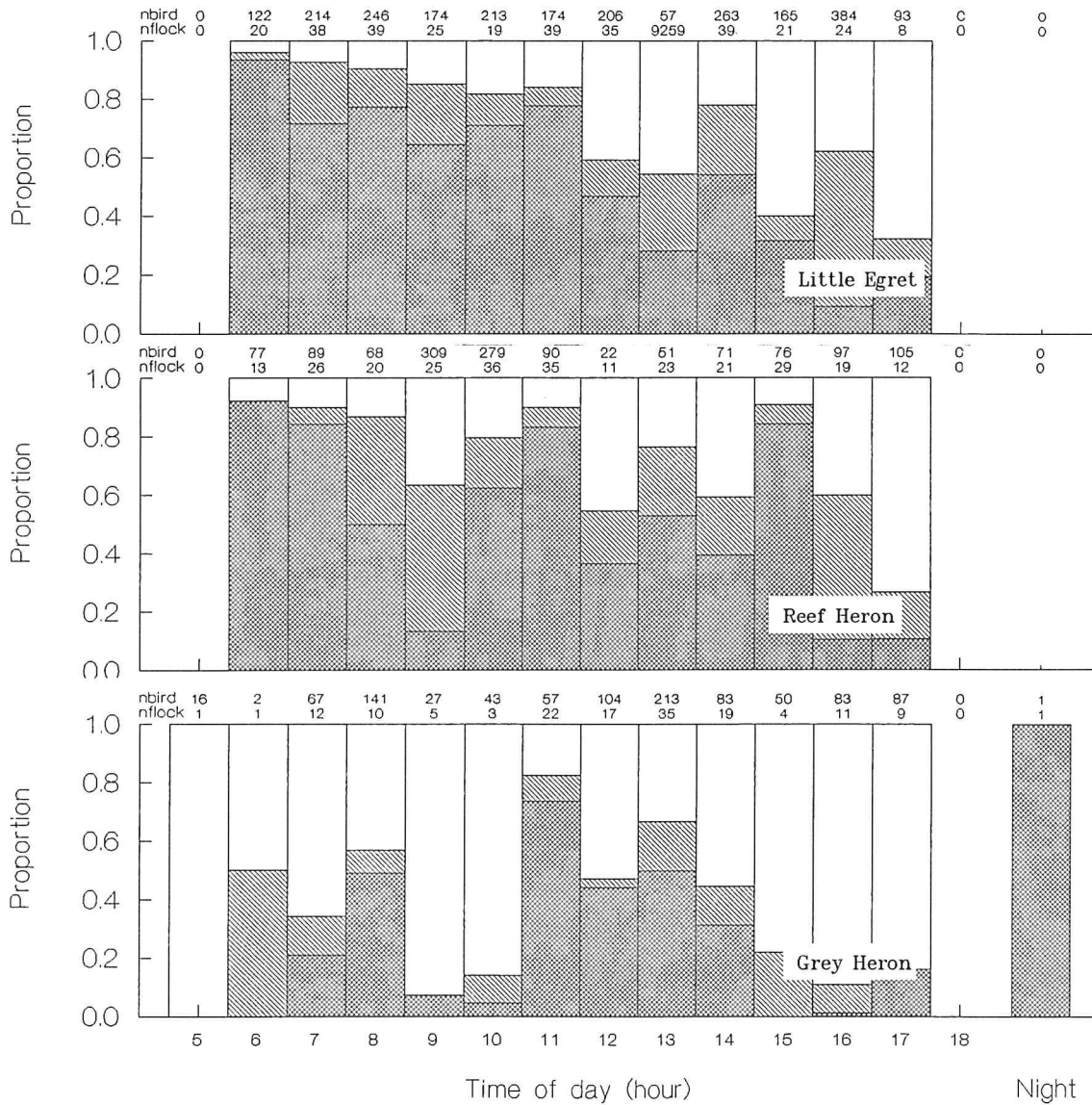


Fig. 28. Time-budgets of stalking herons in Songor and Keta Lagoon in October-November 1994. See Fig. 25 for legend and explanation.

They were also seen taking fish left to dry on the banks. They fed throughout the day time (Fig. 28). At night, Little Egrets left the lagoons for their communal night roosts, probably mostly located in trees (although the roost in the freshwater marsh near Anloga was in shallow water). Any daytime roosting also took place at elevated sites, such as mangrove bushes or fishing sticks. Fish of up to 1.5 times bill length were seen taken. At Anloga and at Tegbi, Little Egrets showed foot-paddling.

Reef Heron - *Egretta garzetta gularis* (Guild 5) - Reef Herons fed in the lagoons, both on dry and wet mud and in deeper water (foraging water depth 0-11.1 cm, median 5.3 cm, n=169 flocks), concentrating their efforts at sites where humans with fish traps or socially foraging wader flocks concentrated the schools of fish. Their diurnal rhythm was similar to that of Little Egrets (Fig. 28). They also fed communally with Little Egrets and Greenshanks and took advantage of socially foraging flocks. Fish of 0.15, 0.4, 0.4, and 0.7 times bill length were seen to be taken.

Great White Egret - *Egretta alba* (Guild 5) - Great White Egrets fished during the day at sites where fish were concentrated, usually at human fish traps. They were always found together with Little Egrets and Reef Herons, and were sometimes seen in mixed social flocks of wading birds. They were absent from the lagoons at night. Fish up to 1.5 times bill length were seen to be taken.

Grey Heron - *Ardea cinera* (Guild 5) - Grey Herons were seldom seen feeding, and were often seen arching with outstretched wings to the sun. At Totokpoe, they spent much of day roosting in a long line on dry mud near mangroves. At Fiahor, they often roosted on sticks used for fish traps and fishing devices. Grey Herons probably feed at night since they were around the study site near Fiahor at the earliest daylight. When feeding during the day the birds foraged in very dispersed groups of up to 30 individuals in knee-deep water, some wading slowly but most in the waiting mode. An ingested prey observed was a large fish, measuring the same length as the bill. On

another occasion, a long eel-like fish (probably Muridae) was "stolen" from a Curlew.

White Pelican - *Pelecanus onocrotalus* (Guild 6) - The flock of White Pelicans at Keta Lagoon rested on the extensive dry mudflat south-east of Fiahor and south-west of Dudu Island. However, on occasions they were seen flying into the lagoon from elsewhere; once circling on a thermal north of Fiahor, and a couple of times off Tegbi. Obviously the pelicans were very mobile, and they probably have alternative roosting sites somewhere else inland. Thermal soaring is energetically cheap, so travelling distances regularly should provide no problems for them. A group was also seen soaring north of Adina once. Past observations at Totokpoe and Afiadenyigba indicate that pelicans feed in social groups both in the early morning and late afternoon. A group of pelicans that started feeding just before dusk, around 17:50 hr, were seen flying into the lagoon at a point between Woe and Dudu Island. On one occasion they landed in shallow water just off the mudbank and started to feed socially.

Little Tern - *Sterna albifrons* (Guild 7) - At Totokpoe, Little Terns roosted on bare mud and foraged in the lagoon and at sea just behind the surf, probably only taking small fish. During the study period, juveniles which were still being fed by their parents were observed. These birds were obviously from the resident stock. At Tegbi, small numbers (up to 10) were seen either roosting together on mudbanks or feeding in shallow water. During the morning and evening, we encountered concentrations of up to 200 Little Terns around socially feeding flocks of shanks. They dived around these hectic flocks, and sometimes right in the middle of the foraging shanks and herons. Little Terns seem to reap considerable rewards from the social foraging efforts of shanks and herons, which is likely to concentrate and confuse the large schools of small tilapia.

Common Tern - *Sterna hirundo* (Guild 7) - Common Terns roosted on bare mud. Especially in the early morning, Common Terns fed on fish in the lagoon near Totokpoe. Like Black Terns with which their activities seemed very

much synchronized (Fig. 29), Common Terns did most foraging at sea. At dawn almost the entire population flew out from the roost near Totokpoe (Figs. 30 and 31). During the entire daylight period terns were observed to fly in and out of the lagoon in relatively small numbers. From 10:00 to 12:00 hr and from 16:00 to 18:00 hr numbers of returning Common Terns peaked (Fig. 31). At dusk over 90% of all terns were present in the lagoon. It appears that the majority of terns fly out twice each day to forage.

Roseate Tern - *Sterna dougallii* (Guild 7) - Roseate Terns roosted on bare mud and only foraged out at sea from Totokpoe during daytime. They depart on foraging trips very early in the morning (they were heard as early as 5:15 hr as they flew out to sea).

Sandwich Tern - *Sterna sandvicensis* (Guild 7) - Sandwich Terns roosted on bare mud or sand and foraged only at sea, usually in rather

smaller flocks than the other tern species (up to 10 birds). A few times, juveniles were seen flying after a parent bird, begging for food. Birds were seen flying out at sunset from the roost near Totokpoe, heading eastward. On a couple of evenings Sandwich Terns were heard in the dark. At Anloga, some Sandwich Terns roosted with other terns and waders on a mud island during daytime.

Royal Tern - *Sterna maxima* (Guild 7) - Up to 126 Royal Terns roosted on bare mud during the night and sometimes in daytime at Totokpoe, and foraged out at sea during the day. Several times juveniles were observed pursuing adult birds in flight, loudly begging for food.

Caspian Tern - *Sterna caspia* (Guild 7) - A maximum of three Caspian Terns were seen roosting on bare mud at Totokpoe. At Fiahor small numbers were fishing in the lagoon. A juvenile was seen associating with two adults, indicating that family groups are retained during

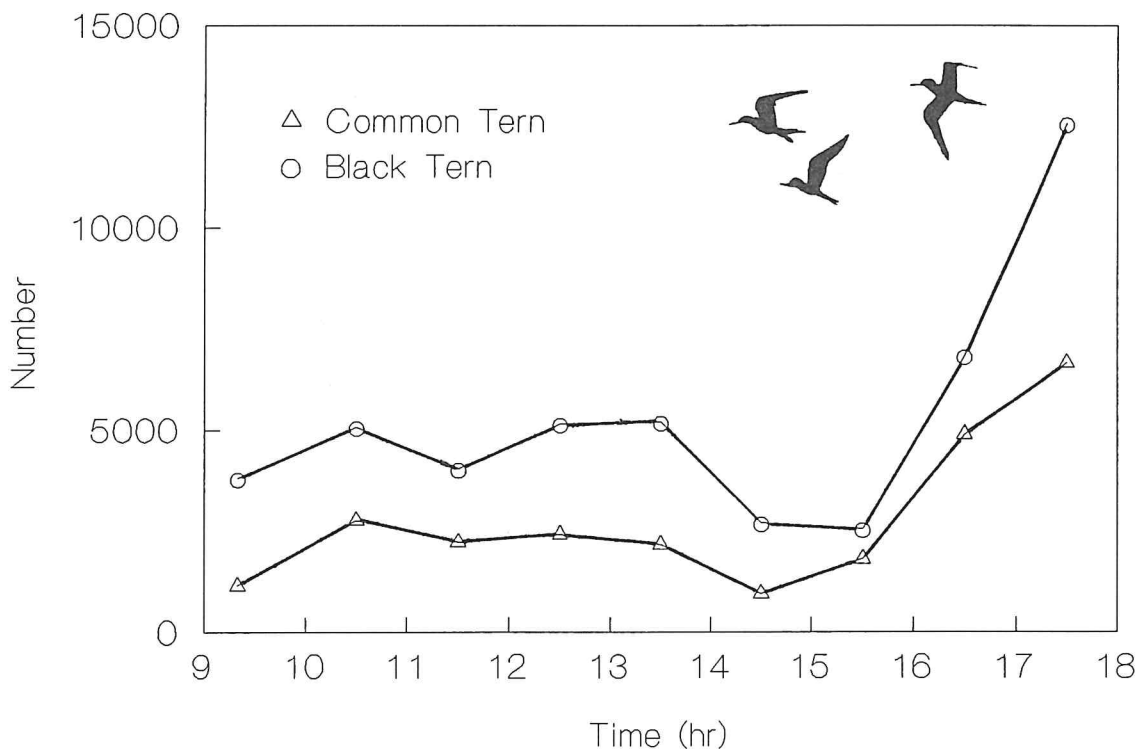


Fig. 29. Diurnal changes in the numbers of Common Terns and Black Terns (counted separately) on the roost near Totokpoe based on detailed counts made on 18 October 1994.

migration, at least to this stage. Although the juvenile was difficult to distinguish on plumage characteristics, its wheezy call was distinctive. On 10 November a flock of at least 12 birds was observed near Dudu Island in Keta Lagoon.

Whiskered Tern - *Chlidonias hybridus* (Guild 7). - Flocks of Whiskered Terns fed in shallow water in the middle of Keta Lagoon. We made

only one observation of this species at Songor Lagoon (on 10 October). During day-time, Whiskered Terns were sometimes seen roosting on mud islands adjacent to or amongst roosting flocks of waders. At Fiahor most Whiskered Terns were seen on the lagoon but fairly well offshore. They were probably flying back and forth between Woe and Fiahor during feeding trips. Whiskered Terns sometimes joined socially feeding mixed wader and heron flocks.

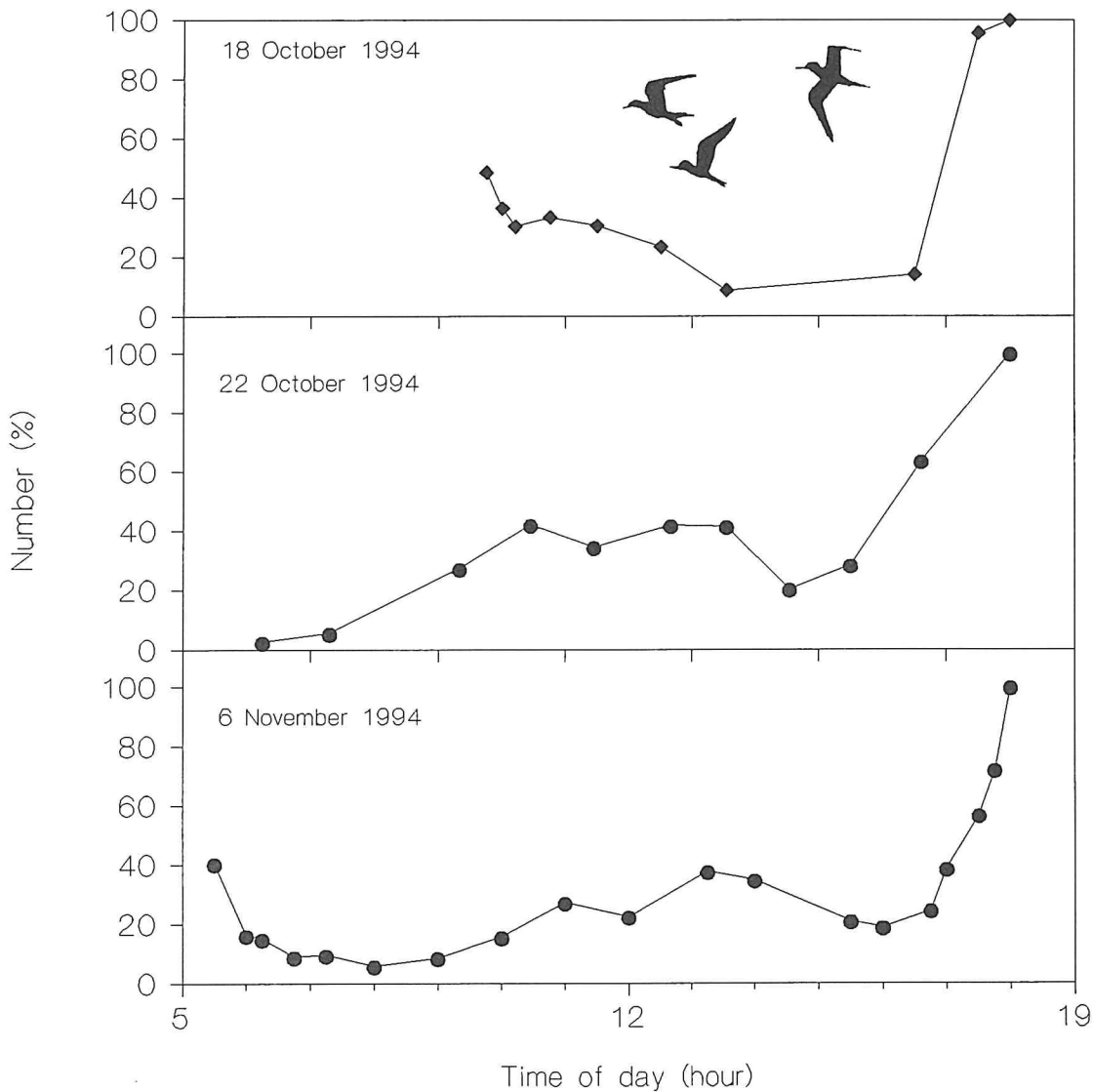


Fig. 30. Diurnal changes in the combined numbers of Common and Black Terns (not counted separately) on the roost near Totokpoe on 18 and 22 October and 6 November 1994. The relative numbers on the roost are presented as percentages of the maximum, which was always reached during the last count before nightfall.

Black Tern - *Chlidonias niger* (Guild 7) - The great majority of Black Terns were encountered near Totokpoe, where they were roosting (during the day and at night) on bare mud (Figs. 29 and 30). They mainly foraged at sea. On the lagoon small numbers fed on fish in gullies with seepage water. Feeding success was determined to be around one fish per 10 min. On some days, big concentrations fed in the gullies near Totokpoe and on the main water

body of the lagoon around groups of fishermen pulling up their nets. Most of the terns, however, fed at sea. At dawn almost the entire population flew out from the roost near Totokpoe (Figs. 30 and 31). During the entire daylight period, terns were observed to fly in and out of the lagoon in relatively small numbers (Fig. 31). From 10:00 to 12:00 hr and from 16:00 to 18:00 hr numbers of returning terns peaked (Fig. 31). At dusk 95% of all terns

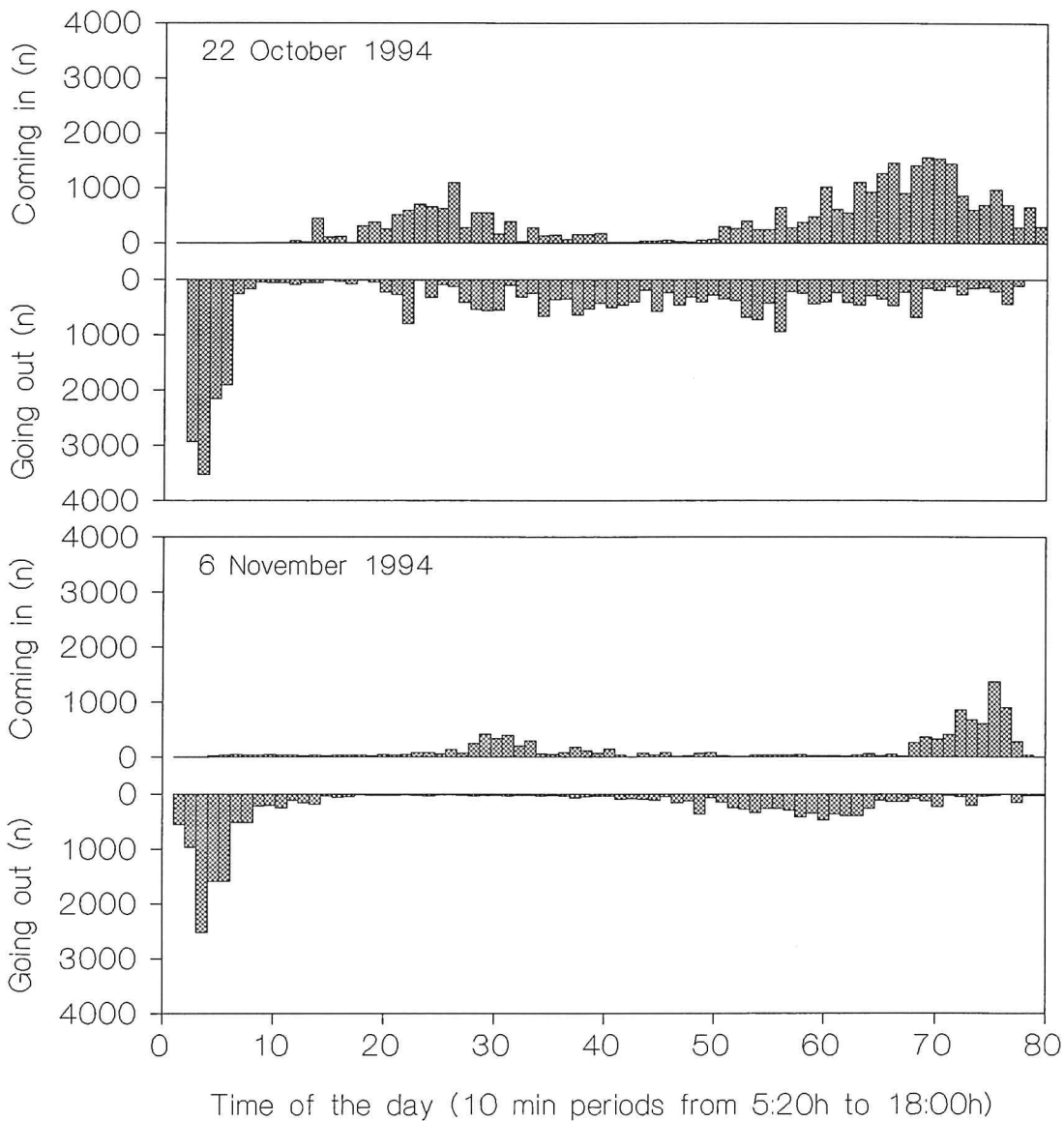


Fig. 31. Diurnal changes in the combined numbers of Common and Black Terns (not counted separately) flying out from the roost to sea and coming back from the sea per 10 min period. Such counts were made on 22 October and 6 November 1994 close to the roost near Totokpoe.

were present in the lagoon. The remaining 5% probably returned within 30 min after sunset. Possibly, the majority of the terns fly out twice each day to forage. The time spent at sea is probably very variable, but early morning monitoring suggest that a foraging trip lasted 4 hrs on average. On a couple of evenings, flocks of Black Terns were seen flying near Ada-foah, following the coast to the west in the direction of the roost at Totokpoe. This could suggest that an alternative daytime-roost may exist to the east, possibly in the delta of the Volta River. Large flocks of foraging terns were seen during the morning far out at sea near Ada-foah as well. At Tegbi a single Black Tern was observed diving in shallow water to catch a polychaete worm (size 1.5 times bill length).

8.3. SOCIAL FORAGING IN WATERBIRDS

"Classic" social foraging (*sensu* GRIMES 1969, ZWARTS 1974) of sometimes large flocks, feeding with very directionally-synchronised movements, was regularly seen. However, most social flocks were not so directionally synchronised within the flock. Instead, they fed all together in equally dense and noisy flocks but typically pecked, walking rapidly with no seeming regard for the movements of other individuals. Although it will be hard to figure out whether this was actually a social style of foraging or instead a form of scramble competition in an area of high food availability, we will refer to all these temporally synchronized foraging behaviour as "social foraging".

Most waterbirds at Songor and Keta Lagoon fed in pretty large aggregates or flocks, which varied in size from "1 bird" to almost 600 birds (Fig. 32). Although almost half of these flocks were comprised of one species, many of them contained more, up to a maximum of six waterbird species (Fig. 33). This was true for foraging as well as roosting flocks. Social foraging was recorded in six wader species (Greenshank, Marsh Sandpiper, Spotted Redshank, Redshank, Avocet and Black-winged Stilt). All but the Redshank belonged to guild 4 (Fig. 34) of pelagic foraging waders. As elsewhere in Africa (e.g., SAINO *et al.* 1995), social foraging was also the rule in White Pelicans, although we observed it only on a few occasions at dawn. Social foraging was most

often seen in Greenshanks, Marsh Sandpipers, Spotted Redshanks and Avocets. For Spotted Redshanks, Marsh Sandpipers, Avocets and Greenshanks between 10-30% of the flocks containing this species were engaged in social foraging. Three wader species other than Redshanks were occasionally associated with social flocks (Wood Sandpiper, Bar-tailed Godwit and Curlew Sandpiper). As a rule, egrets (Little Egrets, Reef Herons, and, sometimes, Great White Egrets) joined such flocks as well. Thus, socially foraging flocks usually contained more than one species. The flocks were generally very dense: mean nearest neighbour distance was 1.3 bird-lengths (intra-specific distances, $n=180$, $SD=1.1$). The larger flocks (>100 individuals) were always very dense, while smaller flocks were sometimes somewhat less crowded.

The daily timing of recorded socially feeding flocks is shown in Fig. 35. Whilst social foraging occurred during much of the day with a small peak in late morning, it was particularly common during dusk and during the night. During the latter two periods of the day egrets are absent from the lagoon (off to their night-time roosts), and could thus not interfere with the foraging waders in the flocks. For some species such as Avocets and White Pelicans, social foraging at night probably provides the bulk of their food intake.

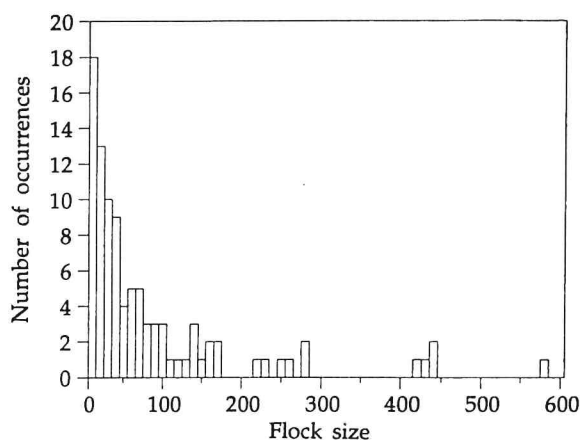


Fig. 32. Distribution of flock sizes (all species combined) in Songor and Keta Lagoon in October-November 1994.

A social flock of birds will often involve a line of birds running in unison. When fish are restricted to escaping in only one main direction ('forward', away from the birds) they do so very quickly, and the running of ploughing shanks is an attempt to overtake escaping fish. This is apparently very successful, judging by the few occasions in which we were able to follow an individual bird for any more than about a second. A feeding run would typically last only a few seconds in a shanky wader but could cover 5-10 m in this time, and could be seen making several swallows (presumed fish captures).

This high intake rate was not exclusive to directionally synchronized social behaviour. The large, dense, pecking assemblages also had apparently high feeding rates (although we have no data on actual intake rates). In this case, the fish are presumably unable to swim any distance unobstructed, and in a dense bird flock a ploughing bird might be likewise unable to travel any distance without obstruction. Ploughing may then be a technique restricted to open water and edges of large flocks (and is frequently seen in breakaway groups from pecking flocks), while pecking can be used wherever fish are in a sufficiently high density to be harvestable, e.g. inside social foraging flocks.

Social foraging is thus a feeding method restricted to fish-eating birds, and it is probably an example of bird behaviour enhancing prey availability directly. The fish present in the Ghana lagoons are small tilapia, common cichlid species (see Chapter 9). Very small individuals form schools in shallow water, and can be readily seen when walking through open water. These fish should then provide an abundant food source for piscivorous birds, but their actual availability is reduced by the fact that they can move fairly quickly when disturbed. When they are disturbed (e.g. by walking biologists) schools tend to swim rapidly forward and to the sides. By spreading out in a line it is possible to 'herd' tilapia for quite some distance, especially by blocking their escape reactions to the sides. Local fishermen fish in this fashion. In this way a school of fish can become concentrated, and maintained in densities far above that which a solitary feeding bird would encounter.

Most definitions of social foraging would logically have in them the aspect that there is a social element to the behaviour. Apparently, social flocks comprised of pecking birds may be difficult to distinguish from simply dense active flocks of individuals in an area of high prey density, where a form of scramble competition may actually be occurring. Certainly, once there is a high density of birds in an area, fishes' escape reactions will become just as confused as in a school which has been herded by a flock of socially feeding birds. The only functional social aspect would then be in the initiation of the feeding bout, where the activities of many

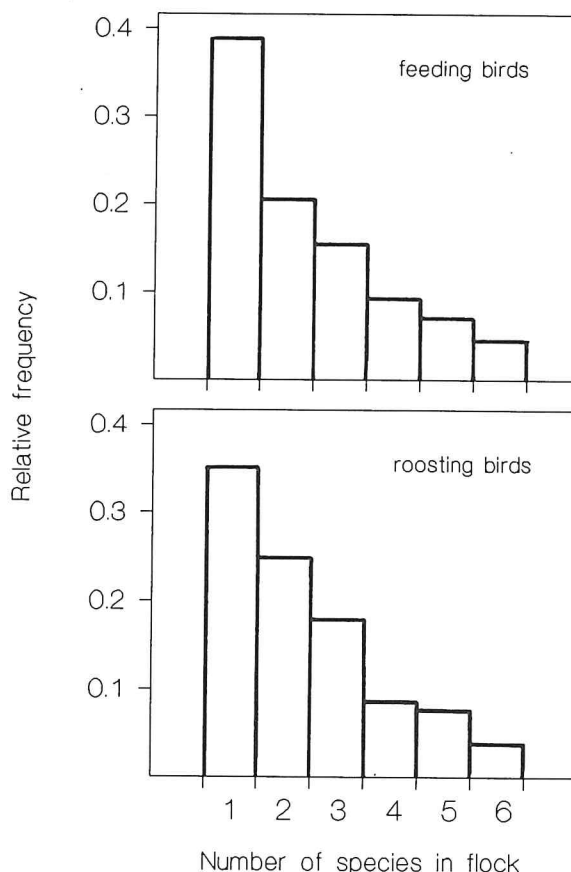


Fig. 33. Number of species in the flocks of waterbirds comprised mainly of foraging individuals (percentage of birds feeding is greater than 25%) (A), or showing a large number of non-foraging and roosting birds (B).

birds may be required to concentrate prey. If fish swim into shallow water or beds of vegetation, pecking may then be most profitable method, and a flock could easily change from an obviously social flock into an apparently non-social one.

That these flocks do manage to concentrate fish is also indicated by the fact that terns, especially Little Terns, were often seen diving in and around social flocks. Terns are able to 'cash in' on the increased fish availability caused by the feeding activities of other birds. This provides a nice parallel to the situation in

many marine areas where terns feed when predatory fish force smaller fish to the surface of the sea, making them available to terns.

Social feeding is a common and widespread feeding method in several species of wading waterbirds in the Ghanaian coastal wetlands. It probably contributes considerably to the energy intake of many species each day, and provides almost all energy for a few. It is illustrative that the social foraging mode to catch tilapia is employed by the birds as well as the humans (see cover photographs). As such, the phenomenon warrants further study.

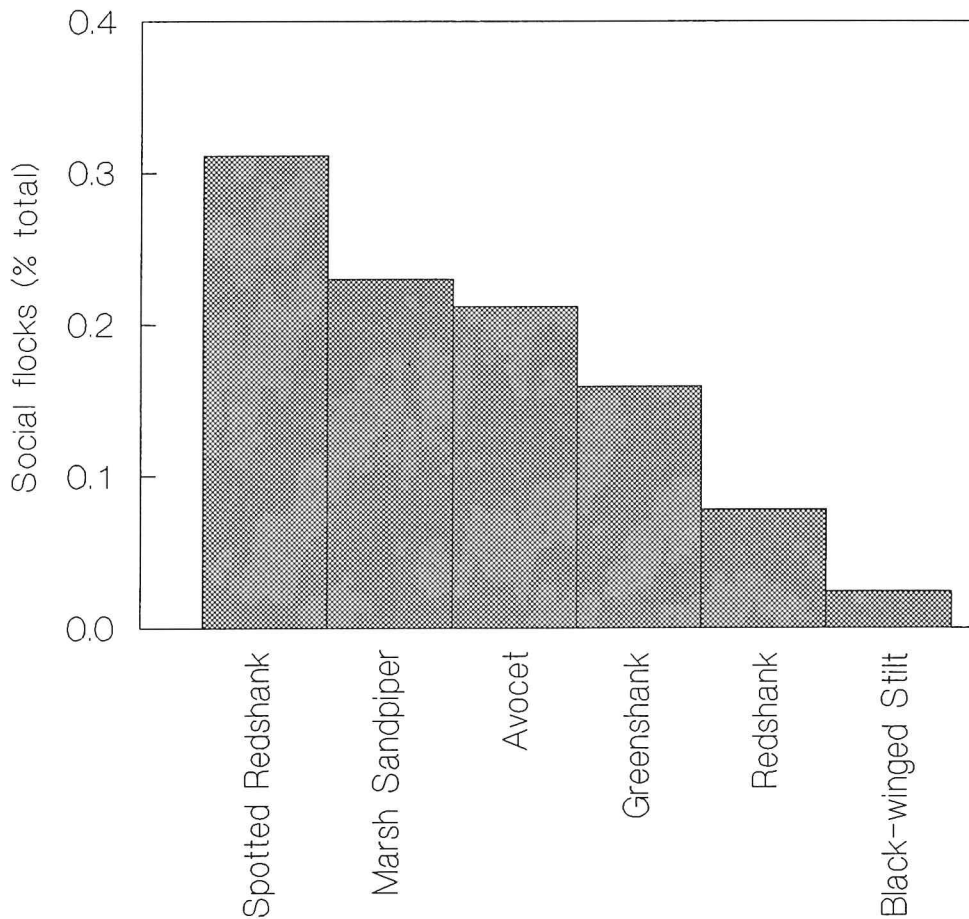


Fig. 34. Incidence of social feeding in flocks of six wader species in Songor and Keta Lagoon in October-November 1994. The number of flocks in the samples containing the various species are 45 for Spotted Redshank, 318 for Marsh Sandpiper, 33 for Avocet, 320 for Greenshank, 154 for Redshanks and 411 for Black-winged Stilts.

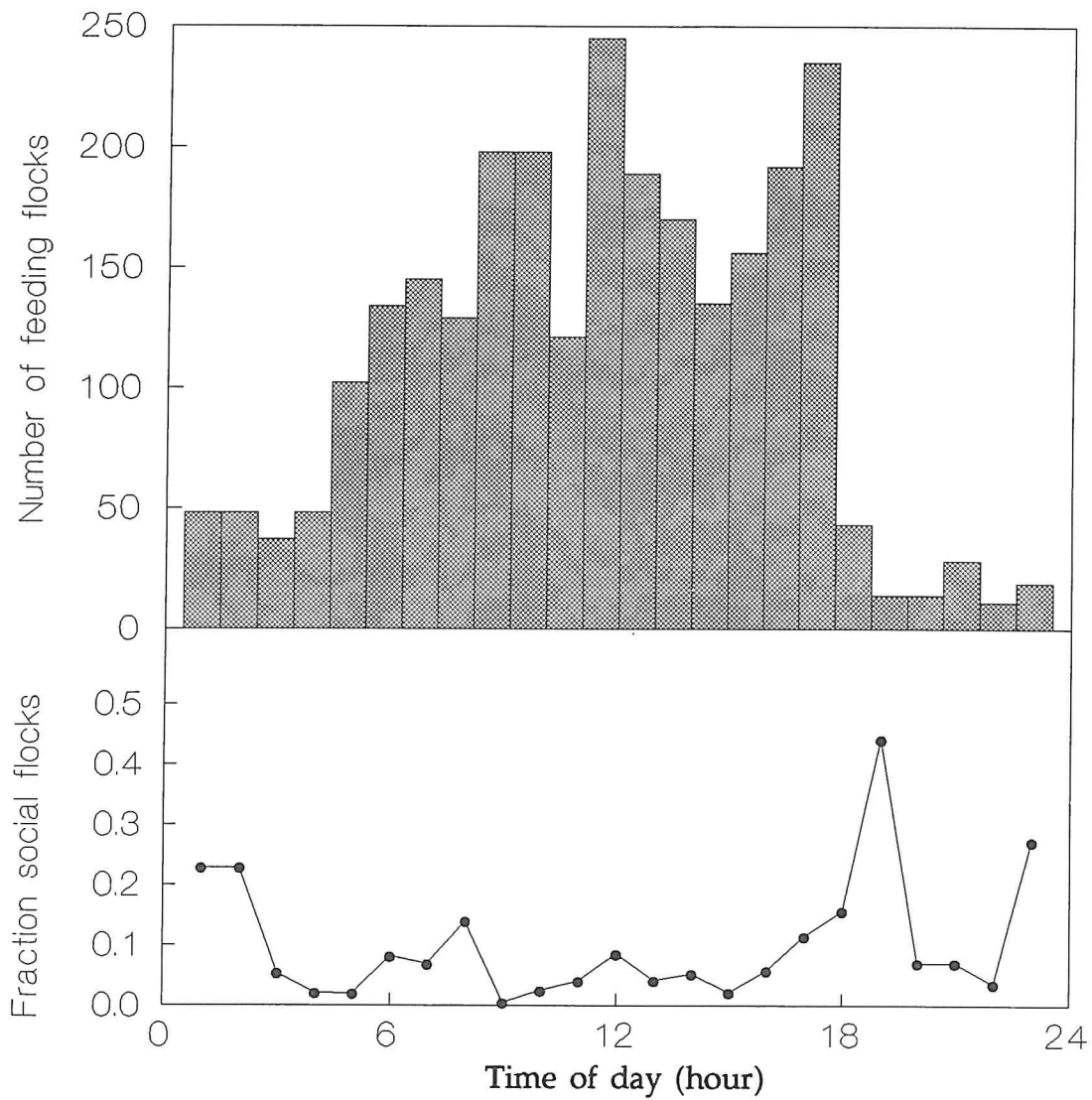


Fig. 35. Incidence of social feeding by waterbird flocks in Songor and Keta Lagoon in October-November 1994 as a function of time of the day. A gives a breakdown of the recorded numbers of flocks per hourly interval, and B the fraction of flocks engaged in social feeding.

8.4. SYNTHESIS OF HABITAT PREFERENCES, FORAGING TECHNIQUES & TIME-ACTIVITY BUDGETS

Table 5 summarises the observations on feeding habitats, feeding styles and diet of the waterbird species using Songor Lagoon and Keta Lagoon. A total of 3,199 flocks containing 118,648 individuals of 36 different waterbird species were scanned during the study period.

Water depth selection - Figure 23 shows the ranges of water depth selected by foraging birds within the different guilds. Feeding habitats varied from dry mudflats to wet mud and shallow water of no more than 20 cm. Small waders, e.g. Ringed Plovers, Curlew Sandpipers and Little Stints, foraged on the dry banks, wet mud and water of less than 3 cm depth; medium sized waders such as Black-winged Stilts, Greenshanks and Bar-tailed Godwits, required water depths up to 10 cm for feeding, while the relatively big egrets and herons fed in deeper water of up to 17 cm depth. The spatial distribution patterns of feeding waders on the lagoon can be summarised as follows: species such as Ringed Plover, Kittlitz's Plover, White-fronted Plover, Little Stint, Turnstone, Grey Plover and Common Sandpiper forage on the outer edges and wet mudbanks; followed by species such as Curlew Sandpiper, Sanderling, Knot and Marsh Sandpiper in the shallow water margins; the Greenshanks, Spotted Redshanks, Black-winged Stilts in the deeper water; with the Reef Herons and Little Egrets in the inner layer. The choice of feeding habitats varied within and between the guilds and was mainly dependent on two factors: (1) the size of the bird (more specifically the leg length and height above the ground). A positive correlation was observed between tarsus length and depth of water selected by the birds for foraging (Fig 36, $r^2=0.82$, $n=20$, $P<0.001$); and (2) food availability. Thus, the deeper areas of the lagoon and recently flooded areas devoid of prey items were not used by the birds.

The sites used by the birds for roosting consisted of dry mud banks, islands within the lagoons and shallow water of up to 16 cm depth (Fig. 24). Herons and egrets also roosted com-

monly on structures in the water such as sticks used in the various fishing devices. There was no significant correlation between water depth and leg length for roosting birds ($r^2=0.05$, $n=20$, $P=0.336$), although there was the tendency for bigger birds to select deeper water (Fig. 36).

All the tern species encountered used the lagoons as roosting habitat and foraged mainly at sea, but Little Terns, Black Terns, Whiskered Terns and Caspian Terns sometimes foraged also on the lagoons.

Feeding styles - Several prey hunting and detection techniques as well as methods of catching prey items were exhibited by the different water-bird species. Large stalking waterbirds like herons would walk slowly through shallow water searching for prey items or stand motionless watching out for the prey and stab it when found. They would also often join aggregations of communally and frantically feeding waders, thus trying to capitalize on the confusion created by all the waders amongst the fish present. Some of the smaller waders would intermittently make a run, pause and watch, and then make another run to sometimes catch a surface-living benthic invertebrate or fish, obviously using a visual means for detecting the prey items. This mode was predominant among the plovers. Others, e.g. Wood Sandpiper and Redshank, also gave the impression of feeding by eye-sight, but these birds did not show the intermittent run and wait pattern of the plovers and appeared to be pecking randomly on the surface of the water or mud. Some of the waders feeding on exposed mud would walk and use their bill to probe in the mud, clearly using tactile means to discover buried prey. Most of the waders occurring in big flocks in shallow water fed by rapidly moving their slightly opened bills through the water. One way this was done was ploughing, in which a bird immersed the lower half of its bill in the water at a shallow angle and ran forward very quickly for a distance of 5-15 m. On many occasions such birds were running at great speed, thus pursuing the small fish (tilapia) that they were undoubtedly feeding on. Sweeping or scything, the swishing of the bill from side to side through the water (PIERCE 1985) was less frequently observed than

ploughing, but this must have been due to the low observation frequencies of Avocets and Spotted Redshanks, of which sweeping represents the main feeding technique. It was seldom seen in singly foraging birds except for the occasional Black-winged Stilt. Black-winged Stilts exhibited a wide range of feeding styles: pecking, probing, sweeping and ploughing, sometimes feeding singly, in loose flocks or joining in social foraging flocks.

Most of the waders observed in the Ghana lagoons fed and roosted in mixed species aggregations or flocks. Flock sizes ranged from 1-600 birds, with most individual birds feeding in flocks of 50 or larger (Fig. 32). Dense flocks of waterbirds that were all frantically foraging at the same time, giving some sort of organized impression, were classified as social foraging flocks. The clearest case was provided by birds behaving in a directionally synchronised fashion (i.e. all moving in a particular direction during social foraging, see previous section), thus giving the impression of behaving as a single

large "organism" and was particularly common in the Greenshanks, Spotted Redshanks, Marsh Sandpipers, Avocets and White Pelicans.

Diet - Prey items ranged from seeds of widegeongrass *Ruppia maritima* to various invertebrates (mainly polychaetes, molluscs and crabs) and fish, mainly juvenile tilapia. All the species in guilds 2 and 3 (plovers and sandpipers) fed on invertebrates and seeds and either pecked from the surface or probed in the mud for the prey. Species in guilds 4-7, comprising the shanks, stilts, herons and terns fed mainly on fish (Table 5).

Diel rhythmicity - The daytime was spent on two main activities, feeding and roosting, with a tiny fraction of the time spent on comfort activities (preening, bathing, stretching). The 26 shorebird species for which sufficient data on diel rhythmicity were obtained fall into five of the seven guilds initially defined (see section 8.1): guild 2, Visual surface foraging waders

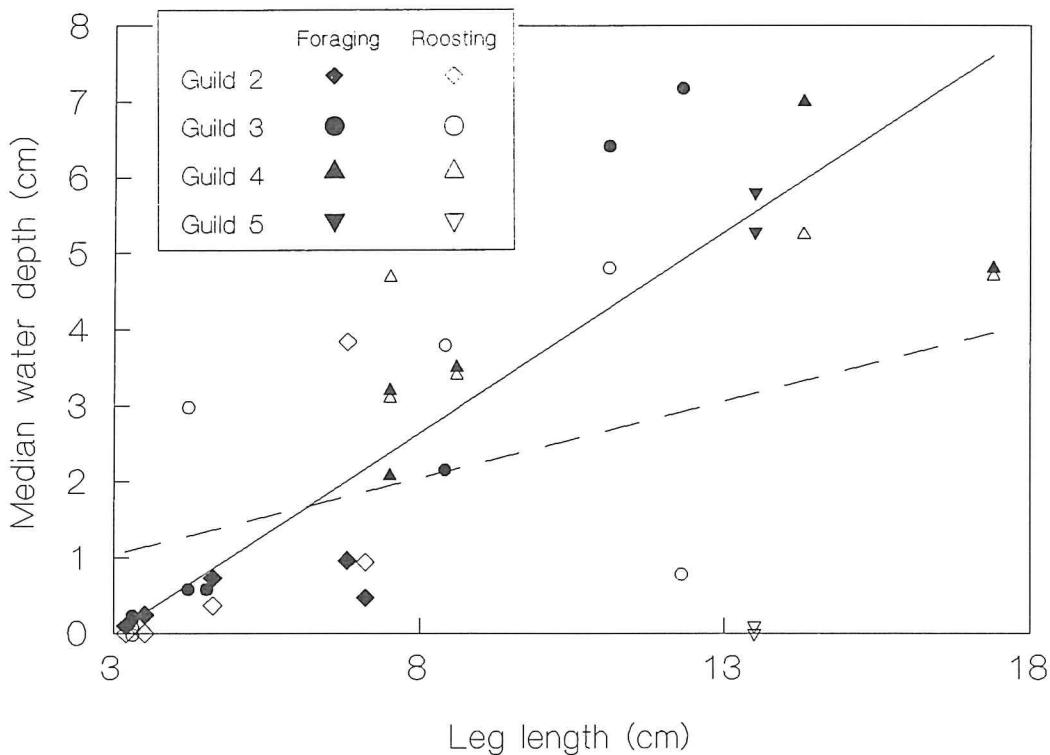


Fig. 36. Water depth as a function of exposed leg length in the different species and waterbird guilds. Plus statistics.

(Kittlitz's Plover, White-fronted Plover, Ringed Plover, Grey Plover, Common Sandpiper, Whimbrel, Turnstone, Wood Sandpiper, and Redshank); guild 3, Tactile surface foraging waders (Black-tailed Godwit, Bar-tailed Godwit, Curlew, Knot, Sanderling, Little Stint, Curlew Sandpiper); guild 4, Pelagic foraging waders (Marsh Sandpiper, Greenshank, Spotted Redshank, Black-winged Stilt and Avocet; guild 5, Stalking herons (Little Egret, Reef Heron, Great White Egret and Grey Heron) and Guild 6, Fishing pelicans (White Pelican).

Fourteen out of the 26 species showed a circadian activity pattern, feeding day and night, while the remaining 12 were diurnal, with no purely nocturnal species. The herons and egrets (guild 5) feeding on fish and using visual means for prey detection, fed only during the day time while all the species in guild 4, the pelagic foraging species which also fed mainly on fish, but used a combination of visual and tactile clues for prey detection, both day and night. In addition to the pelagic foragers, nocturnal foraging was observed also in three of the nine visual surface foragers, Ringed Plover, Grey Plover and Redshank; in three of the tactile surface foragers, Black-tailed Godwit, Little Stint and Curlew Sandpiper and in the White Pelican which also uses both tactile and visual means to detect prey. Night feeding, therefore, was common in many of the waterbird groups that use the lagoons in Ghana irrespective of the sensory mechanism they used to detect prey, but appeared to be more predominant in the species which detect their prey by touch.

The activity patterns of the birds varied greatly between and within guilds (Figs. 25-28) and no common pattern emerges for any guild. However, some general trends can be discerned. Some wader species fed throughout the day with no significant variation between the proportion of birds foraging at different times of the day, e.g. Ringed Plover, Wood Sandpiper, Little Stint, Black-winged Stilt, Little Egret and Reef Heron. Some species showed a morning and an afternoon peak foraging activity, e.g. Bar-tailed Godwit, Redshank, Curlew Sandpiper and Marsh Sandpiper. A range of other combinations, e.g. dawn and midday peak, (Grey Plover) dawn, midday and dusk peak

(Sanderling), were also observed. Three of the five species which foraged mainly in social flocks (Greenshank, Avocet and White Pelican) fed mainly at night and spent the greater part of the day roosting.

All the seven species of terns foraged from dawn to just after darkness and a constant stream of birds from the roosting site on the lagoons going out to sea was observed throughout the day (see Figs. 30 and 31, showing changes in numbers of terns roosting on the lagoons in daytime and tern movements in and out from the sea).

Which species occurs with which? - Especially during foraging, there was a tendency for species of similar guilds to occur in the same flock (look at the rather strong diagonal band in Table 6). An added factor was the choice of water depth, and for this reason visual and tactile surface foraging waders with short legs often fed together as well. Common Sandpipers and Avocets showed the least tendency to feed in flocks with others, the former species usually being on their own, the latter species usually being in monospecific flocks. During roosting (which tends to occur in shallower water as we have seen before), waders of the various guilds occur more widely together (Table 7). It is striking that many of the species often occur together roosting with one or more Greenshanks. It is as if Greenshanks are positively selected to roost with, perhaps because they act as good sentinels against disturbance and danger.

Time-activity budgets - Because of the difficulty in quantifying the activity of the birds during the night, the analyses of the time-activity budgets were based only on the daytime (dawn to dusk) records. The night foraging data were restricted to species records, and where possible, the number of individuals involved were also counted, but no attempt was made to chart the proportion of time spent on different activities. Most species spent at least two-thirds of the daytime feeding. Species which spent the greatest proportion of the day time foraging (over 75%) were Wood Sandpiper, Kittlitz's Plover, Common Sandpiper, Turnstone, Ringed Plover and White-fronted

Plover, all belonging to guild 2 (the visual surface foragers) which also fed on small prey. Species which spent the least proportion of the day time foraging (less than 40%) included Grey Plover, Curlew, Black-tailed Godwit, Greenshank, Avocet, Grey Heron and White Pelican. All these species, apart from the Grey Heron, were observed to also forage at night, and it could therefore be argued that they spend the day-time roosting and on comfort activities because they get most of their food requirement at night.

A comparison of the proportion of the day time spent foraging in predominantly social foraging species with non-social foragers indicate that the social foragers spent far less of the day-time foraging (mean of 35% as compared with 63% in the non-social foragers). There are two possible explanations for this: one is that social foraging may be so profitable that individuals using that style of feeding need

to spend little time to obtain their energy requirement. The second is that the greater part of foraging takes place at night so that the day-time can be spent at leisure.

A comparison of species which fed predominantly on small prey (invertebrates) with fish-eating species (excluding the Black-winged Stilt which fed on both fish and invertebrates), shows that the species feeding on small prey spent a lot more of the day time feeding (66%) than the fish-eating species (37%) (see also Fig. 37A). This relationship is best illustrated by the herons who fed on fish, were not observed to feed at night, and spent on average, only 47% of their time foraging.

The day-time spent foraging was also related to the size of the bird species, with small waders spending far more time feeding than bigger birds (Fig. 37B). An analysis of covariance with guild as a factor and body mass as the covariate showed guild to explain

TABLE 6.

Feeding together of the most abundantly observed waterbirds of the ground foraging guilds in Songor and Keta Lagoons in October-November 1994. Each row presents the percentages of occasions that a particular species occurred together in the same flock as a species in the top-row. The total number of flocks observed that contained at least one individual of the species is given in the last column. A species recorded with itself was either seen alone, or in a monospecific flock. The degree of shading indicates the strength of the association, with black squares indicating that a percentage of co-occurrence exceeded 20%. The guilds 2-5 are indicated with the boxes from the top left to the bottom right, respectively.

5487	Kittlitz's Plover	Ringed Plover	Grey Plover	Common Sandpiper	Wood Sandpiper	Redshank	Bar-tailed Godwit	Curlew	Sanderling	Little Stint	Curlew Sandpiper	Marsh Sandpiper	Greenshank	Spotted Redshank	Black-winged Stilt	Avocet	Little Egret	Reef Heron	Grey Heron	Other		
Kittlitz's Plover	100	3.6	1.2	5.9	1.2	1.8	0.0	6.5	14.2	0.6	1.2	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	9.5	169	
Ringed Plover	4.3	100	5.7	0.5	4.2	3.5	2.1	0.4	5.1	8.3	3.9	4.5	0.6	2.5	0.0	1.4	1.1	0.2	5.6	6.1	949	
Grey Plover	1.4	12.6	100	0.2	2.8	8.2	4.0	1.2	3.0	7.2	16.3	6.3	9.1	1.4	5.8	0.0	2.3	1.4	0.5	6.1	428	
Common Sandpiper	3.4	8.5	1.7	100	0.0	3.4	0.0	1.7	0.0	3.4	6.8	3.4	0.0	0.0	0.0	0.0	1.7	0.0	1.7	1.7	59	
Wood Sandpiper	2.9	11.5	3.4	0.0	100	6.3	0.6	1.1	0.3	10.3	11.8	8.9	5.5	2.6	5.7	0.0	2.6	1.1	0.9	1.1	348	
Redshank	0.3	5.6	6.0	0.3	3.7	100	3.2	1.2	2.4	4.9	13.8	5.7	13.1	3.9	9.4	0.3	5.1	3.2	0.5	3.7	587	
Bar-tailed Godwit	1.1	7.3	6.2	0.0	0.7	7.0	100	14.3	2.2	3.3	5.1	13.2	8.1	9.2	2.6	5.5	0.7	3.3	2.6	0.7	7.0	273
Curlew	0.0	3.8	4.7	0.9	3.8	6.6	5.7	100	0.0	1.9	11.3	6.6	7.5	2.8	5.7	1.9	4.7	0.9	5.7	2.8	106	
Sanderling	3.6	5.8	4.3	0.0	0.3	4.6	3.0	0.0	100	12.8	9.4	18.1	3.6	2.6	0.3	1.6	0.0	1.0	0.3	0.0	8.6	304
Little Stint	4.6	4.0	0.3	4.7	3.8	1.8	0.3	7.7	11.5	100	3.6	3.5	0.5	2.7	0.0	1.0	1.0	0.3	4.6	4.6	768	
Curlew Sandpiper	1.8	14.7	5.4	0.3	3.1	6.1	2.7	0.9	4.2	12.5	13.5	8.9	9.1	1.6	5.4	0.2	2.5	1.7	0.4	4.9	1322	
Marsh Sandpiper	0.1	4.7	3.4	0.3	3.9	11.4	2.8	0.9	1.4	3.5	14.8	13.9	5.4	4.3	8.3	0.5	4.2	2.9	0.6	2.5	792	
Greenshank	0.2	4.8	4.3	0.0	2.1	8.6	2.8	0.9	0.9	3.0	13.4	13.8	14.4	4.7	9.5	0.9	6.7	5.4	0.8	2.9	897	
Spotted Redshank	0.0	2.6	2.6	0.0	3.9	9.9	3.0	1.3	0.4	1.7	9.0	14.6	13.6	1.3	11.6	0.9	9.0	7.7	0.4	2.1	233	
Black-winged Stilt	0.2	3.0	3.0	0.0	2.5	6.9	1.9	0.7	0.6	2.6	9.0	8.2	10.6	3.4	100	0.9	5.7	8.5	0.5	3.0	801	
Avocet	0.0	0.0	0.0	0.0	0.0	3.8	3.8	0.0	0.0	5.7	7.5	5.3	3.8	13.2	0.0	100	3.8	5.7	0.0	1.9	53	
Little Egret	0.0	2.6	2.0	0.2	1.8	5.3	1.8	1.0	0.6	1.6	6.7	6.7	12.2	4.3	9.4	0.4	100	7.5	5.7	4.1	491	
Reef Heron	0.0	2.5	1.5	0.0	1.0	4.8	1.8	0.3	0.3	2.0	5.8	5.8	12.2	4.6	13.2	0.8	5.8	100	2.5	5.3	395	
Grey Heron	0.0	1.6	1.6	0.8	2.4	2.4	1.6	4.9	0.0	1.6	4.1	4.1	5.7	0.8	3.3	0.0	3.1	8.1	100	9.8	123	
Other	3.6	11.8	5.8	0.2	0.9	4.9	4.2	0.7	5.8	7.8	14.5	4.5	5.8	1.1	5.3	0.2	4.5	4.7	2.7	11.1	449	

most of the variation (SS=3849, F=2.99 and P=0.044) with body mass also contributing (almost) significantly (SS=1304, F=4.05, P=0.06, n=26).

It may be concluded, therefore, that the proportion of time spent foraging is not related to

the sensory mechanism used to detect food and or style of feeding (i.e. the guild) *per se*, but rather on the individual size of the bird and its energy requirements, prey size, and the method of hunting in terms of whether foraging is done solitarily or socially.

TABLE 7.

Roosting together of the most abundantly observed waterbirds of the ground foraging guilds in Songor and Keta Lagoons in October-November 1994. Each row presents the percentages of occasions that a particular species occurred together in the same flock as a species in the top-row. The total number of flocks observed that contained at least one individual of the species is given in the last column. A species recorded with itself was either seen alone, or in a monospecific flock. The degree of shading indicates the strength of the association, with black squares indicating that a percentage of co-occurrence exceeded 20%. The guilds 2-5 are indicated with the boxes from the top left to the bottom right, respectively.

1997	Kittlitz's Plover	Ringed Plover	Grey Plover	Common Sandpiper	Wood Sandpiper	Redshank	Bar-tailed Godwit	Curlew	Sanderling	Little Stint	Curlew Sandpiper	Marsh Sandpiper	Greenshank	Spotted Redshank	Black-winged Stilt	Avocet	Little Egret	Reef Heron	Grey Heron	Other	
Kittlitz's Plover	0.0	0.0	0.0	8.0	8.0	0.0	0.0	0.0	0.0	8.0	12.0	4.0	4.0	4.0	0.0	0.0	0.0	0.0	4.0	4.0	25
Ringed Plover	2.9	5.3	0.5	2.4	2.9	2.4	0.0	8.6	8.6	13.9	1.9	6.2	0.5	2.9	0.0	0.0	0.0	0.5	0.5	5.7	209
Grey Plover	0.0	6.7	0.0	0.0	1.8	4.2	7.3	1.2	4.2	3.6	11.5	4.8	6.3	1.8	4.2	0.0	2.4	1.8	0.0	12.1	165
Common Sandpiper	0.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9
Wood Sandpiper	4.1	10.2	6.1	0.0	8.2	8.2	2.0	2.0	0.0	6.1	10.2	8.2	4.1	6.1	0.0	0.0	0.0	0.0	2.0	0.0	49
Redshank	1.1	3.4	4.0	0.0	2.3	5.7	3.4	0.6	1.7	1.7	10.3	6.1	6.9	7.5	1.1	2.3	1.7	0.6	3.4	174	
Bar-tailed Godwit	0.0	4.2	10.1	0.0	0.8	5.0	7.6	1.7	5.0	3.4	14.3	5.9	17.6	4.2	1.7	0.8	3.4	1.7	0.0	12.6	119
Curlew	0.0	0.0	8.7	0.0	4.3	4.3	8.7	8.7	0.0	0.0	13.0	8.7	0.0	0.0	4.3	0.0	0.0	0.0	0.0	0.0	23
Sanderling	0.0	5.5	6.0	0.0	0.0	2.6	5.2	0.0	10.3	6.4	19.8	4.3	6.9	1.7	1.7	0.0	0.0	0.0	0.0	9.5	116
Little Stint	1.3	3.8	0.0	1.9	1.9	2.5	0.0	11.9	5.0	0.0	0.0	1.3	8.2	0.6	1.3	0.0	1.3	0.6	1.3	8.2	159
Curlew Sandpiper	0.9	8.5	5.6	0.0	1.5	5.3	5.0	0.9	6.7	11.4	7.0	8.2	16.7	2.9	5.0	0.6	2.9	1.8	1.2	7.9	341
Marsh Sandpiper	0.4	1.5	3.0	0.0	1.5	10.4	2.6	0.7	1.9	0.7	10.4	10.4	6.7	10.0	0.4	3.0	2.2	0.4	3.7	269	
Greenshank	0.2	2.2	4.6	0.3	1.9	7.6	3.5	0.8	1.3	2.2	9.6	13.7	4.0	9.1	2.0	3.9	3.4	1.2	3.9	593	
Spotted Redshank	1.0	1.0	2.9	0.0	1.9	11.4	4.8	0.0	1.9	1.0	9.5	7.7	3.8	8.6	1.0	0.0	0.0	0.0	11.4	105	
Black-winged Stilt	0.0	2.4	2.8	0.0	1.2	5.3	0.8	0.0	0.8	0.8	6.9	11.0	3.7	8.6	1.2	2.0	2.0	0.8	6.1	246	
Avocet	0.0	0.0	0.0	0.0	0.0	3.6	1.8	1.8	0.0	0.0	3.6	1.8	1.8	5.4	0.0	0.0	0.0	0.0	1.8	56	
Little Egret	0.0	0.0	2.2	0.0	0.0	2.2	2.2	0.0	0.0	1.1	5.4	4.3	12.5	0.0	2.7	0.0	0.0	0.0	9.2	5.4	184
Reef Heron	0.0	0.7	2.0	0.0	0.0	2.0	1.4	0.0	0.0	0.7	4.1	4.1	13.5	0.0	3.4	0.0	0.0	0.0	8.1	4.1	148
Grey Heron	0.9	0.9	0.0	0.0	0.9	0.9	0.0	0.0	0.0	1.8	3.5	0.9	6.2	0.0	1.8	0.0	5.0	10.6	6.2	113	
Other	0.4	4.6	7.7	0.0	0.0	2.3	5.8	1.5	4.2	5.0	10.4	3.8	8.8	4.6	5.8	4.2	3.8	2.3	2.7	0.0	260

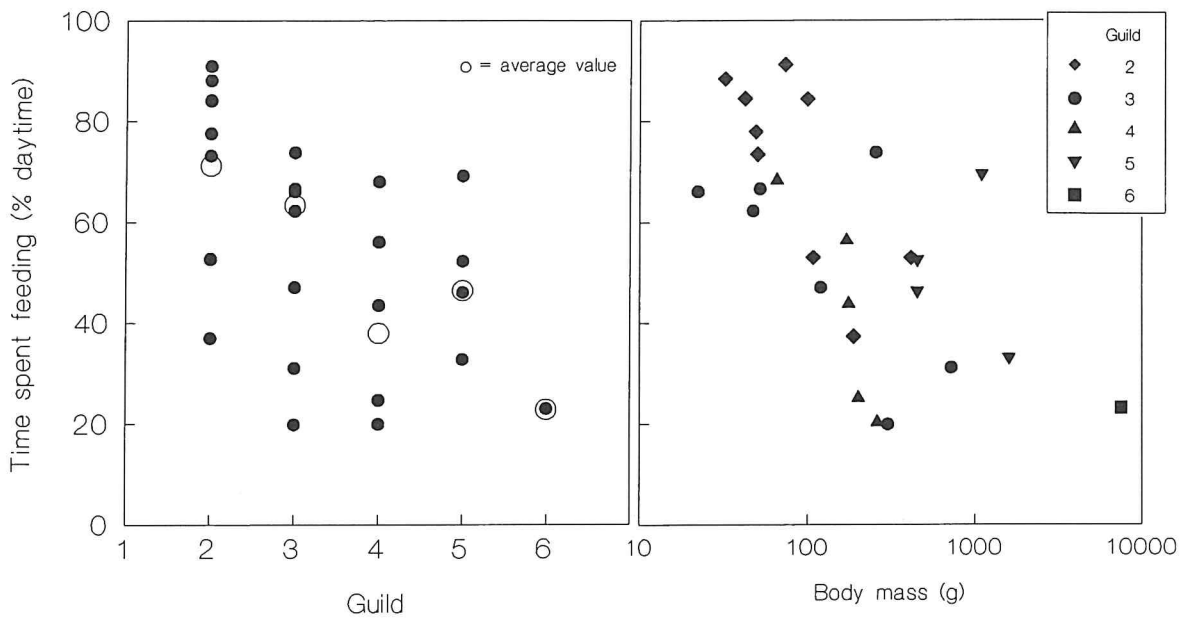


Fig. 37. Species averages for the time spent feeding during daylight in Songor and Keta Lagoon in October-November 1994 as a function of guild number (A) and body mass (B).



Getting the fish-catch on the beach near Winneba (Photo: P. van Gaalen).

9. HABITAT CHARACTERISTICS, FOOD RESOURCES AND AVAILABILITY IN RELATION TO ENVIRONMENTAL CONDITIONS

9.1. PHYSICO-CHEMISTRY OF THE WATERS

The environmental conditions were characterised on the basis of air and water temperatures, dissolved oxygen content of the water and by particle size analysis of the sediment. The 24 hour sampling of air and water temperatures at Fiahor (Fig. 38A, B), revealed that there is very little fluctuation in air temperature at the site, ranging from a minimum of 23°C to a maximum of 27°C. Water temperatures, however, ranged from 24°C to 31°C (11:00 hr). In the very shallow waters (< 3 cm deep), and in isolated pools, water temperatures could reach a maximum of 45°C by about 15:00 hr in the afternoon. Unlike some other shallow waters with an abundance of emergent vegetation, where oxygen concentration is very low during the last hours of the night to sunrise (KERSTEN *et al.* 1991), there was always abundant dissolved oxygen in the system, indeed in all parts of the lagoon. Where dense algal mats and live *Ruppia maritima* were present, photosynthesis during parts of the day resulted in supersaturated conditions (Fig. 39A, B). Bubbles of gas were often observed being formed on the algal mat and on the green parts of *Ruppia*. Apart from photosynthesis, wind action played a very important role in injecting oxygen into the system. Though no oxygen depletion was observed in the 'classic' sense, lowest concentrations were recorded at dawn and at dusk. At these times, due to the switch in direction of the land/sea breezes, the air was very calm. Usually however, the mild winds (see Fig. 15D) of about 1 m/s were sufficient to ruffle the water surface, mixing the water with oxygen. There were three observed exceptions to this surface disturbance. These were as follows: (1) areas with dense mats of *Ruppia*, (2) areas where the water was very shallow, and (3) areas where canoes and other large structures in the water such as acadjas and fish fences acted as wind breaks.

9.2. SEDIMENTS

During most of the study period, great expanses of the Songor Lagoon were dry. The two areas sampled, Vunya and Totokpoe, were split into three habitat types: Vunya 'old lake', an area of standing water; Vunya 'new lake', an area flooded by the rains of late October and November; and Totokpoe. The substrate at these sites was generally very heavy. Figure 40A shows the results of the particle size analysis for sediments at Totokpoe. Silt and clay make up two thirds of the sediment by weight. Analysis of the sand fraction showed that despite the relatively high proportion of fine particles in the total sample, sand at Totokpoe was less fine than at the other two sites analysed (Fig. 40B). In the Vunya 'new lake', the substrate was solid underneath the immediate surface and impenetrable by birds and samplers alike. In general, however, the mud underneath the areas covered with water was so soft that it was impossible to walk on as one would sink in to well above the knees. Towards the dunes on the shore, the sediments were much more sandy and firmer.

The substrate at the Keta Lagoon sites were on the whole much firmer than at Songor. The samples taken at Fiahor and Tegbi were very much the same in gross composition (Fig. 40A). Detailed analysis of the sand fraction did, however, reveal that the sand at Fiahor had a larger mean grain size than at Tegbi. Another interesting feature of the sediments in the area is that they are very much unsorted. In many intertidal mudflat systems, the action of worms burrowing and feeding causes the finer sediments to move to the surface, resulting in the larger particles being found deeper in the sediment (CADÉE 1979) Figure 41 shows the results of the investigation into the size composition of the larger particles at the sampling stations. At almost all stations the dominant fraction was > 4 mm, the exception being station 2 at Tegbi. When all the samples for each station were pooled, the Anloga station had 89% in this category, compared with 95% and 83% at Fiahor and Tegbi respectively. The >4 mm fraction was made up exclusively of whole

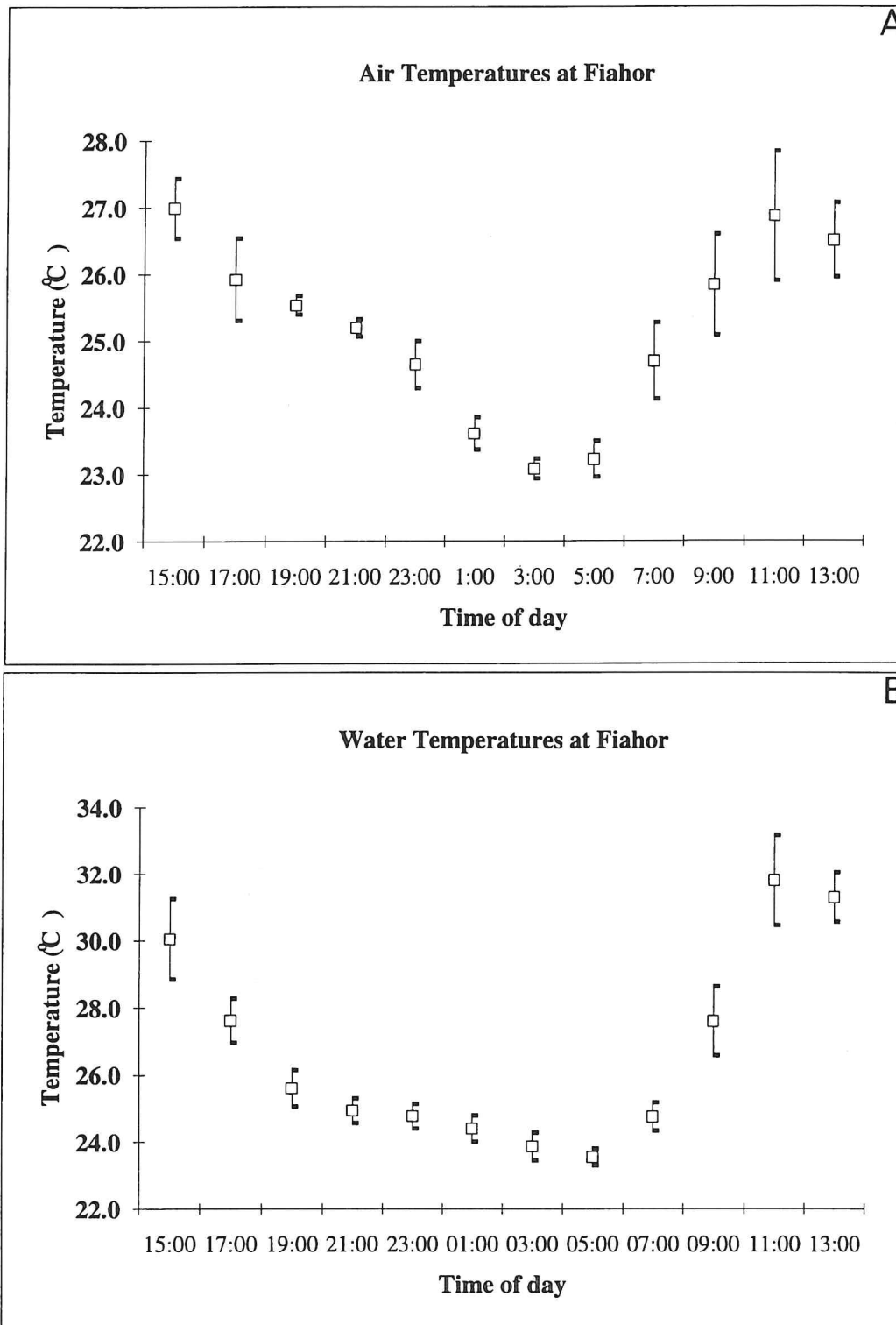


Fig. 38. Changes in the temperature of air (A) and water (B) in the course of a 24 hour period at the benthic sampling transect at Fiahor on 11-12 October 1994.

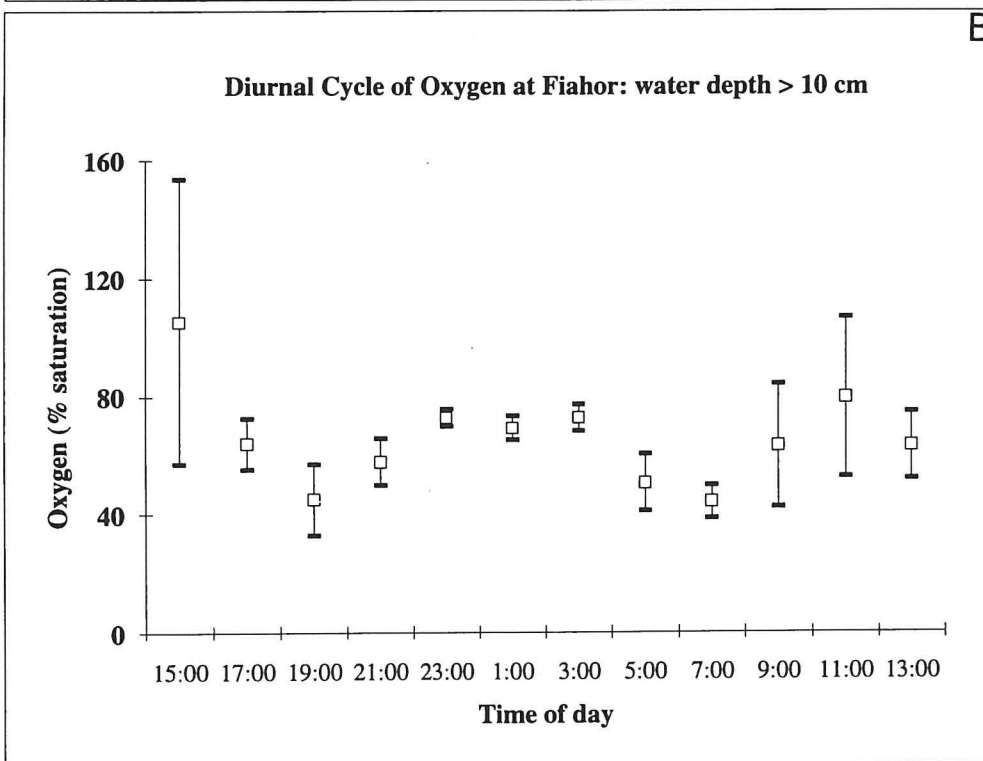
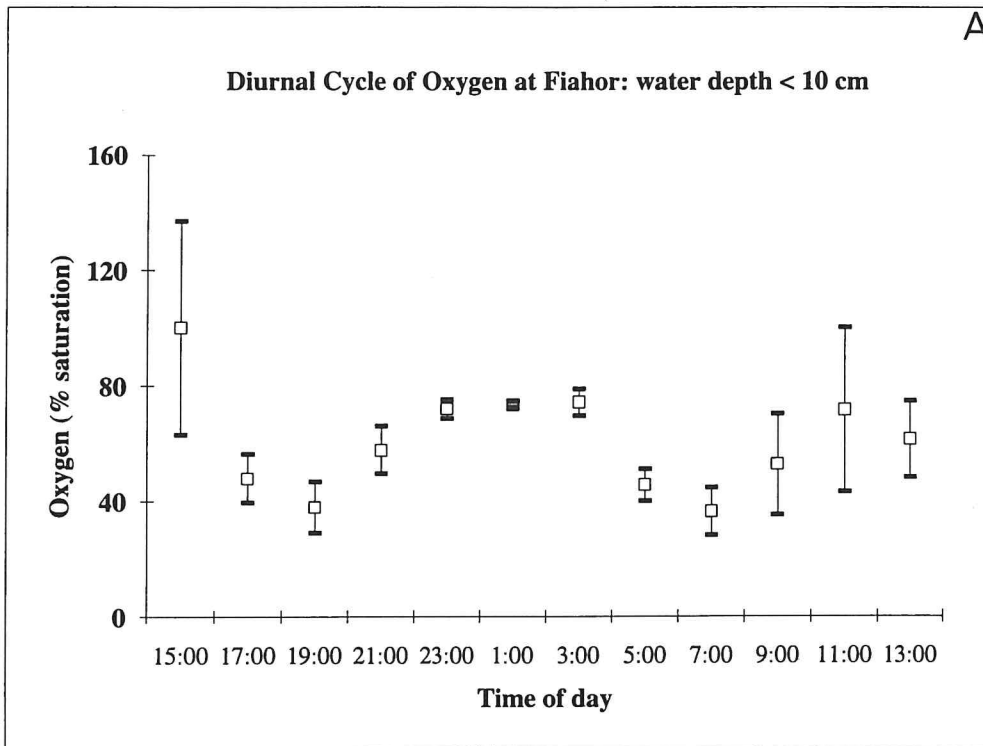


Fig. 39. Changes in the oxygen concentration (% saturation) in shallow water (<10 cm; A) and somewhat deeper water (>10 cm; B) in the course of a 24 hour period at the benthic sampling transect at Fiahor on 11-12 October 1994.

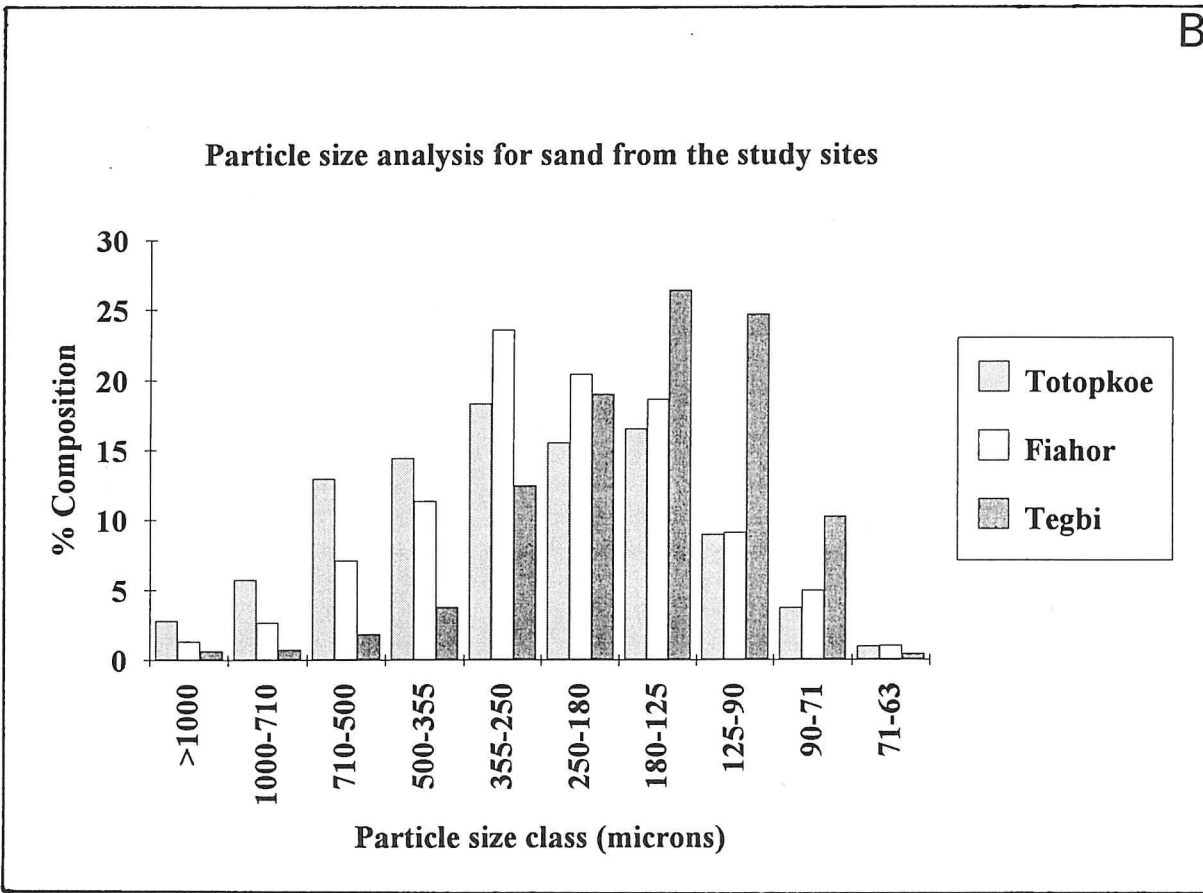
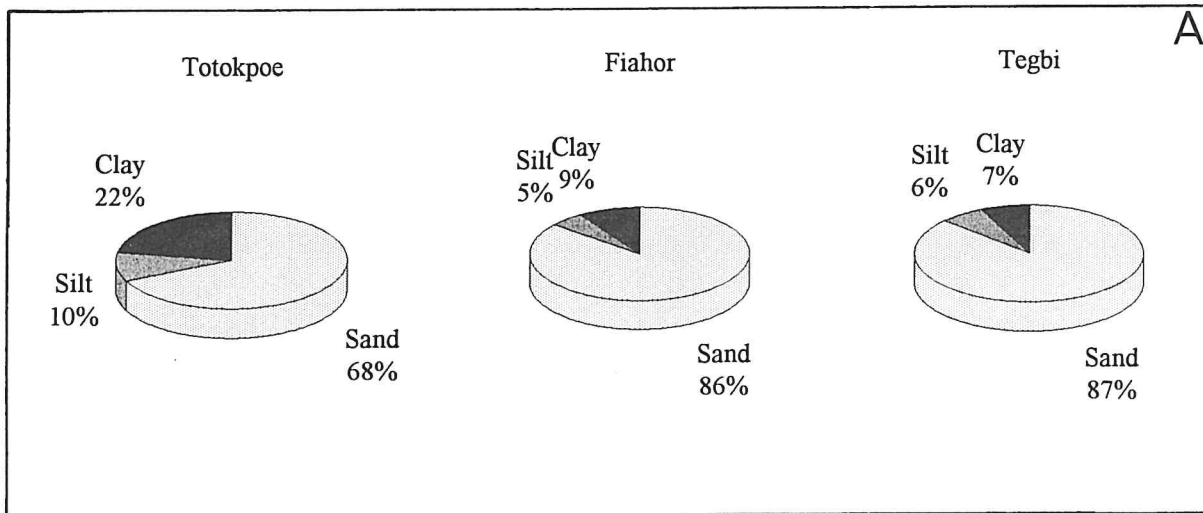
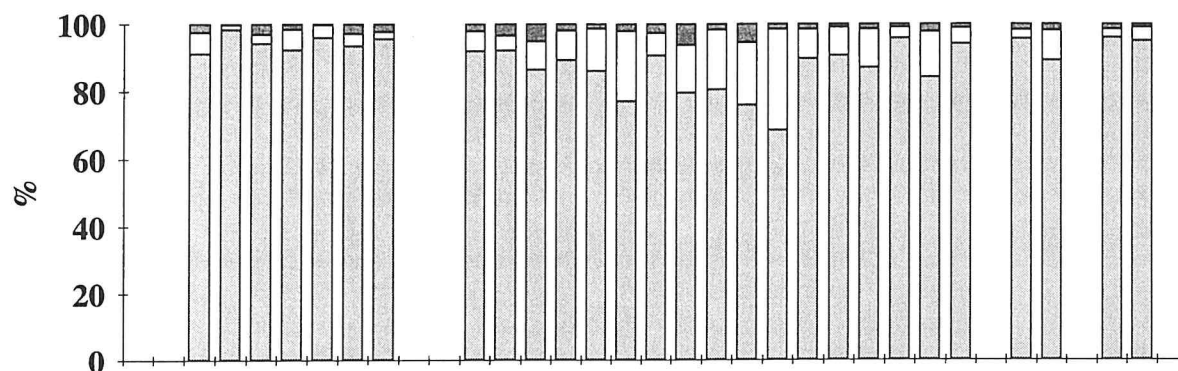
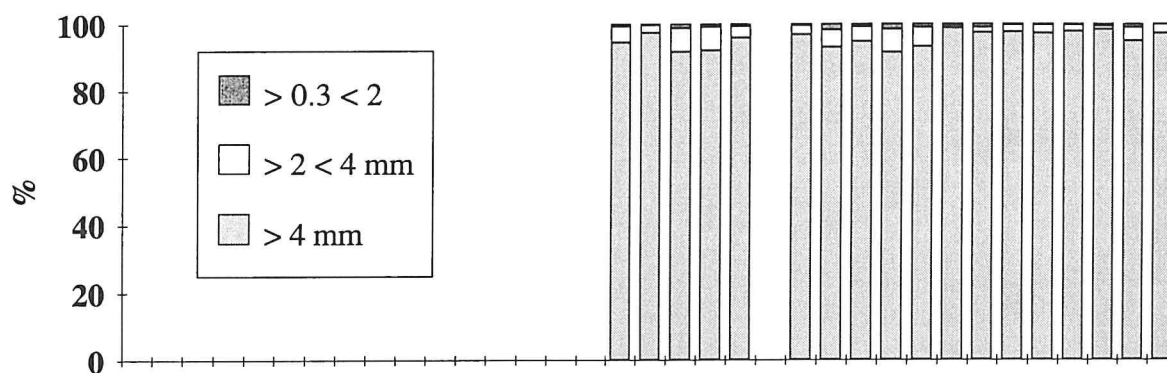


Fig. 40. Composition of particle size of sediments at Totokpoe (Songor Lagoon), Fiahor and Tegbi (both in Keta Lagoon) (A), and a detailed breakdown of the composition of the sand at these sites (B).

Anloga



Fiahor



Tegbi

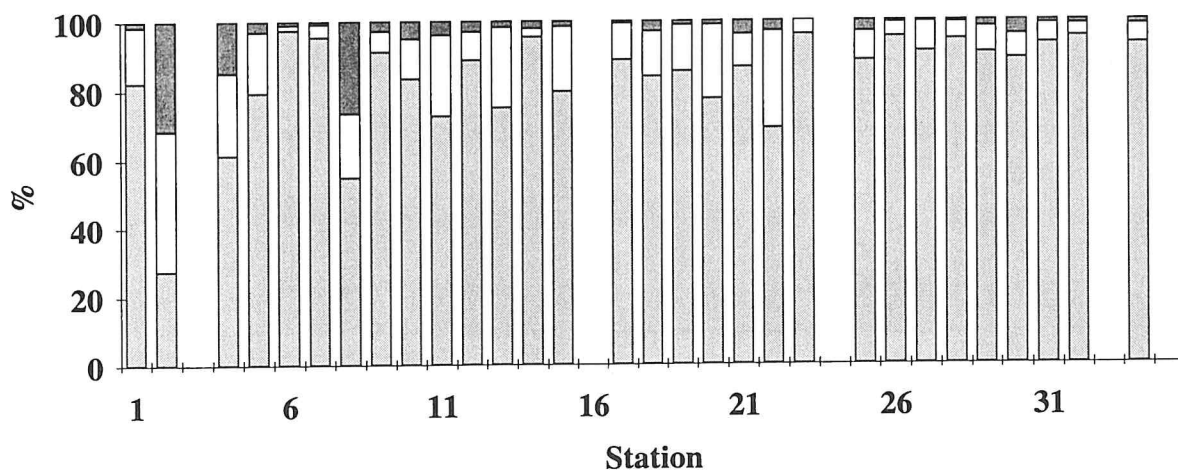


Fig. 41. Composition of sediment particles larger than 0.3 mm along the benthic sampling transects at Anloga, Fiahor and Tegbi, all in Keta Lagoon.

and fragments of mollusc shells such as *Tympanotonus fuscata* and *Crassostrea tulipa*.

9.3. FOOD RESOURCES

Vegetation - The vegetation in the areas of the lagoon used by birds can be separated into two main types, submerged plant material and the emergents. Of the two, the submerged plant material dominated by widgeongrass *Ruppia maritima*, was more important. The coverage of *Ruppia* varied from 0-100% at the sampling stations but this was not directly related to water depth. Due to the lack of water in the lagoons, vast beds of *Ruppia* had been exposed to the air and sun. These beds looked completely dessicated, but contained large quantities of seeds. The seeds were observed to float at higher salinities and were widely dispersed all over the lagoon. At Songor, seeds of *Ruppia maritima* were widespread and abundant on all

the flats near Totokpoe (16,000 /m² in mid-flat, n=5). Seeds of *Ruppia maritima* were also very abundant at Vunya (over 12,500/m², at the 'old lake' and over 7,000/m² in the recently-flooded pan immediately west of Vunya 'new lake') (Fig. 42). The leaves and seeds of *Ruppia maritima* are known to be important as food for waterbirds in many parts of the world (McCANN 1949, VERHOEVEN 1980, DEN HARTOG 1981, ARENGO & BALDASARRE 1995).

Along the transects, it was observed that the deeper stations at Fiahor, unlike those at Tegbi, lacked *Ruppia*. This may have been the result of the greater turbidity of the water at Fiahor. All the sites at Keta had large quantities of seeds present, at Fiahor the number of seeds per square meter ranged from 27,000 to over 200,000 (Fig. 42). Seeds were present in similar quantities at Anloga and Tegbi.

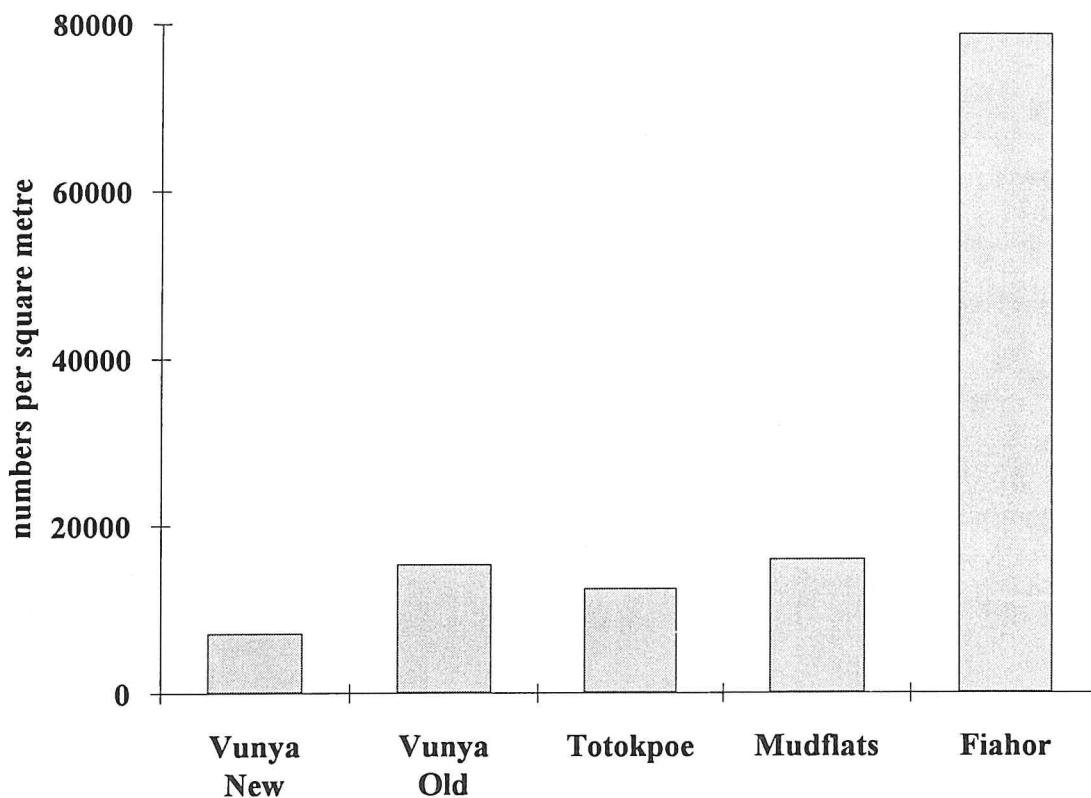


Fig. 42. Density of seeds of widgeongrass *Ruppia maritima* in various parts of Songor Lagoon (Vunya and Totokpoe) and Keta Lagoon (mudflats at Tegbi and Fiahor).

The mean fresh mass of an individual seed was 1.144 mg (SD= 0.121, n = 200), this translating to a mean biomass of about 90 g/m² at the Keta sites (see Table 8). Proximate analysis of the seeds showed that the moisture content of the seeds was about 13%, 6% was fat, 5% was protein, 75% of the remaining was carbohydrate and 1% was ash. Using energy equivalents of 40, 14 and 18 kJ per gram for fat, protein and carbohydrate respectively and the mean seed biomass for Keta, we arrive at a figure of about 1500 kJ/m² as the energy available from seeds. This figure should, however, be taken with caution because although some waders were observed to feed on seeds, their efficiency of digestion of seeds is not known.

At Fiahor, a significant proportion of the dry lagoon bottom was covered by dead *Ruppia maritima*. These mats functioned as a trap for wind blown particles, acting very much like marram grass on sand dunes. A long term sequence of drying and flooding, with new growth of *Ruppia* on elevations created by an accumulation of accreted material and old decaying growth could result in mounds being gradually being built on the mudflats.

Emergent plant material - At most of the sites, there were very few emergent plants due to either the lack of water or the high salinity of the water present. The only site with appreciable emergents was Anloga where the extensive

network of channels and pools contained many macrophytes such as *Typha*. Water lilies (*Nymphaea* and *Nymphoides* spp.) were present between the emergent vegetation at this site and their seeds might be fed upon by tree ducks.

Worms - Most of the sites had some worms present, mainly polychaetes, but also some oligochaetes (see Table 9; Fig. 43). Specimens of the worms have been sent for further identification.

In Songor Lagoon, at Vunya, we were able to crumble the solid mud and follow worm burrows down through the cores. These reached depths of at least 15 cm, and the inhabiting worms were no doubt under-represented in our samples (although some worms were located in the burrows). The depths that these large polychaetes reached, also made them unavailable to birds unless they were close to the surface (to defaecate, for example). Worms of size 20-40 mm were present at densities up to 1000/m². Tiny worms were abundant and total worms densities probably exceeded 5000/m². Due to the high clay content of the substrate near Totokpoe, the sieving of samples was very difficult as the mud was very sticky and it is likely that in the effort to clear the sample of mud we could have destroyed many of the small worms present. In the sandy seepage area, sieving of the top sandy layer was possible, and extremely high numbers (up to

TABLE 8.
Seeds of *Ruppia maritima* as a food resource for waterbirds in Songor and Keta lagoons.

		Number of seeds per m ²	Dry mass of seeds per m ² (g)	Protein per m ² (g)	Fat per m ² (g)
Vunya New Lake n= 10	Mean	7.143	8.17	0.41	0.49
	Minimum	1.020	1.17	0.06	0.07
	Maximum	14.796	16.93	0.86	1.01
	SD	3.795	4.34	0.22	0.26
Vunya Old Lake n= 5	Mean	15.408	17.63	0.89	1.05
	Minimum	10.714	12.26	0.62	0.73
	Maximum	26.020	29.77	1.51	1.78
	SD	6.325	7.24	0.37	0.43
Fiahor n- 17	Mean	78.679	90.01	4.55	5.37
	Minimum	27.551	31.52	1.59	1.88
	Maximum	205.612	235.22	11.90	14.04
	SD	37.662	43.09	2.18	2.57

TABLE 9.

Presence of common macro-invertebrates at the sampling sites in Songor and Keta Lagoon in October-November 1994.

Site	Songor Lagoon			Keta Lagoon		
	Vunya	Seepage	Totokpoe	Anloga	Fiahor	Tegbi
Annelida						
Polychaetes						
small*	x	x	-	x	-	x
large**	x	x	-	x	-	x
Oligochaetes	x	x	-	x	x	x
Mollusca						
Gastropoda						
<i>Hydrobia accrensis</i>	x	-	-	x	x	x
<i>Tympanotonos fuscatus</i>	x	x	-	x	x	x
<i>Bolinus cornutus</i> †						
<i>Neritina adansoniana</i>	-	-	-	x	x	x
Bivalvia						
<i>Brachidontes niger</i>	-	-	-	x	x	x
<i>Congeria ornata</i> †						
<i>Corbula trigona</i> †						
<i>Tellina nymphalis</i> †						
<i>Gastrana multangula</i> †						
<i>Tivela tripla</i>	-	-	-	x	x	x
<i>Loripes aberrans</i> †						
<i>Melanooides tuberculata</i> †						
<i>Pachymelania byronensis</i>	-	-	-	x	-	-
Crustacea						
Amphipods ^a	x	x	x	x	x	x
Isopods ^{aa}	-	-	-	x	x	-
<i>Parapenaeopsis atlantica</i>	-	-	-	x	-	-
<i>Penaeus kerathurus</i>	-	-	-	x	-	-
<i>Penaeus notialis</i>	-	-	-	x	-	-
<i>Callinectes amnicola</i> †						
<i>Cardisoma armatum</i> †						
<i>Ocypode africana</i>	-	-	x	-	-	x
<i>Sersarma huzardi</i> †						
<i>Uca tangeri</i>	-	-	-	x	-	-
Insecta						
Isoptera (<i>Macrotermes</i> spp.)	-	-	-	-	-	x
Dermaptera	-	-	-	-	x	-
Odonata (nymphs)	-	-	-	x	-	x

* possibly *Dipsio africana*

** possibly *Glycera convulata*

† dead remains

^a possibly *Urothoë grimaldi*

^{aa} possibly *Excireolana latipes*

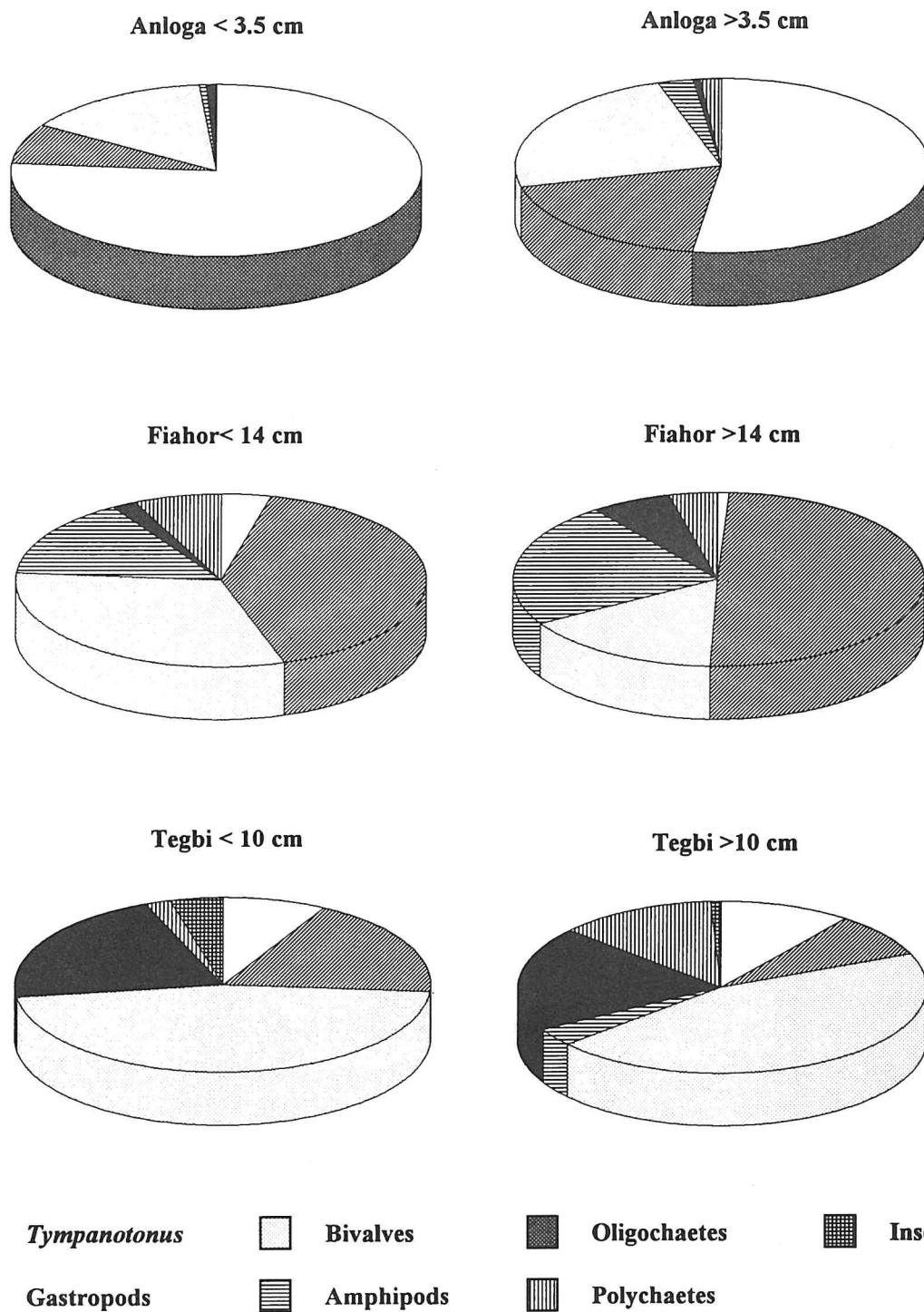


Fig. 43. Numerical composition of the benthic macro-zoobenthos (invertebrates) at the three study sites in Keta Lagoon. The sampling stations were divided in equal halves relative to water depth, with the different median water depths of the standing water at each site being given by the division point.

10,000/m², n=6) of polychaetes were found, mostly small sized (10-15 mm). These occurred at depth accessible to probing waders (e.g. Curlew Sandpipers). Polychaetes were also found at Totokpoe in wet mud between the dune ridge and the main water body, but in very low numbers.

The results of the benthos studies at Keta Lagoon sites have been separated in two components at each site: samples from shallow water sites and those from deeper water sites, where the division between shallow and deep water was set at the median of water depths, i.e. Anloga: 3.5 cm, Fiahor: 14 cm, and Tegbi: 10 cm. At Anloga, very few worms were present, no polychaetes were found at stations with less than 3.5 cm water depth (see Table 10; Figs. 43 and 44). At water depths above 3.5 cm, worms were present at densities of about 50/m². At Fiahor worms were present at higher

densities, ranging from 650 to 1,400/m² at water depths less than 14 and greater than 14 cm respectively. Worms were most abundant at Tegbi, where densities were in the order of 2,500/m². At this site, birds were seen taking large worms with lengths up to an estimated 30 cm.

Molluscs - Very few live molluscs were found in Songor Lagoon (Table 9). Some small snails, perhaps *Hydrobia accrens*, were collected on the mudflat areas at densities of about 500 /m².

Five molluscs, three gastropods and two bivalves, were found to be very abundant at Keta Lagoon (Tables 9 and 10). The gastropods were *Tympanotonus fuscata*, *Neritina adansoni* and *Hydrobia accrens*, the bivalves were *Tivela tripla* and *Brachydonates niger*. Figures 43-46 show that the three sites were each dominated by different groups of

TABLE 10.
Abundance estimates for major benthic macro-invertebrate groups at sites in the Keta Lagoon.

Site	Density (n/m ²)			
	Mean	SD	Mean	SD
Anloga				
Water depth	< 3.5 cm		> 3.5 cm	
Number of samples	n = 14		n = 20	
<i>Tympanotonus</i>	3,317.47	607.89	1,116.33	770.34
Gastropods	254.26	438.77	277.12	609.42
Bivalves	533.97	604.52	556.98	539.84
Amphipods	0	0	55.88	147.43
Oligochaetes	25.89	103.79	17.99	85.50
Polychaetes	0	0	36.60	121.28
Fiahor				
Water depth	< 14 cm		> 14 cm	
Number of samples	n = 9		n = 11	
<i>Tympanotonus</i>	84.93	299.57	106.13	194.98
Gastropods	996.27	1,468.49	1,383.52	1,693.75
Bivalves	1,365.29	551.92	1,282.01	900.85
Amphipods	0	0	106.13	194.98
Oligochaetes	583.79	517.42	1,167.14	1,146.25
Polychaetes	66.21	225.54	257.77	587.61
Tegbi				
Water depth	< 10 cm		> 10 cm	
Number of samples	n = 17		n = 17	
<i>Tympanotonus</i>	903.65	859.85	781.65	760.74
Gastropods	2,317.44	917.24	769.24	575.31
Bivalves	7,723.91	530.40	4,776.63	694.75
Amphipods	0	0	333.49	389.24
Oligochaetes	2,470.81	1,034.00	2,137.94	545.35
Polychaetes	277.71	390.23	1,269.22	630.81
Insects	543.44	537.75	56.69	182.59

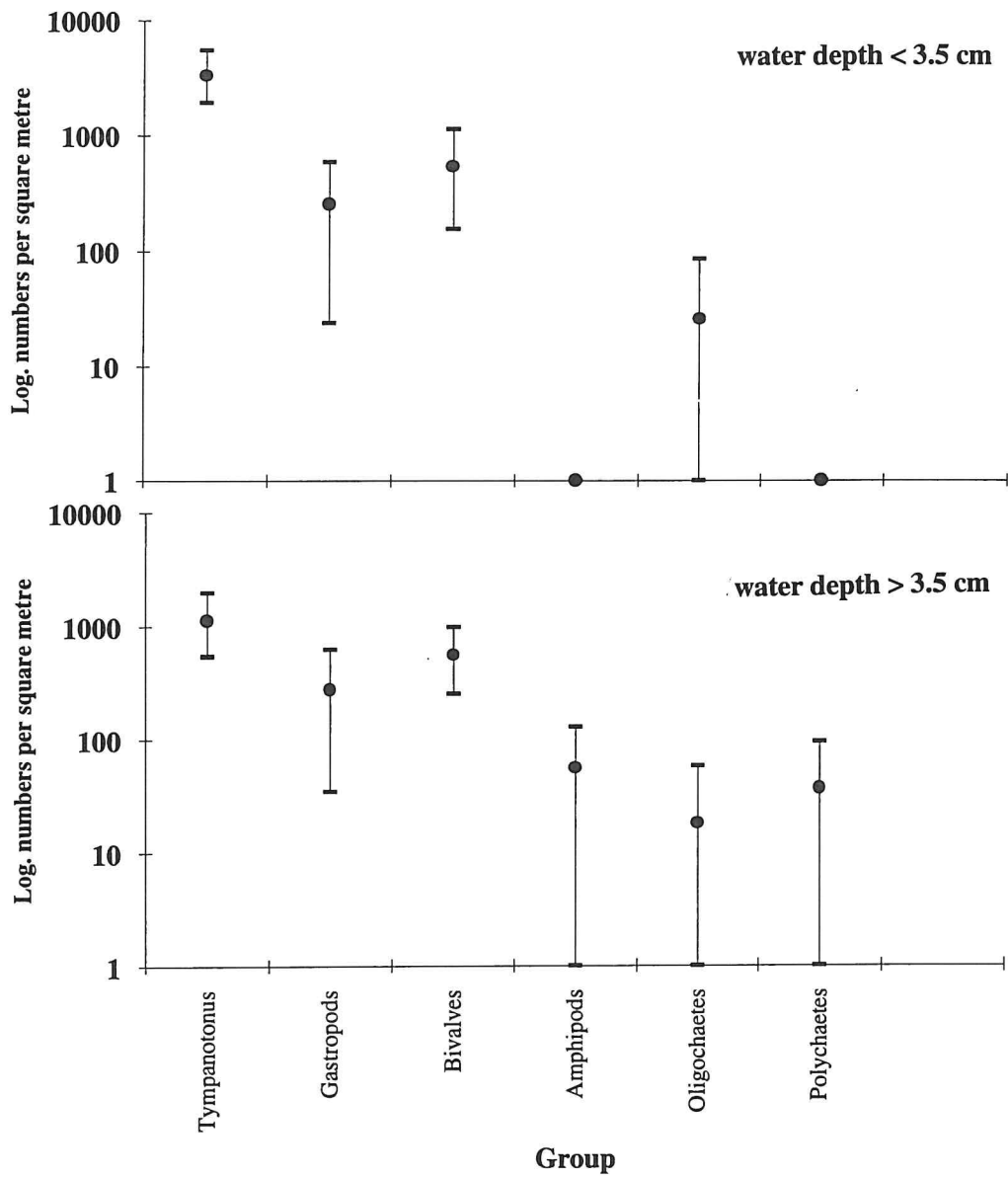


Fig. 44. Density of the different major groups of benthic invertebrates found at different depths of standing water (A: water more shallow than 3.5 cm; B: water deeper than 3.5 cm) at the Anloga benthic sampling transect in Keta Lagoon.

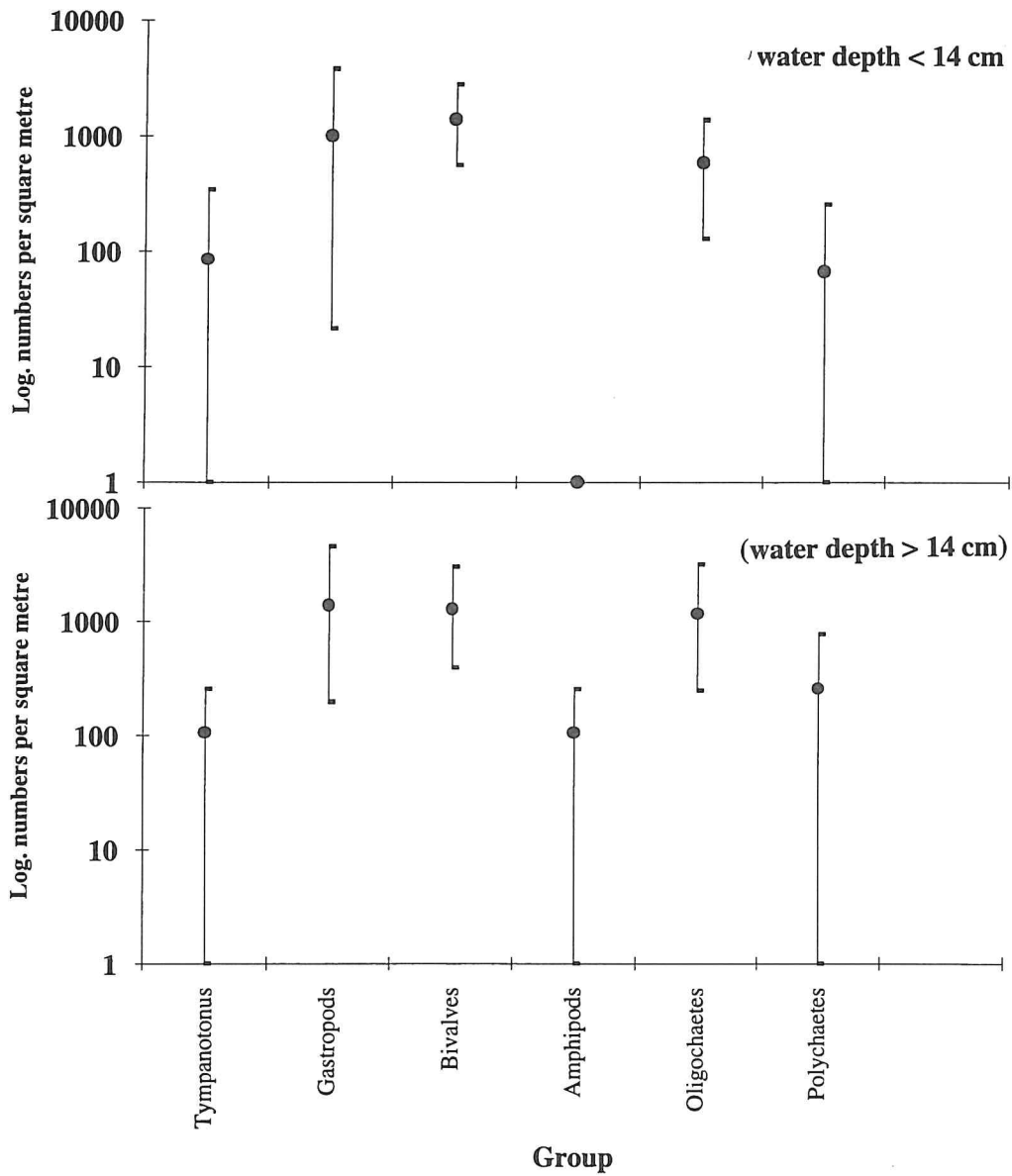


Fig. 45. Density of the different major groups of benthic invertebrates found at different depths of standing water (A: water more shallow than 14 cm; B: water deeper than 14 cm) at the Fiahor benthic sampling transect in Keta Lagoon.

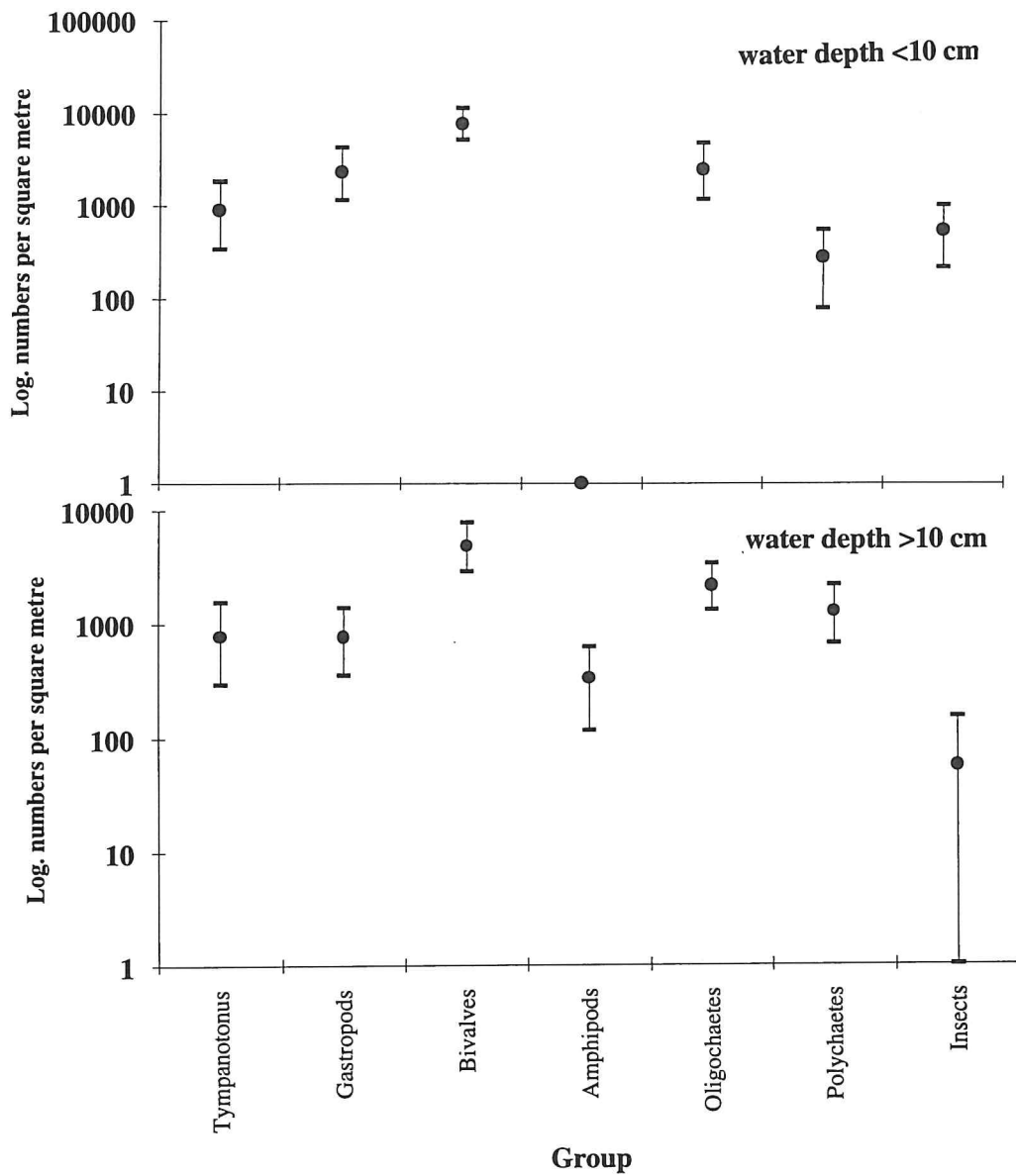


Fig. 46. Density of the different major groups of benthic invertebrates found at different depths of standing water (A: water more shallow than 10 cm; B: water deeper than 10 cm) at the Tegbi benthic sampling transect in Keta Lagoon.

molluscs: Anloga by *Tympanotonus*, Fiahor by bivalves (mainly *Tivela tripla*) and Tegbi by *Brachydontes niger*. Anloga had densities of *Tympanotonus* ranging from a minimum of 1,900 to a maximum of 5,500 (95% confidence limits) with a mean of 3,300 (Fig. 44). Fiahor had the lowest densities of *Tympanotonus* averaging about 100/m² (see Fig. 45), while Tegbi had around 800/m² (see Fig. 46). Samples of *Tympanotonus* were randomly collected from Fiahor (five stations, 4, 6, 10, 20 and 29) and Tegbi (four stations 1, 4, 7 and 11) to estimate the proportions of empty shells. Twenty-eight percent of the *Tympanotonus* shells at Fiahor and 30% at Tegbi were found to be empty. Some of the specimens on the dry mudflat were still alive, sealed in their shells. At Tegbi, we observed that the wind could push the land/water interface towards the high water mark for distances of up to 100 m. This caused expanses of the mud flat which would otherwise be dry, to be flooded for periods of several hours. At such times, the exposed *Tympanotonus* would become active and move around (feed) until the water receded again. *Neritina adansoniana* was most abundant at Tegbi. Mean numbers ranged from a minimum of 250 /m² at Anloga (water depths < 3.5 cm) to a maximum of 2,300 /m² at Tegbi (water depths <10 cm) (Table 10). Tegbi was the only site where large differences were observed in the numbers of gastropods in 'shallow' and 'deep' water with roughly three times as many snails in the shallower water. Many of the larger bivalves (*Brachydontes niger*) found in the exposed areas of the Keta lagoon area were dead, especially those fixed to clumps of *Ruppia*, and it would seem that the tolerance of this group to dessication is not as high as some of the other species.

Crustacea - In Songor Lagoon, amphipods were present in the soft surface mud at Vunya and could be seen swimming in the water, crawling over and burying into the mud surface. Amphipod densities reached 700-1800/m². Amphipods were also present in significant numbers (700-800/m², n=6) at Totokpoe. Ghost crabs (*Ocypode africana*) were present on the sand dunes around Totokpoe, but no attempt was made to assess the population density. It

was clear that the site held large populations of crabs, because fairly fresh remains of *Callinectes*, *Cardisoma* and *Uca* could be seen lying on the surface of the mud on the dry lagoon bed (Table 9).

At all sites in Keta Lagoon, amphipods were present, though more often in the deeper water stations. Numbers were relatively smaller than at Songor Lagoon (Anloga: 50/m², Fiahor: 100/m², and Tegbi: 300/m²; Table 10). A few specimens of an isopod (*Excirrolana latipes*) were caught at Anloga and Fiahor. Freshly excavated burrows of crabs were present at all the sites. These were probably *Cardisoma armatum* or *Sersarma huzardi*. As in other coastal wetland sites in Ghana, the holes were more frequent around stands of the sedge *Paspalum* (GORDON 1994).

Insects - Three orders of insects were found in the benthos samples. At Fiahor, small mounds of freshly excavated material in exposed sandy areas induced us to dig for the organisms. By following the burrows down to a depth of about 60 cm we discovered large (2.5 cm) earwigs (Dermaptera) at the interface between water saturated sand and the overlying dry sand. At Tegbi and Anloga, nymphs of dragonflies were found in the samples. Termites (*Macrotermes* spp.) were also found at Tegbi. These were winged reproductives which had emerged from mounds after rains and then fallen into the lagoon. The biomass of these insects was estimated to be about 1 g/m². The termites were rapidly eaten by the fish and birds inhabiting the lagoons, and as they are present only after rain, they should be considered a very temporary and sporadic food resource.

Biomass values - The results of the dry mass and ash free dry mass investigations are presented in Table 11. The values for the groups show considerable variation. For example, the mean weight of gastropods was 1.51 mg at Anloga while at Fiahor it was 5.99 mg. Similar scale of variation was shown for the bivalves with mean weights of 0.54 mg at Anloga and 5.55 mg at Tegbi. The apparent variation in mean weights between sites was due to the method used in selecting the actual specimens used for the determinations. We had selected

species and specimens which were representative of the group composition at each site, so for example at sites where the large bivalve outnumbered small bivalves, we took more of the large bivalves to make up the pooled results.

Too few amphipods were collected during the sampling period for mass determinations, so that ALTENBURG *et al.*'s (1982) figure of 5 mg per individual has been used for the calculations. No worms were analysed from Anloga, so for calculation of biomass at this site we used the mean of the Fiahor and Tegbi figures. Table 12 presents a summary of the biomass data. At all the sites, molluscs contributed most to the benthic biomass (Fig. 47), ranging from 98% to 80%, at Anloga and Fiahor respectively. The total benthic biomass for each of the sites is presented in Fig. 48. Tegbi had the highest AFDM per unit area (range 40.9 - 623 g/m²). The Anloga and Fiahor sites had lower values with a maximum benthic biomass of 18.5 g/m². At Fiahor, we observed that the deeper half of the transect had higher mean biomass values than the shallower half. The reverse situation,

i.e. higher biomass in the shallower water, prevailed at Anloga and Fiahor.

To examine the effect of *Ruppia* distribution on macro-benthic abundance and biomass, we separated stations on the Fiahor and Tegbi transects which had more than 50% *Ruppia* cover from those sites which had less. On the basis of this criteria, *Ruppia*-stations were 23, 24, 25, 26 and 27 at Fiahor and 19, 21, 23, 25, 27, 29, 31 and 33 at Tegbi. (Note that vegetation estimates at Tegbi were carried out only at odd numbered stations.) The results of this analysis are presented in Table 13. At Fiahor, *Tympanotonus*, bivalves and amphipods were more abundant in stations without *Ruppia* as compared to stations that had *Ruppia*. At Tegbi, gastropods, bivalves and oligochaetes were less abundant in stations with *Ruppia*. Table 14 presents total biomass estimates at Fiahor and Tegbi for stations with and without *Ruppia*. The figures for Tegbi under the two conditions (with or without *Ruppia*) are similar. However, there is a significant difference between the figures for the two conditions at Fiahor.

TABLE 11.

Dry mass and ash-free dry mass values for individual benthic macro-invertebrates from Keta Lagoon. The dry masses of gastropods and bivalves include the shell.

	n	Dry mass		n	Ash-free dry mass	
		Mean	SD		Mean	SD
Anloga						
<i>Tympanotonus</i>	17	56.98	94.31	26	5.38	9.31
Gastropods	11	27.88	15.54	11	1.51	1.03
Bivalves	17	16.80	10.19	16	0.53	0.41
Oligochaetes	-	-	-	-	-	-
Polychaetes	-	-	-	-	-	-
Fiahor						
<i>Tympanotonus</i>	8	97.11	126.83	6	19.83	22.14
Gastropods	13	39.11	19.18	12	5.99	7.61
Bivalves	17	31.18	24.94	12	2.41	2.75
Oligochaetes	17	1.60	1.95	15	0.92	0.61
Polychaetes	10	3.03	1.29	9	2.47	1.04
Tegbi						
<i>Tympanotonus</i>	21	282.58	201.95	18	8.85	10.63
Gastropods	18	41.14	11.01	17	3.19	1.92
Bivalves	30	92.96	162.46	28	5.55	10.55
Oligochaetes	11	1.74	1.06	10	1.04	0.73
Polychaetes	12	5.46	18.51	9	0.84	0.66
Insects	3	93.93	160.81	3	2.28	2.77

TABLE 12.

Biomass estimates and ash-free dry mass of benthic macro-invertebrates from the Keta Lagoon sites.

Site	AFDM (mg/m ²)		
Anloga			
	Water depth	<3.5 cm	>3.5 cm
<i>Tympanotonus</i>		17,848	6,006
Gastropods		381	416
Bivalves		288	301
Amphipods		0	279
Oligochaetes		25	18
Polychaetes		0	60
Total		18,543	7,080
Fiahor			
	Water depth	<14 cm	>14 cm
<i>Tympanotonus</i>		1,684	2,105
Gastropods		5,968	8,287
Bivalves		3,290	3,090
Amphipods		0	531
Oligochaetes		537	1,074
Polychaetes		164	637
Total		11,643	15,723
Tegbi			
	Water depth	<10 cm	>10 cm
<i>Tympanotonus</i>		7,997	6,918
Gastropods		7,393	2,454
Bivalves		42,868	25,510
Amphipods		0	1,667
Oligochaetes		2,570	2,223
Polychaetes		233	1,066
Insecta		1,239	129
Total		62,300	40,968

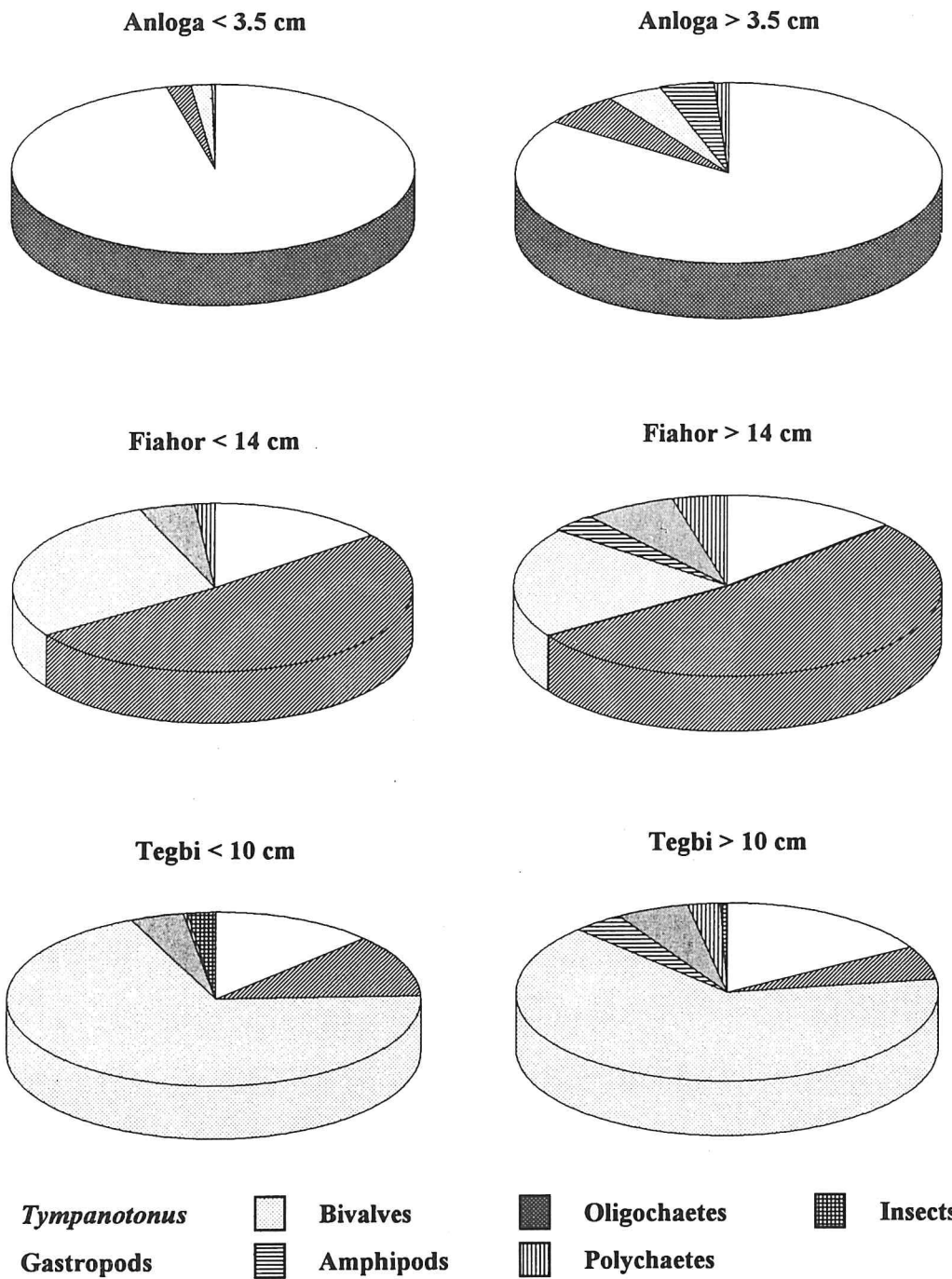


Fig. 47. Biomass (AFDM) composition of the benthic macro-zoobenthos (invertebrates) at the three study sites in Keta Lagoon. The sampling stations were divided in equal halves relative to water depth, with the different median water depths of the standing water at each site being given by the division point.

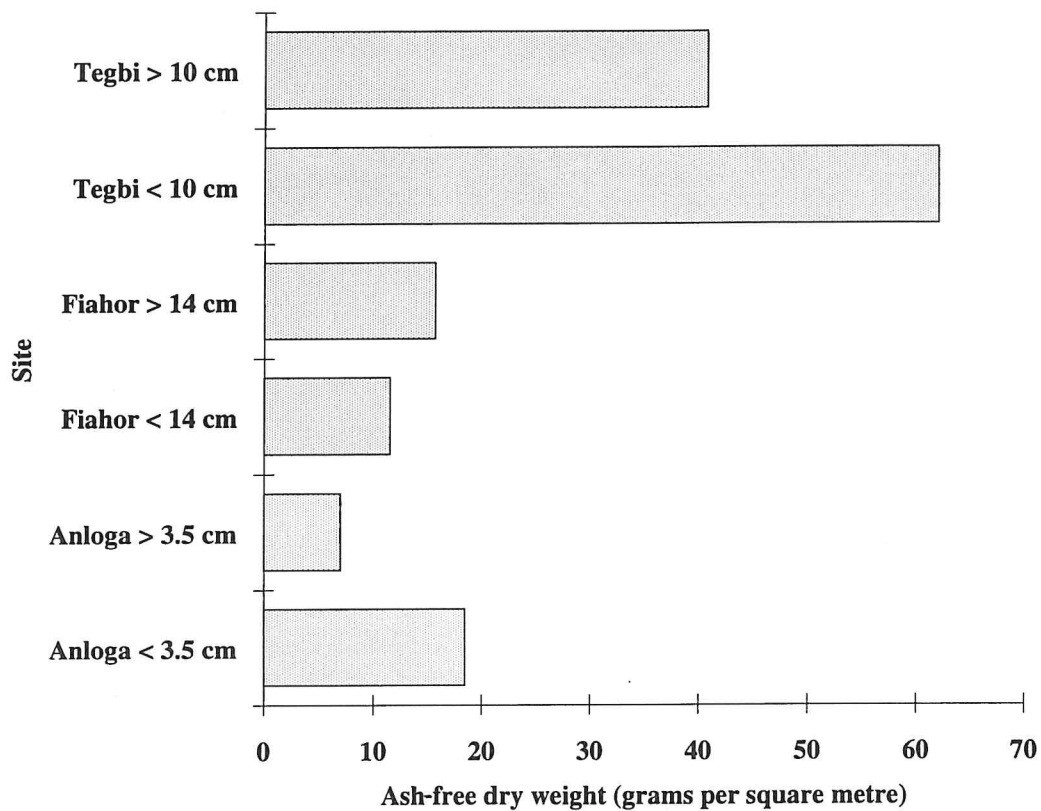


Fig. 48. Breakdown of total biomass values (g AFDM/m²) at the three study sites in Keta Lagoon. The sampling stations were divided in equal halves relative to water depth, with the different median water depths of the standing water at each site being given in the Fig..

TABLE 13.

Abundance estimates (n/m²) for major benthic macro-invertebrate groups at submerged stations in Keta Lagoon with and without a partial cover of *Ruppia maritima*.

	Stations without <i>Ruppia maritima</i>			Stations with <i>Ruppia maritima</i>		
	Mean	SD	n	Mean	SD	n
Fiahor						
<i>Tympanotonus</i>	204	422	15	102	228	5
Gastropods	1,496	2,836	15	14,280	11,162	5
Bivalves	2,176	1,607	15	1,428	1,744	5
Amphipods	34	132	15	0	0	5
Oligochaetes	816	879	15	5,814	7,906	5
Polychaetes	204	422	15	1,428	2,084	5
Tegbi						
<i>Tympanotonus</i>	1,615	2,221	18	1,562	2,127	16
Gastropods	3,683	3,782	18	1,243	1,535	16
Bivalves	9,180	6,587	18	6,758	4,854	16
Amphipods	0	0	18	510	589	16
Oligochaetes	4,250	4,807	18	2,933	2,374	16
Polychaetes	397	595	18	1,913	1,564	16

TABLE 14.

Total biomass (g AFDM/m²) of benthic macro-invertebrate at submerged stations in Keta Lagoon with and without a partial cover of *Ruppia maritima* (same stations as in Table 13).

	Stations without <i>Ruppia maritima</i>	Stations with <i>Ruppia maritima</i>
Fiahor	19.4	98.1
Tegbi	81.5	64.7

Fish - One species of fish, *Sarotherodon melanotheron*, dominated the fish community in the lagoons and in many cases it was the only species present. Keta Lagoon had a more diverse fauna than Songor (see Table 15). Most of the fish were cichlids; two species of *Hemichromis* were present, *H. faciatus* and *H. bimaculatus*. Small mullets (*Mugil* spp.) were also present at Keta. The results of our limited fish sampling indicate that there are large schools of very small fish present in the Keta Lagoon, these being observable directly in the shallow waters around Anloga, Fiahor and Tegbi. The fish were present even in some of the ephemeral waters found in small depressions. For example, tilapia was observed in a depression caused by a foot print where the

salinity was over 70 ppt and the water temperature was over 40°C.

At Songor Lagoon it was very difficult to catch any fish by any of the methods used at Keta, due to the soft mud. The local people use fish traps set in artificial channels to catch tilapia, but the results that we would have obtained from making such a system, did not warrant the effort required for its construction. The fish caught by this method by the local fisherfolk (mainly small boys and women) were observed during the study period and were all small (maximum length 5 cm).

The results shown in Fig. 49 indicate that the three main fishing methods used at Keta were size-selective, with the sweep net being more efficient in the size classes smaller than 2 cm,

TABLE 15.
Presence of common fish species at the sampling sites in Songor and Keta Lagoon.

Site	<i>Sarotherodon melanotheron</i>	<i>Oreochromis niloticus</i>	<i>Tilapia zillii</i>	<i>Hemichromis spp.</i>	<i>Mugil</i> spp.
Songor					
Vunya Old	x	-	-	-	-
Channel	x	-	-	-	-
Keta					
Anloga	x	x	x	x	x
Fiahor	x	-	x	-	x
Tegbi	x	x	x	x	x

the NIOZ bottom drag between 4-5 cm, while the cast net had the highest catch at fish-length of 6 cm. It was possible to quantify the densities of fish at Tegbi and Fiahor, and this is presented in Table 16. These results should be viewed as tentative given the small total area of habitat sampled as compared to the total area of the lagoon and the schooling behaviour of the fish. The relative fishing efficiency of the different gears is not known so caution should be used in comparing the density found by one fishing method to another. The NIOZ bottom drag was operated in deeper water and caught larger fish. The net, however, rapidly filled with shells and the speed with which it could be dragged was very low. If this allowed fish to escape, it would explain the low numbers caught. The sweep net was very inefficient when used during the day in clear water, e.g. at Tegbi. The fish could move far faster than the net could be operated and avoided capture by swimming away as a school or by individual darts for freedom in all directions. At Fiahor where the water was more turbid, and where there were floating algal mats decaying on the water surface, the numbers of fish caught were higher. Also at Fiahor, it was observed that fish densities at sites within the *Ruppia* beds were slightly higher than at sites with just mud or epipsammic algae. Observed densities at Tegbi during the night ranged from 1.7 to 2.2 individuals/m². The number of fish caught per haul dropped between 20:00 hr and midnight. This may have been due to disturbance of the fish by the fishing method.

Figures 50 and 51 present length-dry mass plots for *Sarotherodon melanotheron* from the Keta Lagoon. The condition factors (the ex-

ponent derived from the exponential regression analyses) for both juvenile and the larger fish were quite high (3.117 and 2.798 respectively), which indicates favourable circumstances for growth. From earlier work done on growth of this species (EYESON 1979), we conclude that the specimens under 1 cm in total length would be less than a week old. Figure 52 shows a plot of mean dry weights of small tilapia caught at 20:00 hr and at midnight. The results indicate that there is a loss in body mass in each of the size classes over the four hour period. The weight loss may be due to defaecation, or to cessation of feeding, which would contradict PAULY (1976) who recorded that feeding of this species in Sakumo Lagoon was nocturnal. TREWAVAS (1983) suggested that nocturnal feeding might represent attempts to elude predatory birds. Using the results of the abundance estimates and the dry weights (converted to AFDM by using factors given by V. Sambilay Jr., International Center for Living Aquatic Resources, Manila, Philippines, 1993) we arrive at the provisional estimates of the standing stock of fish as AFDM given in Table 17. Our results indicate that, from the methods used and in the areas where we sampled, there is about 0.35 g AFDM fish/m² (or 0.41g DM fish/m², given that the ash fraction of fish dry mass is about 0.15). It is clear that the larger size classes contribute far more to the system in terms of biomass than the smaller fish, even though the smaller fish are far more abundant (or easily caught). This figure also should be taken with caution as the tilapia at the sites exhibited pronounced schooling behaviour and the resulting distribution was very patchy, with very high concentrations of fish in some areas.

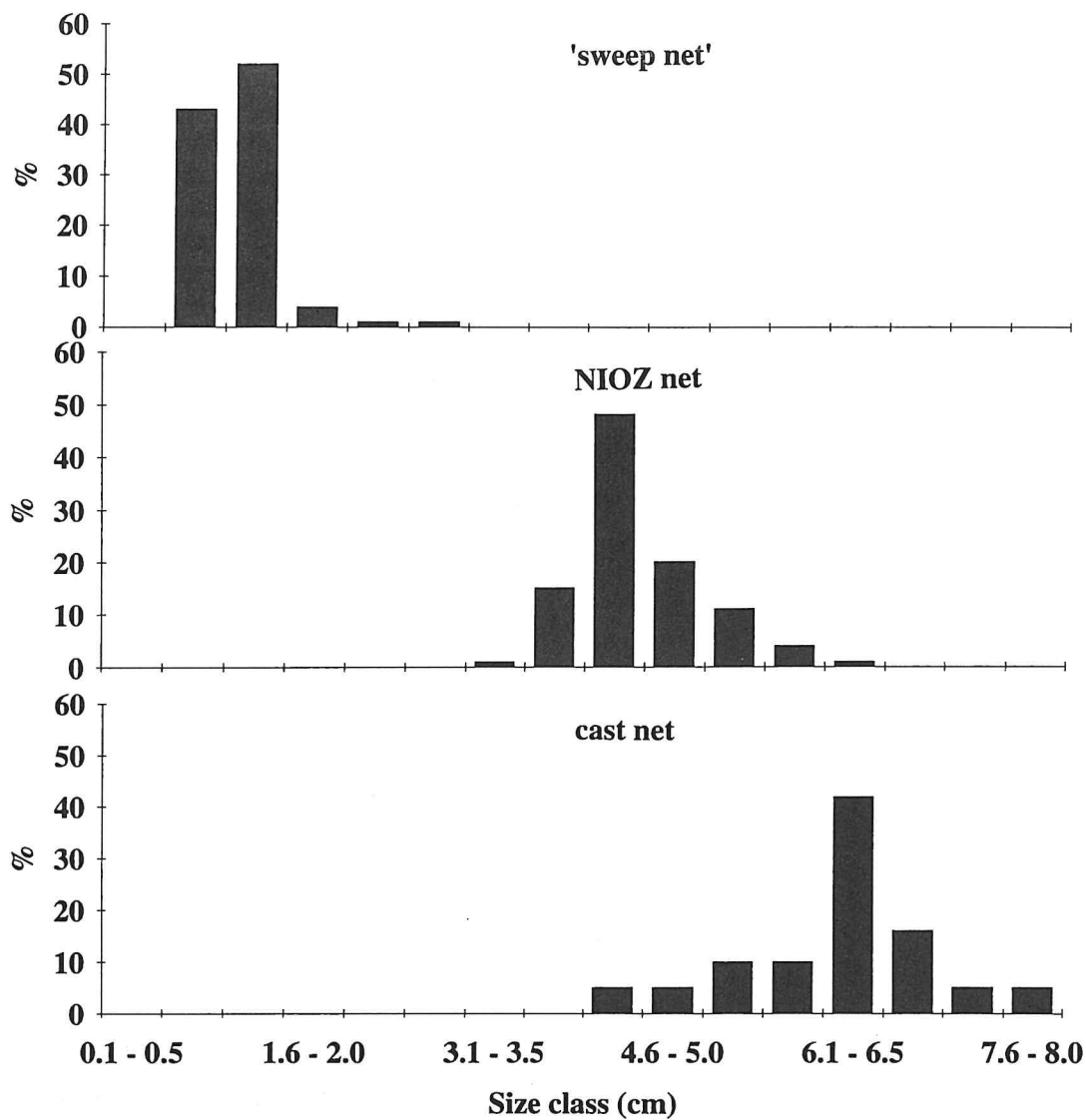


Fig. 49. Size-frequency plots of tilapia caught by three different types of net in Keta Lagoon. See text for further explanation.

TABLE 16.
Density of fish at the Keta Lagoon sites, sampled with different types of gear.

Site	Microhabitat	Day/Night	Method	Density (n/m ²)
Fiahor	outside <i>Ruppia</i>	Day	lift net	1.24 - 2.93
Fiahor	inside <i>Ruppia</i>	Day	lift net	1.91 - 3.12
Fiahor	outside <i>Ruppia</i>	Day	sweep net	1.38
Fiahor	outside <i>Ruppia</i>	Day	NIOZ bottom drag	0.40
Tegbi	outside <i>Ruppia</i>	Night	sweep net	1.66 - 2.26
Tegbi	outside <i>Ruppia</i>	Day	sweep net	0.72

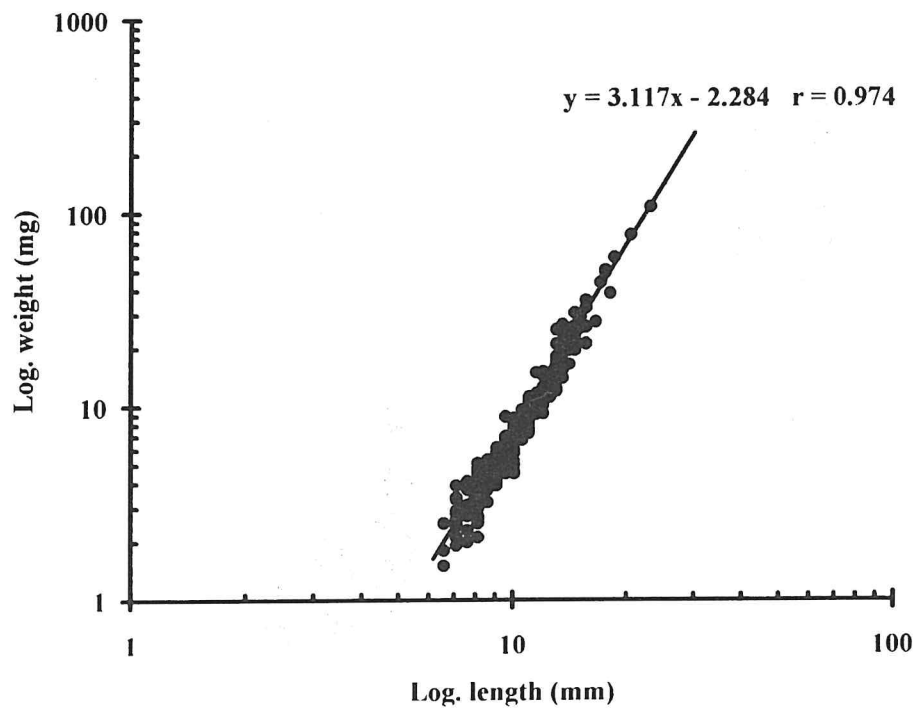


Fig. 50. Dry mass as a function of total length in juvenile tilapia in Keta Lagoon, late October 1994.

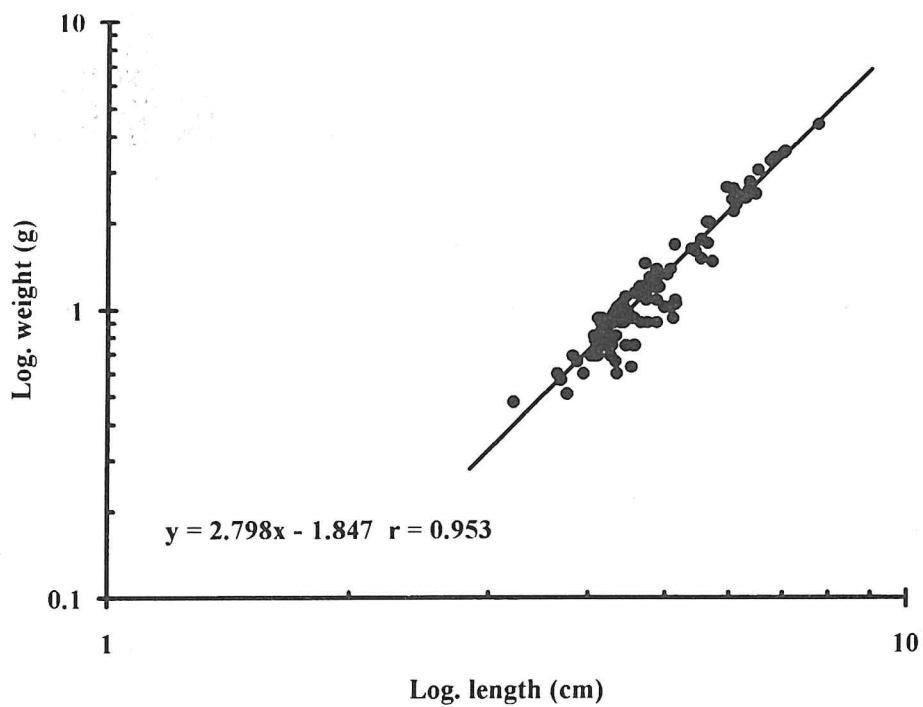


Fig. 51. Dry mass as a function of total length in "large" tilapia in Keta Lagoon, late October 1994.

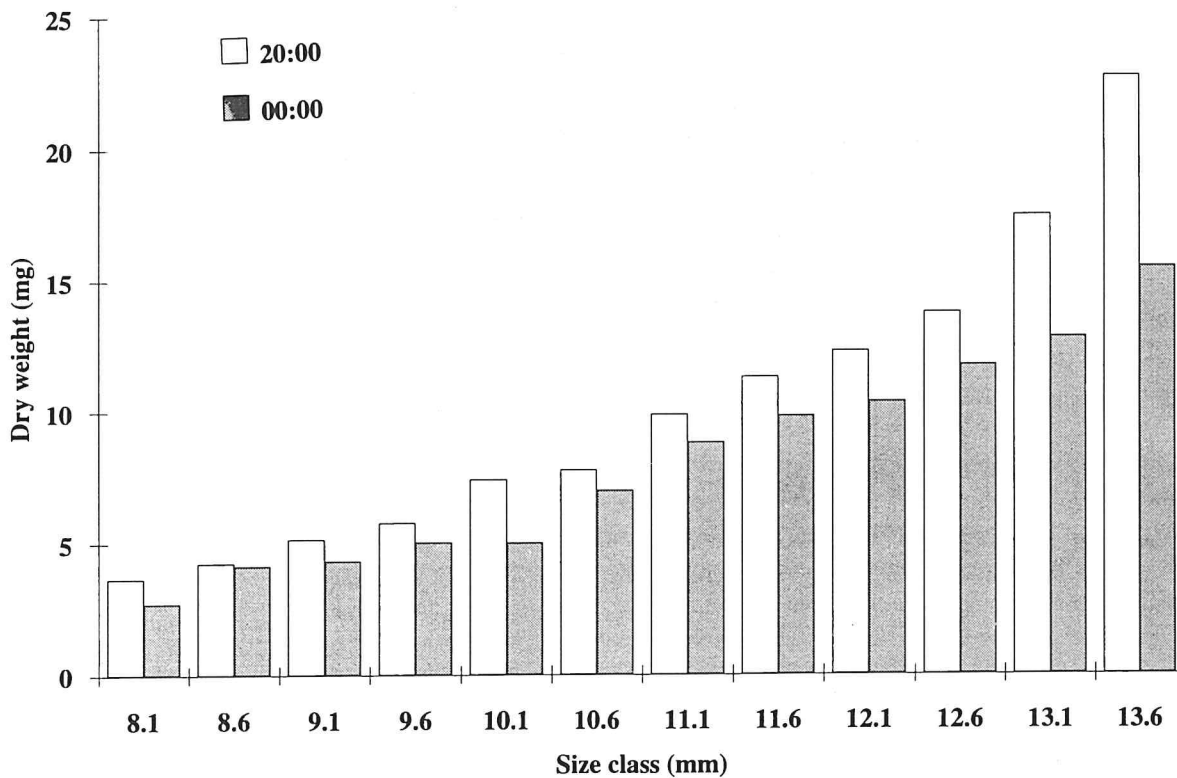


Fig. 52. Mean dry mass of tilapia of different lengths captured at different times of the day at Tegbi, late October 1994.

TABLE 17.
Biomass (in mg AFDM/m²) of fish at the Keta Lagoon sites in October-November 1994.

Site	Microhabitat	Day/Night	Method	AFDM (mg/m ²)
Fiahor	outside <i>Ruppia</i>	Day	sweep net	42.2-45.6
Fiahor	outside <i>Ruppia</i>	Day	NIOZ bottom drag	323.1
Tegbi	outside <i>Ruppia</i>	Night	sweep net	14.5
Tegbi	outside <i>Ruppia</i>	Day	sweep net	10.0

9.4. ENVIRONMENTAL CONDITIONS AND FOOD AVAILABILITY TO BIRDS

From the above breakdown, it is clear that the Songor and Keta Lagoons are rich systems high in standing stock both in numbers of invertebrates and fish and also in biomass. *Ruppia*-seeds are present at 90 g/m², macro-invertebrates at 26 g/m² and fish at least at 0.35 g/m² (all figures AFDM). The question remains, how much of this biomass is available to birds and what are the factors controlling availability? At this time we identify four main environmental factors that control food availability. These are water depth, salinity, water temperature, and sediment texture. Dissolved oxygen concentration, which in other systems has important ramifications (KERSTEN *et al.* 1991), seems to play no major role in these systems.

Water depth - Water depth must be considered the key environmental factor controlling the availability of food for the birds. Water depth in turn directly relates to salinity and temperature. At high water levels brought about by fresh water input from the catchment, many of the food resources present in the lagoons are no longer available as the birds cannot reach them. The vast majority of birds, during the study period, were found feeding in water depths less than 20 cm. Exception to this were the herbivorous ducks (guild 1), the fishing pelicans (guild 6) and the fishing terns (guild 7). The major determining factor is thus how much water is present in the lagoons at water depths less than 20 cm. Associated with this is how long the water has been present at that depth. During our study period we estimated that the whole water area was about 150 km² (after rains). For most of the period we estimated that about 50% of that water area was dry. This gives an area of about 75 km². On the basis of this, we estimate from the slopes of the transects taken at Anloga, Fiahor and Tegbi, that about 20 km² (15-25 km²) would be of the right depth for feeding birds, i.e. between 0 and 20 cm. This is a rather crude estimate. Currently a morphometric survey of the lagoon is being undertaken to prepare hypsographic area- and volume-curves. These will enable more precise estimates of suitable water depths.

The temporal factor comes into play on two fronts. The first is when the water is coming in. At the Vunya 'new lake' a vast expanse of water of the "right" depth was present just after the rains. However, the water had not been present long enough to have been colonised by organisms such as benthos and fish. Indeed, the only potential food available were seeds of *Ruppia*. The second is when the water has been present for a long time with no fresh water input - in such cases evaporation causes the water level to fall. Falling water levels present the best feeding conditions to many of the waterbird species. The gradually receding water margin is actually the best feeding area for the visually surface foraging waders (guild 2) and for the tactile surface foraging waders (guild 3). The drop in water level also serves to concentrate fish in pools and depressions, presenting the pelagic foraging waders (guild 4) and the stalking herons (guild 5) perfect conditions to catch prey. As the water continues to evaporate, salinity increases and the hypersaline conditions cause a decline in numbers of organisms, so although the water level may be right, few prey organisms are present.

Salinity - Most of the organisms found in the lagoons are very euryhaline and salt tolerant. Excessive salinity will however prove lethal to most organisms (e.g., the salinities of over 100 ppt at Songor). Salinity also seems to affect the germination and growth of *Ruppia maritima*. Preliminary results suggest that the seeds germinate best at salinities below 5 ppt but most rapid growth occur between 5 and 15 ppt.

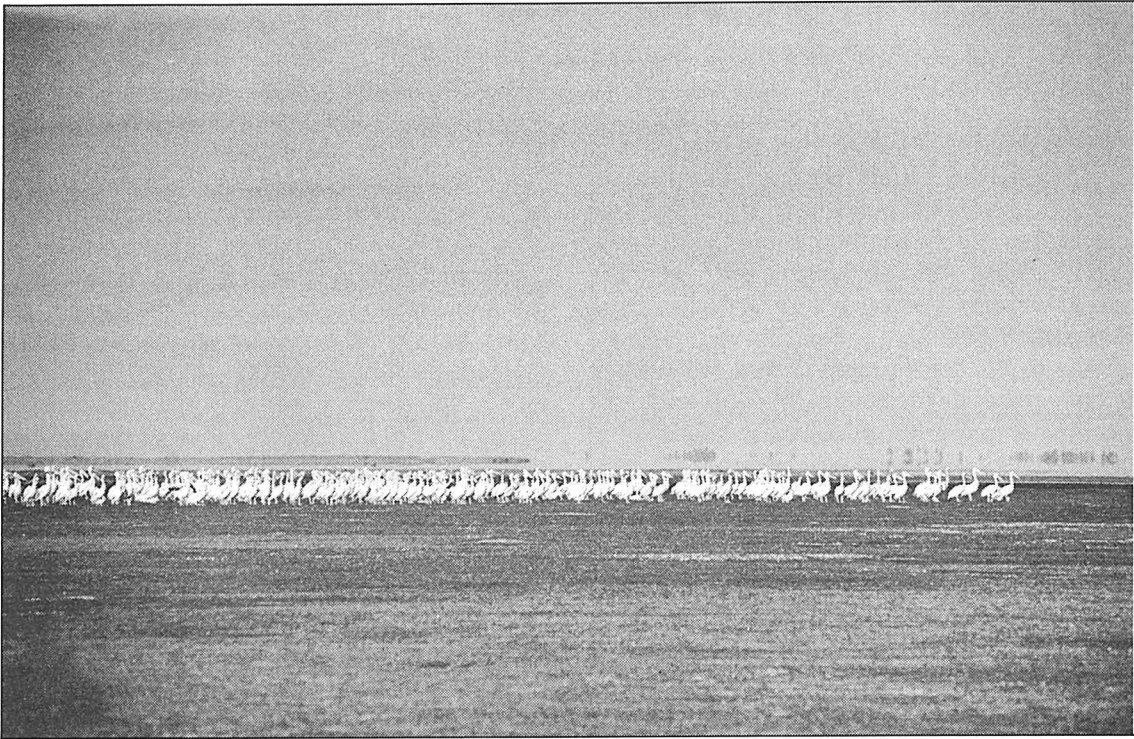
Temperature - Water temperatures in the lagoon can be very high, especially when water levels are very low. The tolerance of the prey species to long periods of elevated temperature under highly saline conditions is not known. Our observations suggest that fish are found in higher densities within *Ruppia*-beds, where temperatures during the day are slightly lower as compared with other parts of the lagoon. Water temperature also affects fish reaction time in predator-prey interactions. Temperatures on the exposed mud flats are very high and the only organism which seems to be able to survive these conditions is *Tympanotonus*.

Sediment texture - The sediments from the sites fall into three main categories: the very sticky, anaerobic mud from Totokpoe which dries to form the hard pan found at Vunya; the sandy sediments found in the seepage areas along the dunes in both lagoons; and the unsorted sediments full of shells found at the Keta Lagoon sites. Of these three, only the second is really suitable for birds to feed on. The anaerobic muds harbour very little life, while the unsorted sediments must be very hard on the bills of the tactile surface foraging waders as they probe in the sediment. The sediment type may account for variations in densities of worms and polychaetes in the different areas.

Other factors - One over-riding factor concerning long-term variations in food availability is the connection with the sea. At high lagoon

water levels, the sand bar separating the lagoon from the sea can break, and for a short time the whole system becomes tidal. The implications of this are twofold: (1) there is an influx of new organisms at every high tide which can colonise the lagoon, and (2) the rise and fall in tide creates a much larger area of water of the right depth for foraging waterbirds.

A factor strongly affecting food availability on the short term is, in the case of animal prey types, the diurnal behaviour of the prey species themselves (e.g., McNEIL *et al.* 1995). The extent to which prey may be available for foraging birds at different times of the day may relate to diurnal changes in some of the factors listed before (temperature, salinity). We have collected too little comparative information during this study to discuss this interesting subject in greater detail.



A pelican flock being disturbed in Keta Lagoon (Photo: P. Battley).

10. DIRECT MAN-BIRD INTERACTIONS

10.1. DISTURBANCE ON ROOSTS AND FEEDING AREAS

The entire Ghana coast is densely populated and the Songor and Keta areas are no exception. Fishing, fish drying and salt collection are the main activities which take place on the lagoons and which could potentially disturb birds using the lagoons. The lagoons were also used for water transport by people crossing from one village to another. Movement of people within the lagoon, along the edges and surrounding areas, on foot and in canoes continued throughout the day and at night and was particularly intense in the Keta lagoon between Fiahor and Woe/Tegbi during the study period. No attempt was made to assess the human use of the lagoons since this was beyond the scope of work, but there was evidence of intensive use. For example, at night around 02:00 hr on one day during the 24 hour observations at Tegbi, three canoes and at least 22 people were fishing in the study area. A continuous flow of canoes carrying people and fish, as well as fishermen and -women fishing, were common throughout the day.

Of the four main activities, the most important in terms of disturbance to birds would be fishing and use of the lagoons for transport. Salt collection is done in the dry season in areas where the lagoon has dried up and such areas will normally not be used by birds. Fish drying is done on the mudflats along the lagoon banks and actually has a positive impact (for the birds, not for the humans) of providing readily accessible food for some species of birds. Species seen foraging on fish spread out to dry included White-fronted Plover, Turnstone, Grey Plover, Greenshank, Black Tern, Little Tern and Black Kite *Milvus migrans*.

There was no evidence that fishing overtly disturbed feeding birds since birds moved and fed unconcerned among the groups of fishing people. In some areas, birds (particularly terns) followed fishing nets and were seen taking fish from the nets. Roosting birds, however, were obviously disturbed by human movement since they took to flight each time somebody passed, something which was irritating when doing observations on bird flocks. Such disturbance

would become more important when birds are breeding, particularly for incubating birds.

Another consequence of the movement of people within the lagoon which could indirectly affect the birds adversely, is the trampling of the substrate. This was particularly evident at Songor (Totokpoe), where movement of people through the soft mud turned the water into a thick mud soup. The effect of this on the survivorship of invertebrate prey items, and the visibility and feeding success of birds is unknown.

It would be necessary for more detailed assessment of the level of human usage of the lagoons and possible disturbance to birds using the sites, to determine whether or not there would be a need to restrict access to critical areas of the wetlands during certain periods of the year.

10.2. TRAPPING

The intensive conservation education undertaken by the Wildlife Clubs of Ghana (junior wing of the Ghana Wildlife Society) has resulted in a significant decline in sea- and shore-bird trapping in most areas along the Ghana coast (GWS unpubl. data). However, some amount of bird trapping and shooting still continues in the Songor and Keta areas. No trapping or shooting was observed during the study but both were reported to have occurred a number of times in recent months (Ntiamo-Baidu pers. obs., Nuoh pers. comm.). We found numerous (ca. 10) Black Tern heads at Totokpoe, one trapped Sanderling at Totokpoe and one Sandwich Tern tangled in fishing gear on a beach near Ada. Traps set for waders and terns have often been seen and destroyed along the edges of the Pute end of Songor lagoon. In September 1994, a pile of tern feathers was seen in this area beside a temporary fireplace, an indication that a substantial number of terns had been caught and dressed at that spot. At Keta, shooting of waterbirds was reported and the species commonly hunted were the White-faced Tree Ducks, herons and egrets. Although the main source of animal protein for the communities living within the Songor and Keta wetland is fish (Ntiamo-Baidu unpubl. data), the birds are known to provide a welcome change in diet for

some coastal people. The use of waterbirds as a food resource and their contribution to protein intake of the communities has not been studied.

10.3. DIRECT COMPETITION FOR FOOD

Both humans and birds depend on the fisheries (including shellfish) resources of the Songor and Keta Lagoons. On the basis of theoretical predictive equations for the expenditure and assimilation efficiency of waterbirds, it is possible to obtain a rough estimate of the predatory impact of waterbirds on the biomass of fish (Table 18). It is estimated that a large bird the size of a heron takes about 300 g of fish per day (fresh mass), a medium sized bird like a Greenshank takes 77 g fish/day and a small bird like a Marsh Sandpiper takes 34 g fish/day. These values can be reworked in DM-terms, as in Table 18. Based on the estimated total populations of these fish-eating waterbirds

in Keta Lagoon on 14 October 1994 (Table 3), approximately 223 kg fish (dry mass) would be eaten by birds per day. This is a small fraction of the estimated human catch of about 11,000 kg fresh fish or 2500 kg dry fish/day, an overall average computed from a reported long-term annual catch of 4,000 tonnes/year in Keta Lagoon (BALARIN 1988). Given that the surface area of suitably deep water is 15-25 km², the predation pressure is 9-15 mg DM fish/m² per day. Since the bird season lasts about 100 peak days, this translates into seasonal predation pressures of 0.9-1.5 g DM fish/m² per season. Since this is twice or three times the overall average standing stock of 0.41 g DM of fish/m² reported in section 9.3, the fish eaten by waterbirds would appear to be a significant loss to the fish stocks, after all. People and birds might be thought to compete for the fisheries resources.

TABLE 18.

Calculation of the predation pressure on stocks of tilapia by fish-eating waterbirds in Keta Lagoon in October-November 1994. The number of birds are the totals counted on 14 October. Body mass was taken from published sources (handbooks and guides). BMR (kJ/day) is a function of body mass; we used the equation for tropically wintering waders ($BMR=2.34 \cdot Mass^{0.72}$, from KERSTEN *et al.* in press). We assume that free-living waterbirds in the tropics that are in energy balance expend an average of 2.5 times BMR (PIERSMA 1994). Given an average assimilation efficiency of 0.77 reported in fish-eating birds by CASTRO *et al.* (1989: table 4), and a energy density of 20 kJ/g dry mass (DM; from V. Sambilay Jr, ICLAM, Manila), implying that DM amounts to 22.5% of fresh mass given that energy density is 4.5 kJ/g fresh mass in small fish (reported by Van Eerden *et al.* 1993), the total predation pressure in kg/day can be worked out. Our limited information leads to an estimated area of suitably shallow water (1-10 cm) of 15-25 km², thus allowing a calculation of the daily predation pressure per m² (see text).

Species	Number	Mass (g)	BMR (kJ/day)	Expenditure. (kJ/day)	Intake (g DM fish/day)	Predation pressure (kg/day)
Marsh Sandpiper	569	65	47	118	8	4.37
Greenshank	1984	200	106	265	17	34.19
Spotted Redshank	369	175	96	241	16	5.78
Black-winged Stilt	5675	170	94	236	15	87.00
Avocet	199	260	128	321	21	4.14
Little Egret	784	450	190	476	31	24.23
Reef Heron	286	450	190	476	31	8.84
Great White Egret	35	1100	362	906	59	2.06
Grey Heron	626	1600	474	1186	77	48.21
Little Tern	237	55	42	105	7	1.61
Whiskered Tern	261	80	55	137	9	2.33
Total						222.75

However, there are different arguments to suggest that competition between waterbirds and people is unlikely. Indeed, the presence of waterbirds may enhance the availability of fish for the people. First of all, the birds are not depleting a stable and permanent standing stock of fish of 0.41 g DM/m². Instead, since they feed on the smallest cohorts, they are eating from a rapidly renewing stock with a turnover that may be as high as 10-15 times each year. If this were so, they would only remove about a quarter of this production of juvenile fish. The removal of these small fishes may actually *enhance* the *growth* and thus the speed at which the remaining juveniles (which are freed from food competition) attain the lengths that make them attractive for the human fisheries (LAË 1994). A comparison of size classes of fish in Keta Lagoon with the sizes taken by fishermen in cast-nets indicate that, whereas birds were taking juvenile fish of sizes in the order of 0.5-2 cm, the fish taken for human consumption were 4 cm and greater (see section 9.3). Thus, birds and people are foraging on completely different fish cohorts. Even if competition between small fish for food resources would not constrain their growth, the high proportions of juvenile fish that fail to survive to adulthood for reasons other than predation by waterbirds, would imply that the proportion of juvenile fish eaten by the birds is likely to have died naturally anyway. In addition, the selection for small fish sizes by fish-eating waterbirds may help to prevent the tilapia

populations from reaching reproductive status (and hence stop growth) at sizes that are far below the profitability threshold for humans. Phenomena such as these have been described in many studies for intensely fished populations in various parts of the world (SUTHERLAND 1990, RIJNSDORP 1992).

The presence of birds on the lagoons could also have indirect benefits on fish production through their defaecation. If minerals such as phosphates and nitrates were limiting the primary productivity of the lagoons, the faecal material from birds would encourage growth of algae (fish food) and aquatic plants such as *Ruppia maritima*, which provide nursery grounds and places for fish to hide.

10.4. BIRDS AS INDICATORS OF FISH

The use of terns by fishermen at sea to locate fish shoals is well documented (e.g., NTIAMOA-BAIDU 1988, 1991b). Every fisherman on the Ghana coast knows that a flock of terns feeding at a particular spot out at sea is an indication of a fish shoal in the waters at that spot and they cue in on the fishing birds by throwing their nets there. For the fishermen on the Ghana coast, this value (and perhaps in a few cases, cultural values as well), is the only justification for protecting terns. Although fishermen follow birds only at sea, terns need the lagoon habitats for roosting and as supplementary feeding areas; and in the case of the Little Tern, also for nesting. The lagoons therefore play an essential role in the survival of seabirds.



Dry-land shorebirds: Collared Pratincoles near Sakuma Lagoon (Photo's: P. Battley).

11. CONCLUDING REMARKS AND RECOMMENDATIONS

11.1. WATERBIRD ECOLOGY AND THE STATE OF COASTAL WETLANDS IN GHANA

Our study has confirmed the great importance of Songor and Keta Lagoon for international migratory populations of waterbirds, as established by NTIAMOA-BAIDU (1988, 1991a). Almost 76,000 waterbirds were counted during this study on a single day in October 1994, thereby unambiguously establishing the large total populations counted previously on separate days. Some species were observed in larger numbers than ever before, amongst which was the observation of 650 individuals of the endangered Roseate Tern and the count of 21,000 Curlew Sandpipers on 14 October (Table 3) and over 31,000 at Woe-Tegbi only on 25 October (Table 4), many more than the maximum of 15,250 previously recorded for the whole of Ghana (NTIAMOA-BAIDU 1991a). Other species were present in lower numbers than usual. With respect to the Africa-breeding tree ducks, only a few 100 of them were present, whereas up to 50,000 have been counted in other years. Their absence and that of Spotted Redshanks (a few 100 rather than many 1000's), may have had to do with the relatively low water levels in the lagoons during the period of study. This underlines the preliminary nature of such short-term studies and the need to establish monitoring programmes to realistically establish the factors affecting the ecology of notoriously unpredictable habitats such as these closed coastal lagoons. We will come back to this point below.

This report thus provides a snapshot at the life-cycle of the waterbirds using the two largest coastal lagoons of Ghana. It provides a glimpse at the ever changing ecology of the lagoons. It has been possible to describe general behaviour, water depth selection, daily feeding rhythms and diets of about 36 waterbird species. We have also been able to describe the waterbirds' distribution during the study period, and to analyse the food resources underlying these particular distributions. A few otherwise abundant species were around in very low numbers. Given the brevity of the study we

cannot correlate their absence with any ecological variable.

However, some of these insights and information will *not* be very specific to the study period. It is unlikely that water depth selection of the different species will vary much from month to month or from year to year. The feeding styles employed by the different waterbird species are likely to be also fairly typical (McNEIL *et al.* 1992). In contrast, diet and daily feeding rhythms, and particularly distribution, are likely to vary with ecological conditions (salinity of the water, food abundance, weather and competitor densities) and time of the year (whether or not birds are preparing for long-distance migration) (see, e.g., MERCIER & McNEIL 1994). This is evident from the seasonal fluctuations in bird numbers observed in the 10-year monitoring of waterbird populations at the two sites.

Is it possible, therefore, to deduce what the waterbirds stand for? What is their role in the ecology of the lagoons, and what does their presence tell us about the lagoons' environments? All ground-feeding guilds (guilds 2-5, i.e. representing the majority of waterbirds collecting their food in the lagoons) require very shallow water, water no deeper than 20 cm. When the mud dries out, it can be used for some time by visual foraging waders (guild 2), but this is likely to be a short period only. Stagnant and deep water will not be favoured by most of the birds. For the fish-eating birds, the predation pressure exerted may not be trivial (though probably not negatively affecting human harvest, see above), but for the benthos-eating waterbirds it probably is, given the abundance of prey and the unavailability of much of the prey. Benthic animals are either too hard-shelled, buried in unstructured sediments that are difficult to probe in, or hidden beneath a layer of widgeongrass (*Ruppia maritima*). Surface-foraging waterbirds can only obtain these prey when the water table lowers and the mud starts drying up. Such waterbirds rely to a fair extent on invertebrate stocks that might otherwise find an early death when the substrates they are living on or in dry out.

The *a priori* conceptual model of seasonal changes in the coastal lagoons (Fig. 4) provided us with a satisfactory framework for

our observations. Obviously, the time scale of the observations reported in this study do not allow us to test the model. With regard to the waterbirds, the causality of the vectors pointing from water influx in the lagoons (direct rainfall and inflow from Volta River) and evaporation processes to water table, and from water table to the suitability of feeding areas for waterbirds (as a function of past time for prey animal renewal and the provisioning of suitable water depths) is clearly supported. The surface-feeding waders (whether locating their prey by visual or tactile means) require exposed mudflats which have been submerged for long enough to have built up large populations of macro-invertebrates. These conditions were most available in parts of Keta Lagoon, which as a result, supported relatively large numbers of tactile surface foraging waders (Fig. 53). This was especially true for the Tegbi area. Pelagic feeding waterbirds (and herons) require shallow water with good fish stocks, and it is clear that such conditions were best provided by the Totokpoe area in Songor Lagoon, and the Anloga corner in Keta Lagoon (Figs. 53 and 54).

The changes in bird numbers on a seasonal basis with regard to the conceptual model of the lagoons' ecology (Fig. 55), suggests that indeed waterbirds (especially the surface and pelagic foraging guilds 2-5) are particularly abundant at the time of the year that they *should* be, at the fall of water levels in the period of October through November. To a certain degree this may appear fortuitous since over the northern summer (May through August) the boreal, subarctic and arctic breeding migrants have breeding duties far north of Ghana. The model does not, however, explain the temporary absence of large numbers of waterbird during December. In the midst of the northern winter, waterbirds with similar life-histories and seasonal schedules remain in other (tidal) areas in West Africa (e.g., PIERSMA *et al.* 1990, ZWARTS & PIERSMA 1990). However, especially in recent years numbers of waterbirds build up again in January and stay on till April. A well-worked out example of a waterbird species that uses the Ghanaian shores in this way, occurring both late in the year (presumably during southward

migration) and early in the following year (during northward migration), is the Knot (NTIAMOA-BAIDU 1993). However, Knots occur in rather low numbers and the Ghanaian coastline is likely to be an (additional) emergency site during their long-distance travels, and almost certainly not a strategic wintering or stop-over area.

The model presented in Figs. 4 and 55 should be subject to further tests, one of which would be to correlate on a sample basis the numbers of specific waterbirds and the water table conditions. This would be possible on the basis of (Landsat-)satellite images. The long series of waterbirds counts carried out at the most important Ghanaian coastal sites could thus be used to test the model in an indirect way.

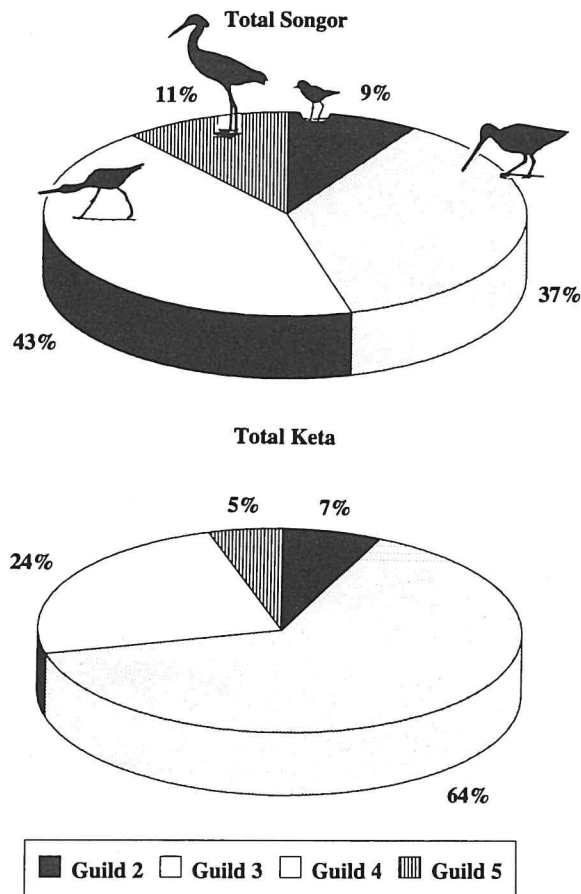


Fig. 53. Comparison of the bird communities (in terms of the four ground feeding waterbird guilds; ducks, pelicans and terns excluded) in Songor and Keta Lagoon, based on the results of the ground counts made on 14 October 1994.

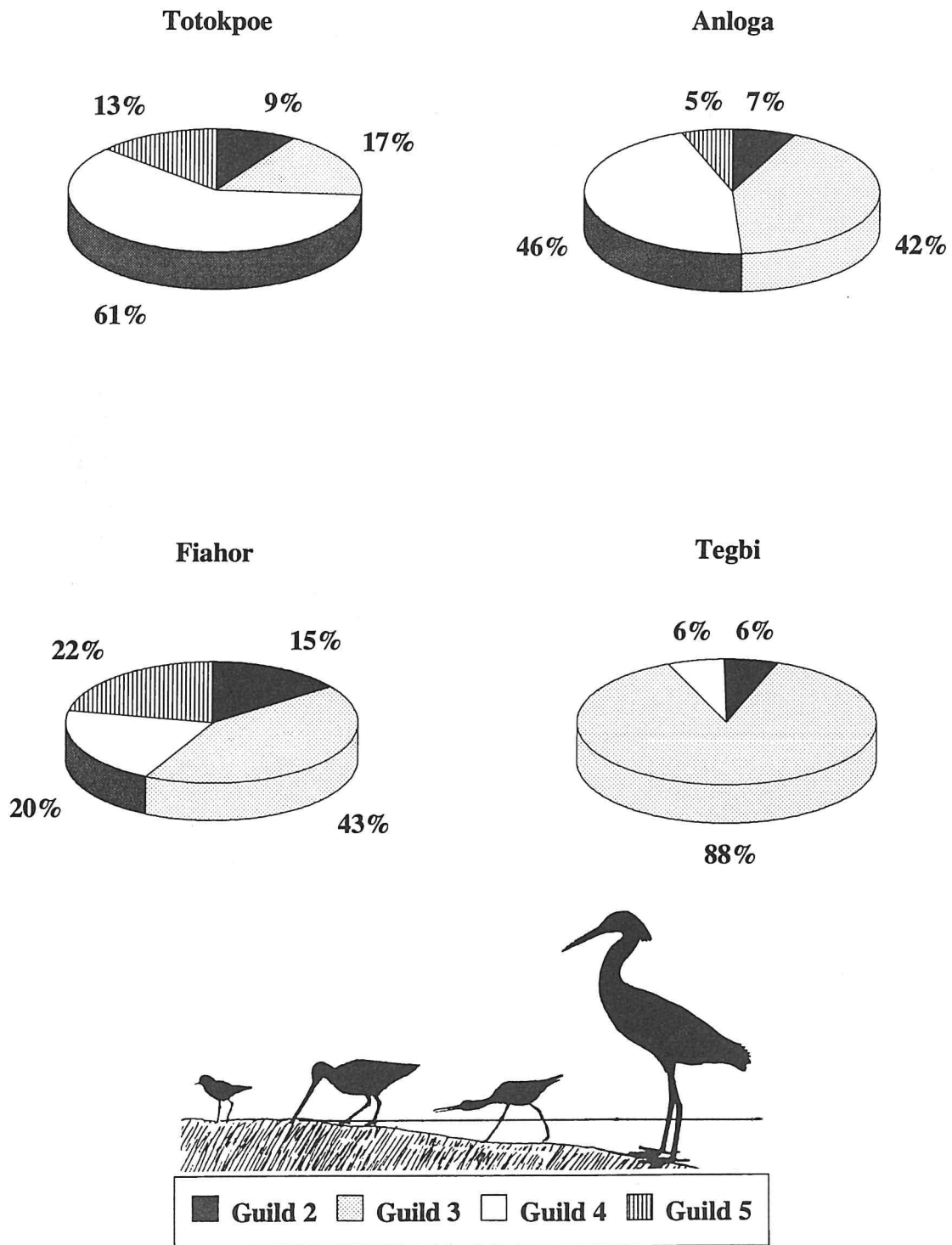


Fig. 54. Comparison of the bird communities (in terms of the four ground feeding waterbird guilds) at the four study areas in respectively Songor Lagoon (Totokpoe) and Keta Lagoon (Anloga, Fiahor and Tegbi), based on the results of the ground counts made on 14 October 1994 (Tables 2 and 3).

Provided that these tests turn out positively, we can then start using the abundance of specific groups of birds to backward-predict the ecological conditions in the lagoons over the past 10 years (1985-1995). This is an exciting prospect. At the same time the establishment of long-term monitoring with respect to water level and the abundance and size distribution of

selected macro-invertebrates and fish (tilapia) at selected sites in the lagoons, may not only enhance the understanding of the ecology of the organisms directly, but also provide further test of the model. Such data will lead to critical refinements of the ecological model of Ghana's coastal lagoons.

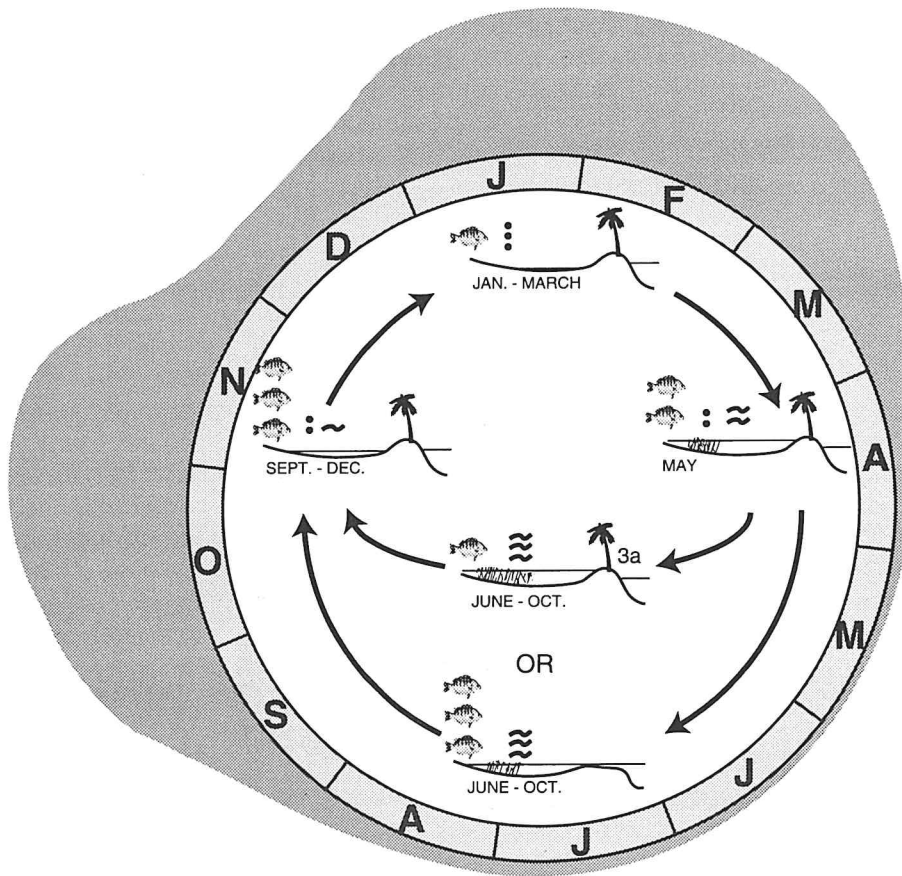


Fig. 55. The *a priori* concept summarizing annual changes in the ecology of coastal lagoons in Ghana (Fig. 4) in combination with the seasonal changes in the relative numbers of waterbirds (the latter after NTIAMOA-Baidu 1991a and unpubl. data).

11.2. KEY SITES FOR WATERBIRDS WITHIN THE SONGOR AND KETA LAGOON SYSTEMS

The observations carried out during this study and the observations over the past 10 years showed that in general terms and given the absence of persecution, humans and waterbirds can live well together in the Songor and Keta Lagoon systems. Humans tend to have a different use of habitat than waterbirds. They prefer deeper water where they catch larger fish. The size-selective predation of the fish-eating waterbirds on the smallest sized fish may enhance, rather than depress human harvests of fish. Yet, human activities may prove detrimental to the birds. The 10,000's of terns roosting near the village of Totokpoe in Songor Lagoon do so where there is little traffic of humans, on a large expanse of soft mud. We conclude that rest and safety are important factors for the terns, and this could be true for other waterbirds as well.

Some areas within the Songor-Keta complexes appear to be of outstanding importance for waterbirds. These are Vunya-Totokpoe in Songor Lagoon (nr. 1, Fig. 56), and the south-western part of Keta Lagoon bordered by Fiahor, Anloga, Woe, Tegbi and Dudu Island in Keta Lagoon (nr. 2, Fig. 56), both of which held

large numbers of waterbirds during this study period. Past records made during nine years of monitoring have shown that the sections near Afiadenyigba in the north of Keta Lagoon (nr. 3, Fig. 56), and the lagoonal area around Adina in the northeast (nr. 4, Fig. 56), also often hold important numbers of waterbirds. Most of these parts are least likely to dry out completely (especially Totokpoe-Vunya and the south-western corner of Keta Lagoon). But when they hold water, they are home to exceptional densities of waterbirds. The area near Fiahor is sometimes also used as a massive night-time roost by a variety of species (NTIAMOA-BAIDU unpubl. data). Although the exact reasons explaining the importance of these sites are not known, it is obvious that these are the areas that must be protected to ensure the lagoons' value as waterbird habitat. Infrastructural developments with a large impact on the ecology of the lagoon should be avoided, and it may be wise to restrict human usage as it relates to disturbance, at least during part of the year. Both the Songor and Keta Lagoon systems have potential for salt development. Even though salt extraction can be compatible with nature conservation in some circumstances, every effort should be made not to destroy the

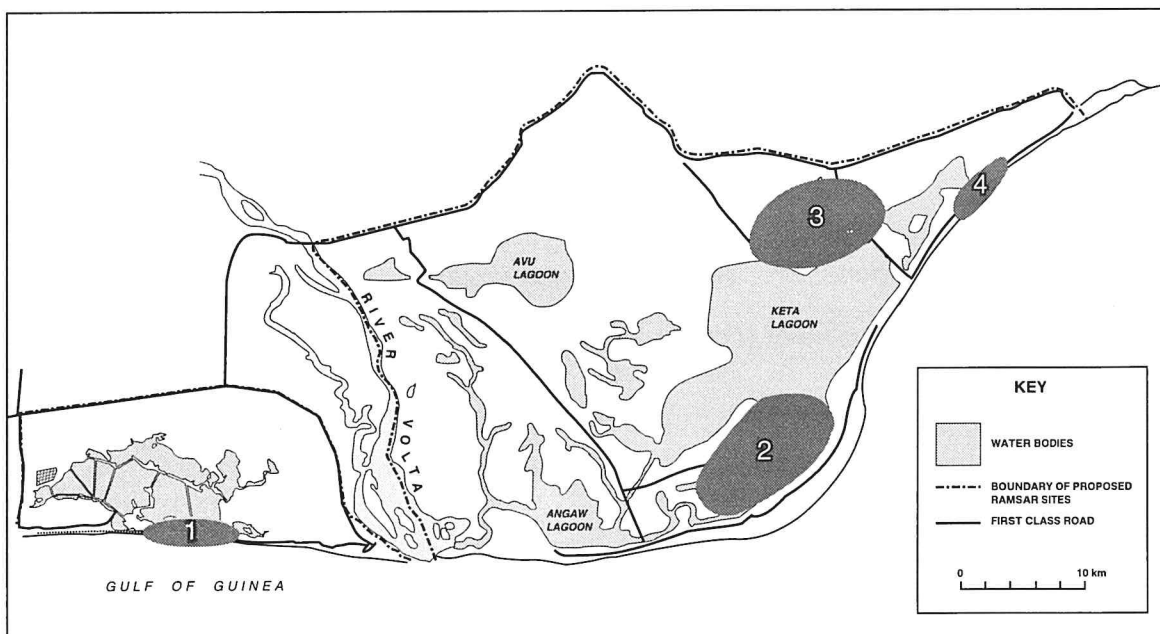


Fig. 56. Four key areas for waterbirds requiring special protection from disturbance and other human interventions in the Songor and Keta Lagoon systems in the Volta delta, Ghana.

integrity of the key areas indicated in Fig. 56.

Although Songor and Keta Lagoons each provide large expanses of water, they appear to be complementary systems. The results of previous counts have shown that the two lagoons provide alternative sites during periods of extreme environmental stress such as during floods (e.g. in October 1987 when Keta Lagoon was flooded, the birds moved to Songor Lagoon) and dessication (when Songor Lagoon is completely dry, Keta is used as an alternative and numbers of birds at Keta increase considerably, NTIAMOA-BAIDU unpubl. obs.). Both lagoon systems need to be maintained for waterbird populations to remain healthy and of international importance.

11.3. MAINTAINING THE VALUE OF THESE WETLANDS FOR WATERBIRDS

The crucial issue which determines whether or not the waterbirds will continue to use the coastal lagoons is that their food resources must be available. Prey availability, i.e. the presence and accessibility of the prey items, is in turn linked with the environmental conditions in the lagoon such as water depth, salinity and sediment texture. Other secondary factors which will influence the value of the coastal lagoons as waterbird habitat are human disturbance, availability of roosting areas and nesting sites. These, therefore, are the key parameters which should be of management-concern in the efforts to maintain the value of the wetlands as waterbird habitat.

What would be the ecological measures that are desirable for the ecology of the lagoon systems to run a healthy course? We suggest that the following factors are of critical importance:

- (1) Maintenance of the seasonality of the water tables. This may involve the upkeep or restoration of the seasonal inflow of water from the Volta River, to supplement water supply by local rainfall in some years.
- (2) Ensuring a regular contact of the lagoon waters with the sea (e.g., by building a sluice in the narrowest part of the seawall), especially in the lagoons that are prone to lose their invertebrate populations completely. Keta Lagoon may be large enough to support viable invertebrate populations

through periods of drought even without "reseeding" by the sea, but this requires much further study.

- (3) Creation of areas where disturbance of waterbirds is low; notably roost sites for herons, tree ducks and terns (see previous paragraph).
- (4) Most waterbird species rely on shallow and calm water. Therefore, parts of the area that have lost their value due to structural changes could be "restored" by providing shallow water areas and artificial windbreaks at some spots. Incidentally, some of the latter structures are currently already in place where fishermen have erected screens and other fishing devices.

11.4. GHANA'S COASTAL LAGOONS IN THE FUTURE

The human community is slow to learn that the world has never been a stable place, that all things will keep changing, especially the ecological phenomena, and that our own presence adds to this unsteadiness. This will be no different for Ghana's lagoons. Given their great importance as economic and cultural resources for the local human populations that should ideally be exploited on a sustainable basis, and for the international populations of migratory waterbirds, it is critical that the monitoring of key environmental parameters be maintained. The knowledge thus gained can provide a basis for decisions that must be made with respect to the management of the lagoons, for the benefit of both humans and waterbirds.

On the basis of the experiences accumulated during this field study, the following suggestions for a sustained, long-term monitoring effort are provided:

- (1) The monthly waterbird counts should be continued, since the numbers of different kinds of birds provide useful integrated assessments of the ecological conditions in different parts of the lagoon. This data resource is far from being fully exploited at the moment.
- (2) Routine data on water level and the extent of flooded area should be collected by the bird counters during each count. This could be done by recording of the water line on numbered pegs at a particular time; by

measuring the depth with a gauge at the deepest points in the lagoons; or by assessing the distance between waterline and permanent shoreline at specific points in the lagoons. Of course, such data could also be assembled in a separate monitoring programme not linked to the bird counts, but it would seem more cost effective to link the two.

- (3) Selected benthic invertebrate and fish populations should be monitored on a regular basis and the recolonisation of recently flooded areas studied. Presently, the basic life-history features (seasonality of growth and reproduction, densities) of the species concerned are unknown. The elucidation of seasonal patterns and long-term changes may yield many hints as to the changes in the functioning of the lagoon ecosystem.
- (4) Analyses of past environments by satellite image analyses of water covered areas in relation to the existing waterbird data should be undertaken to gain an understanding of the linkages between long-term changes in water level and waterbird populations.
- (5) The combination of data from these four programmes would allow us to see to which extent pelagic foraging (fish-eating) birds indicate fish abundance, whether visual and tactile foraging waders indicate the extent of recently uncovered but thoroughly "seeded"

mud, and whether terns indicate small-fish (fry) abundance in the coastal zone outside the lagoons.

This study was concerned mainly with the migratory waterbirds, the waders, terns and herons that use the Ghana coast during the non-breeding season. Casual observations during the study and past observations have shown the areas to be very important also for populations of breeding waterbirds. Resident breeding birds include Collared Pratincoles, Little Terns, Kittlitz's Plovers and White-fronted Plovers. These species and their breeding biology of need attention with respect to the ecological management and wise use of the lagoons. Another category of migrants that requires attention are the herbivorous tree ducks (guild 1). In this study we have not been very successful in assembling information about them. Given their special niche as herbivores, and their occasional abundance and importance as bag for local hunters, the ecology of the White-faced and Fulvous Tree Ducks also warrants urgent scientific attention.

A thorough understanding of the ecology of the coastal lagoons of Ghana would not only be important for the management of the international migratory waterbird populations, but could become crucial when conflicting human interests, such as fisheries, salt exploitation, eco-tourism and safe housing, come to the fore.



Flock-fishers near Fiahor, Keta Lagoon (Photo: P. Wiersma).



The fish-trade at Keta Lagoon (Photo: P. van Gaalen).

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Aerial overview of the Densu Delta, west of Accra (Photo: C. Gordon).

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Plate 1. Dunes, palms and terns at a typical coastal lagoon in Ghana. (Photograph by Paul van Gaalen)

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Plate 13. The harvest of salt in a dried-up part of a Ghanaian coastal lagoon. (Photograph by Paul van Gaalen).





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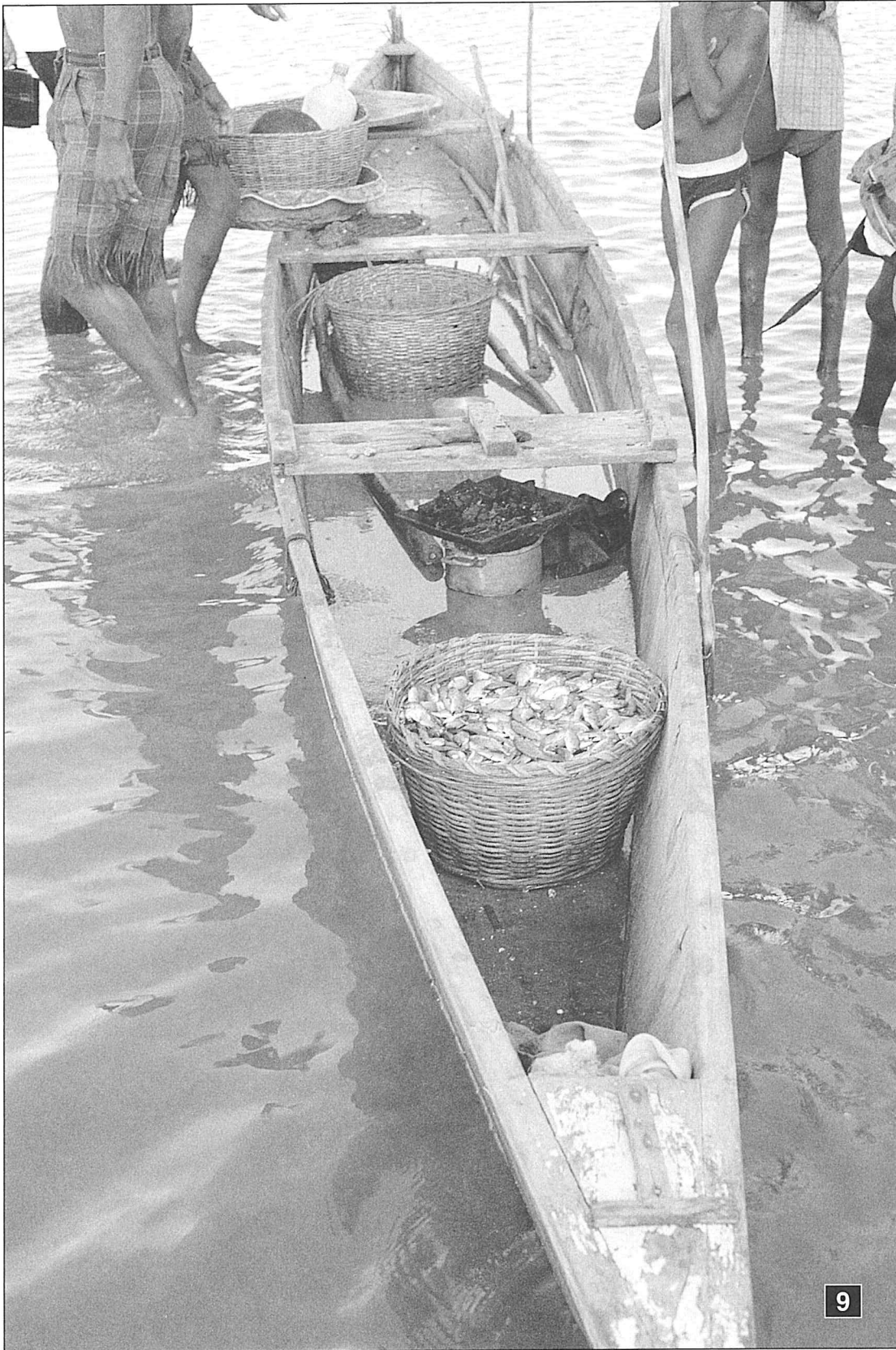


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