Hydrobiology of the Songor and Keta lagoons: implications for wetland management in Ghana

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The hydrobiology of Keta and Songor Lagoons

Implications for coastal wetland management in Ghana

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Executive summary

Keta and Songor lagoons are located alongside the current delta of the Volta River in eastern Ghana. The lagoons and surrounding wetlands are heavily utilised by a large population of people who fish using a variety of techniques, cut reeds for thatch and weaving, harvest salt by intensive and extensive means, and irrigate vegetables using water drawn from shallow wells in the surrounding sandy soil. The lagoons are also important habitat for many aquatic and wetland animals and species and have been recognised as internationally important under the Ramsar Wetlands Convention. However, increasing exploitation of the lagoons and their resources has resulted in degradation and raised concerns about the long-term sustainability of these systems. These concerns are being addressed through the Ghana Coastal Wetlands Management Programme (CWMP), which was implemented by the Ghana Wildlife Department as part of the Ghana Environmental Resource Management Project and funded by the Global Environment Facility. The general aim of the CWMP is to manage five coastal wetland sites to maintain their ecological integrity and enhance the benefits derived from the wetlands by local communities.

In line with the general aim of this program a broadscale baseline description of the ecological character of Keta and Songor lagoons was undertaken. As ornithological and fish surveys were undertaken in separate exercises they were not included in this study. Our surveys covered:

- meteorology;
- bathymetry and hydrology (surface and groundwater and water uses);
- sedimentology (particle size, organic content);
- water quality (field analyses for pH, dissolved oxygen and conductivity; laboratory analyses for major ions, nutrients and metals);
- aquatic fauna (diversity and abundance of benthos and zooplankton);
- aquatic/wetland phytoplankton (species diversity and chlorophyll);
- macrophyte diversity, biomass and phenology.

Most of the field surveys were undertaken in November 1996 with subsequent supplementary surveys and analyses of the samples and data taken over ensuing months. The surveys were based on a systematic sampling grid placed across each of the lagoons and adjoining wetlands as a template for determining spatial patterns. As Keta is much larger than Songor, the sampling effort was also much larger and included large areas of surrounding wetland as well as the open water. Temporal patterns were not determined; however, this important aspect was addressed in recommendations for further monitoring and management.

The data and information collected through these surveys were used with information gathered from other sources to provide comment on the major threats to the lagoons under the general headings of ‘water regime’, ‘water pollution’, ‘physical modification’ and ‘exploitation and production’. Recommendations for monitoring and research were also made.

In assessing further monitoring needs, we recognised that as the lagoons are very large it would be impossible to carry out the same sort of sampling intensity that was used in this baseline study. Thus a stratified random approach was recommended as the basis of a simple bimonthly monitoring strategy for selected hydrology, water quality and biological parameters at 6 sites in Songor and 17 sites in Keta.

A list of further research projects was compiled with an emphasis being placed on environmental issues and management of the lagoons, including:

- re-colonisation by invertebrate fauna;
- environmental tolerance of invertebrate fauna;
- ecology of Penaeids;
- zooplankton dynamics within the main channels of the wetlands;
- development of invertebrate fauna within acadjas;
- determination of the factors controlling the spread of various mollusc species in the wetlands;
- decomposition of aquatic plants;
- resource partitioning between crabs in the lagoons;
- harvesting and usage of aquatic macrophytes by local communities;
- groundwater salinity and mangroves;
- hydrogen sulphide in sediments and its effect on the vegetation in the lagoons.

In order to assist with further monitoring and analyses of results we also included in this report detailed descriptions of the field sampling methods and data collected during the baseline surveys.

Acknowledgments

This study was logistically very demanding, and a large number of individuals were involved before, during and after the fieldwork. Thanks must first go to Mr Bill MacFarlane (***eriss***), Mr HO Ankrah (VBRP/Zoology, Legon) and Mr F Seku (Botany Department, Legon) for their technical assistance in the field. They were ably supported by Mr Erasumus H Owusu, Mr Steven Asamoa, Mr Ali Nuoh and Sammy Adu of the Ghana Wildlife Society. We will not forget the input of the attached staff of the Ghana Wildlife Department, Mr CC Amankwah and Mr Felix Nani. Mr David Kpelle assisted in post fieldwork administration. Thanks also go to Dr Mike Kendall of the Plymouth Marine Laboratory, UK, for polychaete identification.

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1 Introduction

The Ghanaian coastline stretches some 550 km from Togo to Cote d'Ivoire in the Gulf of Guinea (figure 1). There are about 100 coastal lagoons in Ghana which make them an important feature of this sandy coastline, especially as the lagoons provide many benefits and values to human populations (Gordon 1987, 1996). Locally, the lagoons provide valuable resources for trade and consumption. Large quantities of fish and crabs are caught and traded, either smoked or dried. Reeds and other plants are cut for thatch and for weaving mats for sale at markets near and far. Vegetables are grown in sandy garden beds irrigated by water drawn by hand from wells along the edges of the lagoons. Salt is extracted by both intensive and extensive methods. The socio-economic benefits of the lagoons to the local people are apparent to even the most casual of observer.

In recent years, the immense conservation value of these same lagoons has been recognised both nationally and internationally. As with wetlands elsewhere in the world the value of the lagoons as migratory waterbird habitat has received recognition (Ntiamoa-Baidu & Grieve 1987, Ntiamoa-Baidu 1991, 1993, Ntiamoa-Baidu & Gordon 1991, Piersma & Ntiamoa-Baidu 1995, Ntiamoa-Baidu et al 1998). The broader values of these habitats are gradually receiving greater attention as conservation is being increasingly considered as an integral component of sustainable use of the wetland resources, rather than as an issue in isolation.

However, it is evident that the values and benefits provided by the lagoons are under increasing threat from over-exploitation and degradation (Ntiamoa-Baidu & Gordon 1991). The very resources that provide the values and benefits are under pressure from the expanding human population. For the socio-economic values of the lagoons (ie the products and functions) to be maintained it is necessary to ensure that the basic ecological character of the lagoons is maintained. The products and functions of any wetland can not be treated separately from the ecological processes from which they are derived (Finlayson 1996a). Thus, to maintain the resources of the lagoons the pattern of usage must ensure that the ecological processes that support the products and functions valued by the human population are not degraded and, in the worst case, lost forever. Whilst traditional patterns and levels of use can be sustainable in Ghana (Gordon 1990), expanding population pressures can all too quickly degrade the basic resource(s) being used (World Bank 1996). The situation is made more acute in Ghana, where the coastal zone represents less than 7% of the total land area, however, it holds over 25% of the nation's population. The continued trends of the drift from rural to urban centres, the industrialisation of coastal districts as well as the high population growth rate of 3%, place increasing stress on the coastal ecosystems.

In view of such increasing pressures on wetlands the Ramsar Wetlands Convention has proposed management and monitoring processes for Wetlands of International Importance. Integral to these are guidelines for the wise use of wetlands (Davis 1993) and the maintenance of their ecological character (Finlayson 1996b). From a management perspective, the ecological character must first be described (to a minimum necessary level) and key features identified and then monitored to ensure that they are not degraded or lost. Thus, description of the ecological character and the development of a suitable monitoring framework are two steps that are increasingly being seen as essential components of making wise use of wetlands (Finlayson 1996a,b).

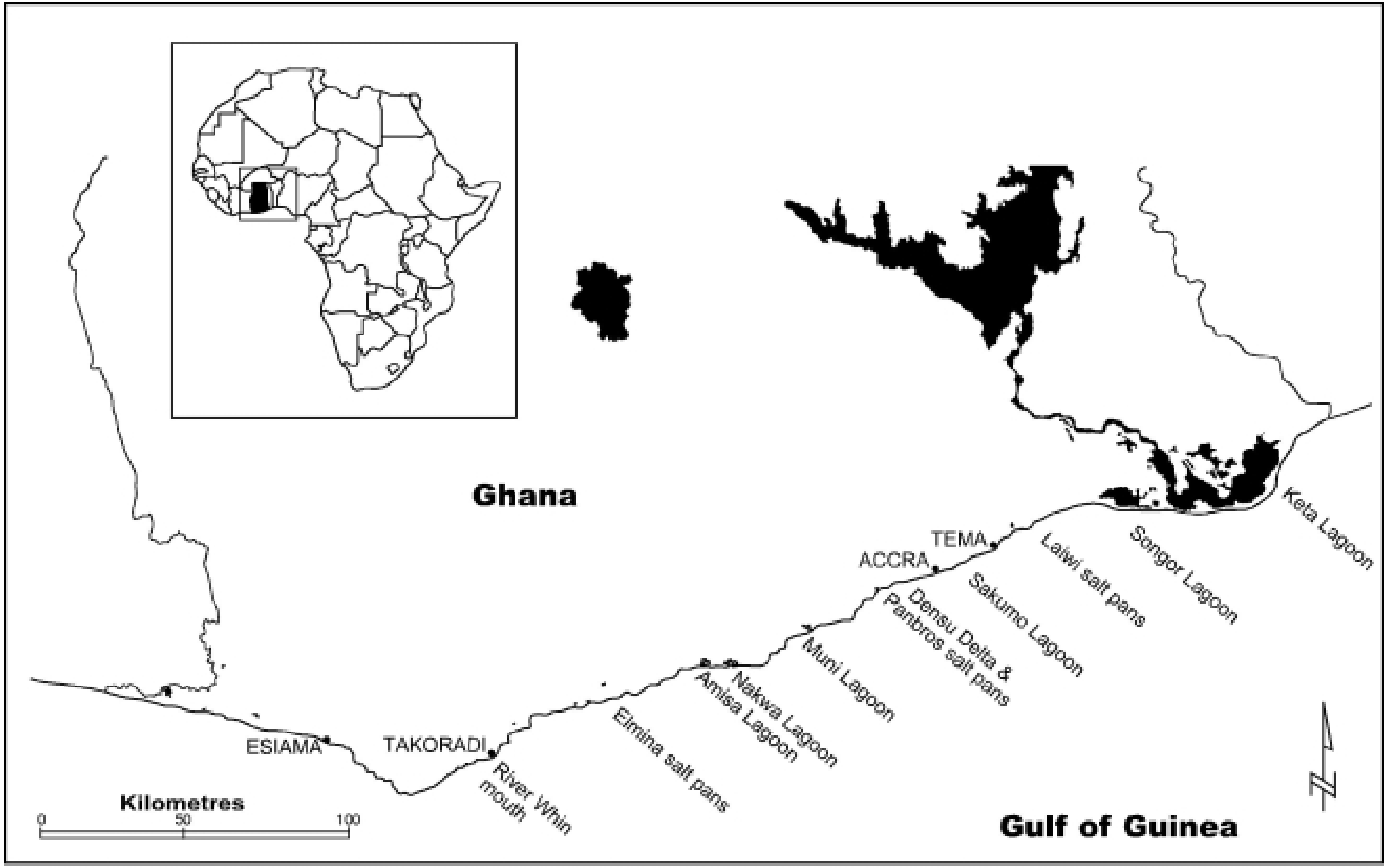


Figure 1 The Ghanaian coastline from Togo to Cote d'Ivoire in the Gulf of Guinea

In this report we provide a description of the ecological character of the Keta and Songor lagoons in the Lower Volta region of Ghana (figure 2) and present a framework for monitoring changes in their ecological character. It is anticipated that the long-term monitoring programs advocated will provide a more detailed temporal description of the ecological character of the lagoons. Keta and Songor lagoons are both internationally important wetlands designated as Ramsar sites on the basis of their total waterbird populations and the occurrence of internationally important numbers of several species (Ntiamoa-Baidu & Gordon 1991, Piersma & Ntiamoa-Baidu 1995, Ntiamoa-Baidu et al 1998). The lagoons and surrounding floodplains support large numbers of people through fishing, salt extraction, reed cutting and water supply. The information on the ecological character and monitoring of these lagoons is presented in line with the current concepts of the Ramsar Wetlands Convention for managing and monitoring wetlands. As such, this information also provides a basis to test the adequacy of the guidelines drawn up to interpret these international concepts.

1.1 Coastal wetlands management project

The Ghana Coastal Wetlands Management Project (CWMP) is implemented by the Ghana Wildlife Department as part of the Ghana Environmental Resource Management Project, funded by the Global Environmental Facility (GEF). The general aim of the CWMP was to manage five coastal wetland sites to maintain their ecological integrity and enhance the benefits derived from the wetlands by local communities.

1.1.1 Background

The genesis of the CWMP can be traced back to 1985, when the Government of Ghana entered into an agreement with BirdLife International (formerly the International Council for Bird Preservation) and the Royal Society for the Protection of Birds, to protect seashore birds, specifically the Roseate Tern (*Sterna dougalii*). To implement the agreement the Save the Seashore Bird Project–Ghana (SSBP-G) was set up to monitor bird populations along the coast of Ghana. The SSBP-G established the importance of several coastal wetlands for migratory shorebirds (Ntiamoa-Baidu 1988).

The information provided by the SSBP-G formed the basis for Ghana to become a signatory to the Ramsar Convention on Wetlands and the Bonn Convention on Migratory Species in 1988. During this same period Ghana was preparing an Environmental Action Plan, under the auspices of the then Environmental Protection Council. As part of the preparatory background documents a Coastal Zone Indicative Management Plan (CZIMP) was prepared (Agyepong et al 1990) which highlighted the need to protect some of the more important coastal sites. Subsequent to this local consultants were commissioned to prepare a base document (Ntiamoa-Baidu & Gordon 1991) for submission to the World Bank for GEF funding. The project was approved in 1992.

1.1.2 Scope

To achieve the overall goal the project set out to:

- develop a technical information base on the interactions between the biotic and abiotic elements of the wetlands
- describe the ecological character of five lagoons
- develop a monitoring framework as part of an overall management strategy for the long-term sustainable use of these lagoons.

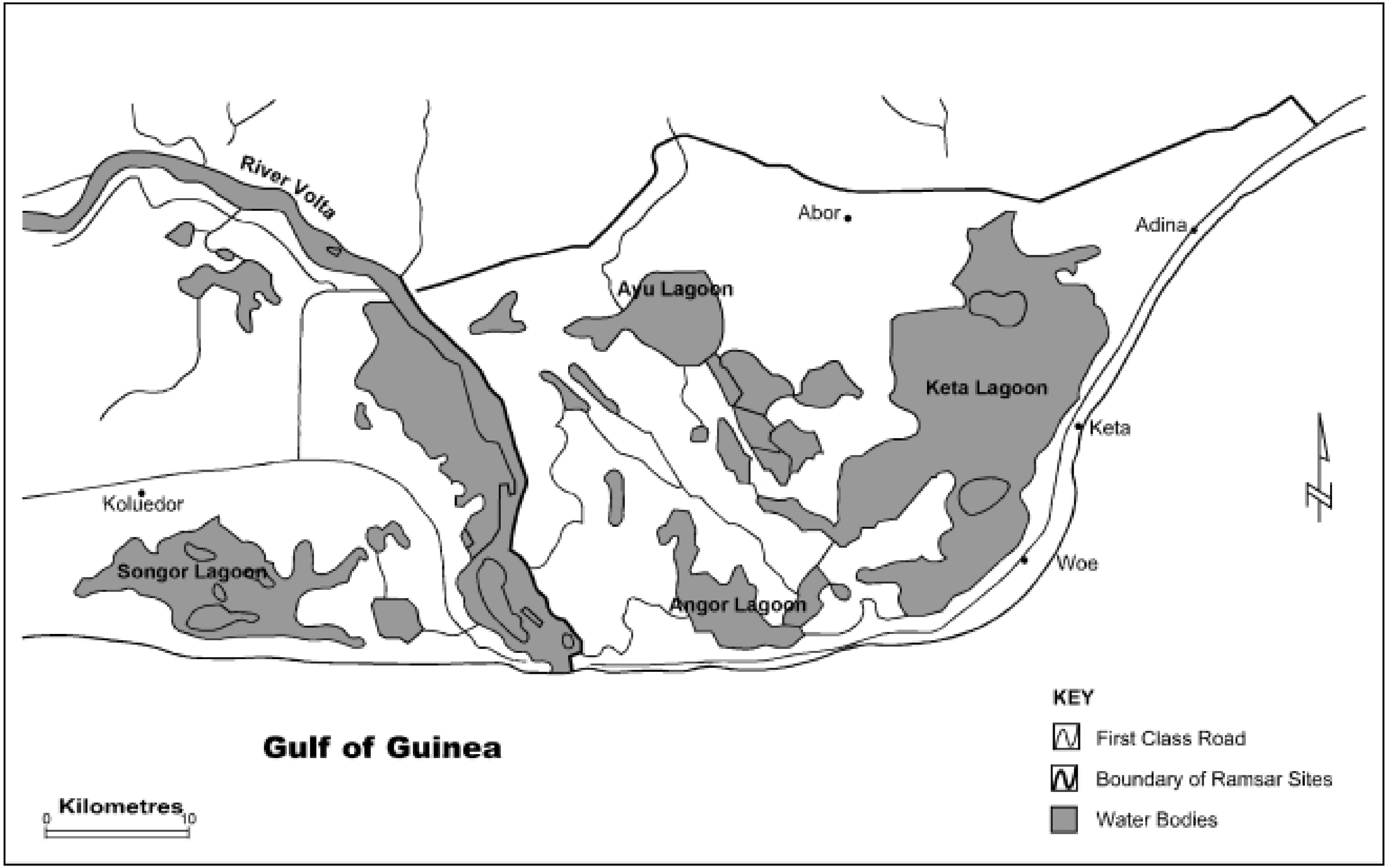


Figure 2 Schematic map of the general project area

Activities planned for the 5-year life span of the project included:

1 Management of the sites including the maintenance of boundaries and trail systems, monitoring of wildlife populations, habitat management, erosion control, tree planting, and training of community rangers/wardens in the principles of wildlife management and conservation.

2 Baseline studies for the current aquatic ecosystems and catchment areas and regular monitoring of key hydrological, limnological and biological indicators.

3 Socio-economic and technical studies of compatible development options on intensified fisheries management, development of aquaculture and salt production with the establishment of an investment fund to finance pilot schemes and infrastructure that will lead to the realisation of the identified options.

4 Environmental education and public awareness programs including the construction and staffing of community education facilities at each site.

5 Preparation of a National Wetlands Strategy to provide a policy framework for general wetland conservation in Ghana to address the conservation issues in wetland sites other than the five coastal Ramsar sites.

1.1.3 Specific objectives and terms of reference

Based on the broad goal given above the aquatic/wetland ecology components of the CWMP had the following specific objectives for the Keta and Songor lagoons in the lower Volta:

- collate available biophysical information and collect data to provide a basis for describing the ecological character of the lagoons, especially the hydrology, physico-chemistry, and the aquatic/wetland invertebrate fauna and the flora;
- identify the major values and benefits derived from the lagoons, especially those related to domestic water supply and the harvest of useful plants and animals;
- identify the major threats to the sustainable use of products harvested from the lagoons, especially those due to water pollution and hydrological regulation;
- establish reference collections of key aquatic/wetland species collected from the lagoons;
- provide training and develop the practical expertise of Ghana Wildlife Department staff;
- provide recommendations for further management of the lagoons, especially regulation of the water regime, to enhance the development of sustainable levels of resource exploitation;
- develop monitoring protocols to enable further description of the ecological character of the lagoons and to provide early warning of adverse ecological change;
- provide advice to the Convention on Wetlands of International Importance on the adequacy of guidelines for establishing and monitoring the ecological character of wetlands and for promoting wise use and management planning.

This study was preceded by an ornithological investigation (Piersma & Ntiamoa-Baidu 1995) and followed by specific investigations of the terrestrial fauna, as well as the fish and fisheries potential of the lagoons (Ryan & Ntiamoa-Baidu 1998). Further, the overall social context of the management and use of resources from the lagoons will be provided by a socio-economic study and the development of the national wetland policy, which will include an integrated monitoring program. Thus, the aquatic/wetland investigations described in this report are part of a larger holistic concept for the management of the major coastal lagoons of Ghana.

1.2 Information required for wetland management

Over the past few decades considerable effort has been directed worldwide towards the management of wetlands. Under the Ramsar Wetlands Convention this involved the promulgation of guidelines and the development and implementation of appropriate national policies for the wise use of wetlands.

The concept of wise use of wetlands was formulated in 1971 with an article in the Ramsar Convention that stated:

> The Contracting Parties shall formulate and implement their planning so as to promote … as far as possible the wise use of wetlands in their territory.

A definition of wise use, based on the concept of sustainable utilisation, was adopted in 1987 (Davis 1993, 1994). Thus, the wise use of wetlands is their sustainable utilisation for the benefit of humankind in a way compatible with the maintenance of the natural properties of the ecosystem. In turn, sustainable utilisation is the human use of a wetland so that it may yield the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

More recent attention to the maintenance of the ecological character of wetlands has highlighted that the wise use and management of wetlands is dependent on a large and holistic information base. According to Dugan (1990) and Finlayson (1996a) the information base required for wetland management has been sub-divided into the following subject categories: wetland classification; wetland inventory; ecological characterisation; wetland values and benefits; management planning; and monitoring. These categories are briefly considered within the context of the information base required for wetland management in Ghana.

1.2.1 Wetland classification

The classification of wetlands is beset with difficulties (Finlayson & van der Valk 1995a) and these seemingly multiply when a regional or an international approach is sought (Scott & Jones 1995). The purpose of wetland classification is to standardise and define the terms being used to describe various wetland types. At an international level a uniform set of terms is needed (Cowardin & Golet 1995, Scott & Jones 1995, Zoltai & Vitt 1995) but at a national level this may not be necessary (Pressey & Adam 1995).

Scott and Jones (1995) issued a warning concerning the level of sophistication required for classification in relation to the amount of information required for management. The important point in classifying wetlands is not the detail of the classification, but the usefulness of the classification for management purposes.

Many national wetland classifications now exist (see Finlayson & van der Valk 1995b). These invariably incorporate local terms and definitions that are not necessarily known or accepted elsewhere. Thus, even at the national level it can be extremely difficult to develop a classification that is consistent and acceptable to all wetland scientists and experts (Cowardin & Golet 1995, Lu 1995, Pressey & Adam 1995).

The wetland habitat classification used by the Ramsar Convention has increasingly been adopted for national and international purposes (Scott & Jones 1995). However, this contains many inconsistencies (Semeniuk & Semeniuk 1995, 1997), namely:

- not all types of wetlands are clearly or unambiguously described;
- repetition of types that are named ‘marshes;

- some wetlands remain ill-defined and encompass a number of types;
- mixed criteria are used to separate wetlands.

Due to the nature of the problem, and despite the deficiencies of the Ramsar classification scheme, Ghanaian wetlands can be fitted adequately into the existing Ramsar Classification scheme. The main advantage of this approach is that the terms used have international recognition and save time and effort in drawing up a National Classification scheme for Ghana.

1.2.2 Wetland inventory

Much of the information required for wetland management can be collected in a directory or inventory of wetlands. A directory and inventory are used to compile the same type of information, but the former is limited to current information and may not be comprehensive (Finlayson 1996a). An inventory usually includes investigative steps to obtain more information and thereby present a comprehensive coverage of sites. Thus, a directory may be the precursor of an inventory. In reality, the terms are used interchangeably.

The information collected through wetland inventories is regarded as a prerequisite for wetland conservation and management (Dugan 1990, Hollis et al 1992, Taylor et al 1995, Hughes 1995, Naranjo 1995, Scott & Jones 1995). Dugan (1990) considers an inventory as the first step in assembling an information base for wetland management. In fact, Contracting Parties to the Ramsar Convention undertake to compile an inventory as part of the process of developing and implementing a national wetland policy for the wise use of all wetlands on their territory. A strategically developed wetland inventory should provide managers and policy makers with the information base that they require not only to manage individual wetlands or threats, but to also place the conservation value of wetlands within the context of broad scale land use and sustainable development priorities.

To be effective in promoting the sustainable use and conservation of wetlands an inventory must be available to and understood by all those formulating and implementing wetland management policies (Naranjo 1995, Pressey & Adam 1995, Wilen & Bates 1995). Thus, they must be framed in a manner suitable for management purposes. Additionally, to remain useful tools for management they need to be regularly reviewed and updated (Naranjo 1995, Scott & Jones 1995, Wilen & Bates 1995). Information categories often used in wetland inventories are shown in table 1. Many of the categories do not relate directly to biophysical information, but are management oriented. Costa et al (1996) summarised the conclusions of a Mediterranean analysis of wetland inventory and the key points are given below as a guide to compiling a wetland inventory.

Objectives of a wetland inventory (Costa et al 1996)

To identify where wetlands are, and which are priority sites for conservation

To identify the functions and values of each wetland

To establish a baseline for measuring change in a wetland

To provide a tool for planning and management

Table 1 Information categories used by Hughes and Hughes (1992) and Scott (1993) in wetland directories

Category	**Information**
Hughes & Hughes 1992 – *A directory of African wetlands*	
Title/Location/Nearest town	Name of wetland/Coordinates/Name of town
Area/Altitude	Area/Height above sea level
General	Description of wetland and environs
Hydrology and Water quality	General features
Flora/Fauna	Important species and populations
Human impact and utilisation	Land uses and changes
Conservation status	Nature protection
Scott 1993 – *A directory of wetlands in Oceania*	
Title/Location	Name and reference number/Coordinates
Area/Altitude	Area and/or length of rivers/Average
Overview	Summary description of site
Physical/Ecological features	Hydrology, soils, climate, vegetation and habitats
Land tenure	Ownership of wetland and surrounding land
Conservation measures taken/proposed	Details of protected areas/Further proposals
Land use/Possible changes in land use	Human activities/Development plans and ideas
Disturbances and threats	Existing and possible threats
Hydrological-biophysical/Social-cultural values	Principal features/Values
Noteworthy fauna/flora	Important species
Scientific research/Conservation education	Major research/education activities and facilities
Management authority and jurisdiction	Responsible authority(ies)
References	Key published literature
Reasons for inclusion in Directory	Reason(s) designated as important

In order to achieve the objectives the following recommendations were made:

> ***Means of achieving the objectives of an inventory (Costa et al 1996)***
>
> Use standardised methods for classification, data collection and storage, delineation and mapping
>
> Incorporate qualitative and quantitative data to provide a baseline for monitoring wetland change and loss
>
> Facilitate analysis of loss of wetland functions
>
> Be regularly updated
>
> Be easily disseminated and made available to wetland managers, decision-makers and the general public.

For the above to be achieved careful planning and testing of techniques is required. A secure funding source is needed and all changes to protocols should be well documented and assessed. Critically, any limitations on the use of the information should be made apparent at the outset.

1.2.3 Ecological characterisation

An important obligation under the Ramsar Wetland Convention is for each Contracting Party to 'designate suitable wetlands within their territory for inclusion in a List of Wetlands of International Importance'. The Convention also states that wetlands should be listed according to their 'international significance in terms of ecology, botany, zoology, limnology or hydrology'. Whilst listing a site as internationally important is an important obligation under the Convention, it may not constitute anything more than a passive conservation step. Thus, the Convention also contains an obligation to '… formulate and implement their planning so as to promote the conservation of the wetlands included in the List' and inform the Ramsar Bureau '… if the ecological character of any wetland in their territory and included in the List has changed, is changing, or is likely to change as the result of technological developments, pollution or other human interference'.

A working definition of ecological character was agreed at the Ramsar Wetland Convention in 1996 based on material supplied by Dugan and Jones (1993) and Finlayson (1996b) and updated in 1999. This is given below:

> Ecological character is the sum of the biological, physical, and chemical components of the wetland ecosystem, and their interactions, which maintain the wetland and its products, functions, and attributes.

This definition provides a theoretical basis for describing the ecological character of a wetland, but does not assist with the practical issues of describing the character. Thus, there is a level of consensus on the concept of ecological character, but questions relating to the ecological meaning of change when it is detected have yet to be answered. Monitoring can provide the necessary information, but it does not necessarily provide the basis for interpreting the significance of change.

Within the context of the Ramsar Convention, change in ecological character was considered as meaning adverse change. This concept is captured in the definition of change in ecological character that was adopted from material provided by Dugan and Jones (1993) and Finlayson (1996b) and updated in 1999.

> Change in ecological character is the impairment or imbalance in any biological, physical, or chemical components of the wetland ecosystem, or in their interactions, which maintain the wetland and its products, functions and attributes.

However, even with this definition we are no closer to ascertaining what exactly constitutes an unacceptable ecological change. To define an unacceptable ecological change we need to firstly establish the values and benefits of the wetland, assess the ecological status of these and then monitor them to ascertain when (if) an adverse change is likely to or has actually occurred. Thus, there is broad agreement on the basic need to assess and describe the ecological character of a wetland, but further attention is required to assessing the significance of any change.

1.2.4 Wetland values and benefits

All wetlands provide values and benefits to people. Values and benefits are taken to include a range of wetland functions, products and attributes that have been previously defined within the Ramsar context (Dugan 1990, Davis 1993, 1994) as follows:

- *Functions* performed by wetlands include the following: water storage; storm protection and flood mitigation; shoreline stabilisation and erosion control; groundwater recharge; groundwater discharge; retention of nutrients, sediments and pollutants; and stabilisation of local climatic conditions, particularly rainfall and temperature. These functions are the result of the interactions between the biological, chemical and physical components of a wetland, such as soils, water, plants and animals.

- *Products* generated by wetlands include the following: wildlife resources; fisheries; forest resources; forage resources; agricultural resources; and water supply. These products are generated by the interactions between the biological, chemical and physical components of a wetland.
- *Attributes* of a wetland include the following: biological diversity; geomorphic features; and unique cultural and heritage features. These have value either because they induce certain uses or because they are valued themselves.

The combination of wetland functions, products and attributes gives the wetland benefits and values that make it important to society. The relative importance of these values and benefits varies between sites due both to the biophysical features of the wetland and the lifestyles of the people.

1.2.5 Management planning

> Wetlands are dynamic areas, open to influence from natural and human factors. In order to maintain their biological diversity and productivity and to allow wise use of their resources by human beings, some kind of agreement is needed between the various owners, occupiers and interested parties. The management planning process provides this overall agreement (Davis 1993).

Further, management planning is a flexible and dynamic way of thinking and contains three basic components: description of the site; evaluation of the main features of the wetland and expression of management objectives; and plans or prescriptions for specific actions. It is also recommended that the plan contain a preamble that broadly reflects the policies of organisations concerned with the production and implementation of the management plan. A summary of the main principles is given below.

Principles for management planning

It is a way of thinking, which involves recording, evaluating and planning and is subject to constant review and revision and is therefore flexible and dynamic.

It involves three basic steps of describing the features of the site/area, defining operational objectives and taking necessary management actions.

Preparation of an elaborate plan is not an excuse for inaction or delay.

Review of the plan may lead to revision of the site description and operational objectives.

It should be a technical, not a legal document, although it may be supported by appropriate legislation.

Finlayson (1996a) notes that the Ramsar guidelines sound simple, but adds that there are major pitfalls, such as making the plan too complicated, making the plan the goal rather than the tool, making the plan inflexible and not allocating resources to ensure that the plan can be implemented.

Underpinning the planning exercise is the establishment of a rationale for management and the setting of obtainable operational objectives. Monitoring is therefore essential. In other words, implementation of a management plan should proceed hand-in-hand with a process to ensure that the objectives of the plan are obtained or accordingly modified in response to new information (Finlayson 1994, 1996b).

1.2.6 Monitoring

Wetland monitoring has received more and more attention in recent years. At a global level this has arisen as awareness of the extent of wetland degradation and loss has increased. Such is the concern at the extent of global wetland degradation that more and more effort is being directed towards developing effective management processes and responses to problems. In many instances this effort is being held back by a lack of relevant information on the nature of the problem, the cause of the problem and the effectiveness of management procedures and actions. Effective monitoring programs can overcome these deficiencies.

In a general sense monitoring addresses the issue of change or lack of change through time and at particular places. Thus monitoring can be defined as the systematic collection of data or information over time. It differs from surveillance by assuming that there is a specific reason for collecting the data or information (see Spellerberg 1991, Hellawell 1991, Furness et al 1994). Thus, whilst it is built upon survey and surveillance, it is more precise and oriented to specific targets or goals (Hellawell 1991, Spellerberg 1991).

> ***Definitions of survey, surveillance and monitoring***
>
> *Survey* is an exercise in which a set of qualitative observations are made but without any preconception of what the findings ought to be.
>
> *Surveillance* is a time series of surveys to ascertain the extent of variability and/or range of values for particular parameters.
>
> *Monitoring* is based on surveillance and is the systematic collection of data or information over time in order to ascertain the extent of compliance with a predetermined standard or position.

A framework for assisting with the design of a monitoring program has been presented by Finlayson (1996b,c). The framework applies to all forms of monitoring (eg changes in the area of a wetland, the ecological health of a wetland, or the underlying reasons behind the loss of wetlands) but it is not prescriptive. Rather, it presents a series of steps that will assist those charged with designing a monitoring program make decisions suitable for their own situation.

In a general sense, monitoring is needed to prevent further unchecked exploitation and degradation of wetlands. Thus, there is a need to assess the impact of human development and minimise ecological change. Success in such programs will depend on our ability not only to detect and monitor changes in the quality of wetlands, but also to provide early indications of likely change and thereby take action to prevent this change from occurring. Thus, with all monitoring techniques there is a need to establish a starting point or to obtain baseline data that identifies the key functions and values of the site.

2 Coastal lagoons in Ghana

2.1 Description of lagoons

Simplistically the lagoons of Ghana can be classified into two types: the open lagoons that are associated with large rivers and have a permanent connection to the sea and the closed lagoons that are formed behind sandbars, with no permanent connection to the sea (Boughey 1957, Kwei 1977, Mensah 1979, Gordon 1987). In ecological terms, open lagoon systems are more stable and faunistically diverse due to the influence of the sea. The closed lagoons are functionally more unpredictable, with conditions changing very rapidly from one point in time to another. These lagoons are usually saline and can be further described as follows:

Open: with one or more narrow opening(s) to the sea most of the time and therefore known as classical open lagoon, eg Nakwa, Amisa and Nyanya lagoons. In Ghana, the mouths of some lagoons have been made permanently open through the intervention of humans for the purposes of road/harbour construction, eg Sakumo II and Benya lagoons at Tema and Elmina respectively.

Closed: cut off from the sea by a sandbar during greater part of the year. The bar may be breached naturally or by humans during the Rainy season. These are classical closed lagoons, eg Sakumo I and Muni lagoons at Bortianor and Winneba respectively. Some closed lagoons receive seawater overflows during spring tides. These are called spring tide-fed closed lagoons, eg Bormis lagoon at Moree.

The functions of lagoons include sediment/toxicant retention, nutrient retention, biomass export, water transport and recreation/tourism. Wildlife resources and fisheries are the main products, but freshwater (isolated) lagoons provide water supply for domestic purposes. The lagoonal attributes are biological diversity and uniqueness to culture/heritage.

In addition to the brackish water lagoons, Ghana has several coastal freshwater lagoons, these coastal freshwater lagoons are found mainly in the Western Region where rainfall in excess of 2000 mm per annum produces conditions of high runoff and stream flow. The underlying rocks in these areas have also undergone profound leaching giving rise to waters, which are extremely ion poor. Typically these lagoons are open to the sea either directly or by a channel. They are also fairly small – the largest of this type, the Amansuri lagoon, is about 2.5 km^2 in area. Other examples include the Domini and Ekpuekyi lagoons, both of which are under 1.0 km^2. As with the brackish and saline lagoons, the functions of lagoons include sediment/toxicant retention, nutrient retention, biomass export, water transport and recreation/tourism. Wildlife resources and fisheries are the main products. These freshwater lagoons also provide water supply for domestic purposes. The lagoonal attributes are biological diversity and uniqueness to culture/heritage.

The actual number of coastal lagoons in Ghana is not precisely known. Published estimates range from 50 (Mensah 1979, Gordon 1987) to over 90 (Gordon 1996, Yankson & Obodai in press). The lack of precision is partly due to the ephemeral nature of many of the smaller lagoons which require rainfall to create a freshwater lagoon habitat behind a sandbar; these sandbars then break to allow sea water to penetrate. Dry conditions result in re-creation of the sandbar, and loss of water by evaporation causes the lagoon to dry up. The smaller lagoons of areas under 0.1 km^2, and maximum water depths of under 1 m, can go through this cycle in a matter of months.

2.2 Management approaches

The management of the coastal lagoons has traditionally been vested in the 'owners' of the lagoon. These are usually local clans, fetishes or stools. Traditional knowledge or culture is the way in which Ghanaian ethnic groups use traditional values and knowledge, structured within specific organisational frameworks, towards solving particular issues and tasks (World Bank 1996). The organisational framework of these societies is the kinship system, or more specifically families, lineages and clans. On the various levels of this framework, specific rights and obligations, dealing with issues like authority, control, adjudication of conflicts, inheritance, succession and land ownership are vested in the members. At each of the organisational levels within the framework, there will be a chief, usually hereditary in lineage, who functions as a custodian or caretaker. Many of the traditional management strategies were geared at controlling resource use by placing limits on access, both spatially and temporally, through the use of taboos and outright bans. For many years, this traditional approach has been sufficient to maintain the ecological integrity of the lagoon environment (Gordon 1992, Ntiamoa-Baidu 1992). Unfortunately, education, religion and acculturation have resulted in the breakdown of traditional management systems. Many of the areas, operate under 'common property' laws. With rising economic pressures, these areas are being exploited unsustainably with local fines and punishments being ignored or disregarded.

The modern system for natural resource management in Ghana follows a three tier approach (Government of Ghana 1995 [Vision 2020]). The three tiers are the district, regional and national levels. Planning and management is heavily predicated on:

- decentralisation of political and state power in order to enhance participatory democracy through local level political institutions with the District Assembly as the focal point;
- decentralisation of administration, development planning, implementation and budget making in which local authorities are actively involved.

One key institution is the District Environmental Management Committee, which has representation from the decentralised departments, such as Fisheries, Forestry and Wildlife. For coastal wetlands, in particular the five Ramsar sites, Muni-Pomadze, Densu Delta, Sakumo, Songor and Keta all have site management committees with representation from primary stakeholders.

The site management committees comprise the Senior Technical Adviser (as Chairman), a Representative of the Environment Protection Council (as Secretary), the Coastal Wetlands Conservation Programme Coordinator, the Game Warden in charge of the site and representatives of appropriate institutions. From the conception of the CWMP (Ntiamoa-Baidu & Gordon 1991), it was emphasised that the successful management of the coastal wetlands would require a multi-disciplinary approach. The Department of Wildlife was therefore to seek the expertise and involvement of relevant organisations for the execution of programs. Another identified crucial factor for the success of the coastal wetland conservation program was the support and involvement of the communities who live in the coastal zone. These are the people whose lifestyles are interlinked with the coastal wetlands and whose activities directly affect the wetland ecosystem. Protection of the wetlands should therefore be 'for' the people and not 'against' them. Every effort has been made to secure the people's participation and involvement; and to integrate their needs with the management processes. Apart from the general community, groups whose involvement was to be specifically sought include the traditional administrators (Chiefs, elders, etc), the town development committees, local political groups such as the District Assemblies, and NGOs such as the 31st December Women's Movement.

3 Ecological surveys of Keta and Songor lagoons

3.1 Sampling strategy

Sampling of each lagoon and the surrounding wetland vegetation was based on a stratified grid drawn at intervals of 1' latitude and longitude (ie ≈ 1.8 x 1.8 km). The points of intersection of the grid were used as the basis for selecting sites for sampling. These points were coded according to the name of the lagoon (K = Keta, S = Songor) and with an alphabetic code for the northing and numeric code for the easting (ie 'KQ15' was located at Keta lagoon at the intersection of the northing or horizontal grid line labeled 'Q' and the easting or vertical grid line labelled '15'). Samples were also collected from the Angor channel that connects the Keta lagoon with the Volta River. These were labelled C1–C12 and located where the sampling grid crossed the channel. The coordinates for each site were taken from 1:50 000 Ghana topographical maps (sheets 0600D4, 0500B2, E0601C3 & E0501A1 for Keta and 0500A2 and 0500B1 for Songor) that were based on aerial photography flown in December 1974.

The sampling grid is shown in figures 3 and 4. A list of site codes and coordinates read from the maps are given in tables 2 to 7. In the field the sites were located with a hand-held Global Positioning System (GPS) recorder (Garmin GPS 38 or 45) with an accuracy of about 100 m. The aquatic sampling sites were located within 300 m of the map coordinate whereas those in the channel were located by GPS and recorded as such. As access to some of the vegetation sites was far more difficult (see below), a GPS reading was taken at the actual point sampled. The GPS readings for each site are shown in tables 2 to 7.

The sampling strategy was divided into two components – one aquatic and the other wetland/terrestrial. All intersecting grid points within the lagoons were used for aquatic sampling (ie physico-chemical and biological parameters). These sites were reached initially by wading and/or hiring wooden canoes poled by local fishermen. An aluminium dinghy with an outboard motor (15 hp) was later used in Keta lagoon and greatly reduced the time and effort spent getting to sites in deeper water.

The wetland sampling was initially undertaken from the landward side of the lagoons and was severely limited by access through extensive stands of reeds (up to 4 m in height) and grasses in water reaching more than 1.5 m depth. Sampling was based on a series of grid points located along the landward side of the lagoon shorelines. The number of sample sites at Keta lagoon was initially limited by logistical issues (ie access and sample processing times) and a subjective choice of sites was made around the perimeter (see table 2). When a boat and outboard motor became available all grid points within 2 km (approx) of the lagoon were visited from either the land or the water side. Once the initial sampling near the edge of the lagoons was completed, sites for phenological sampling in the extensive swamps stretching east of Songor and west of Keta towards the Volta delta, and as far north as Sogakope were added. Sampling was also conducted in the Angor channel from Keta lagoon to the Volta River with vegetation phenological sampling conducted along the grid given in figure 3. The sampling coordinates recorded at these sites are presented in appendix 6.

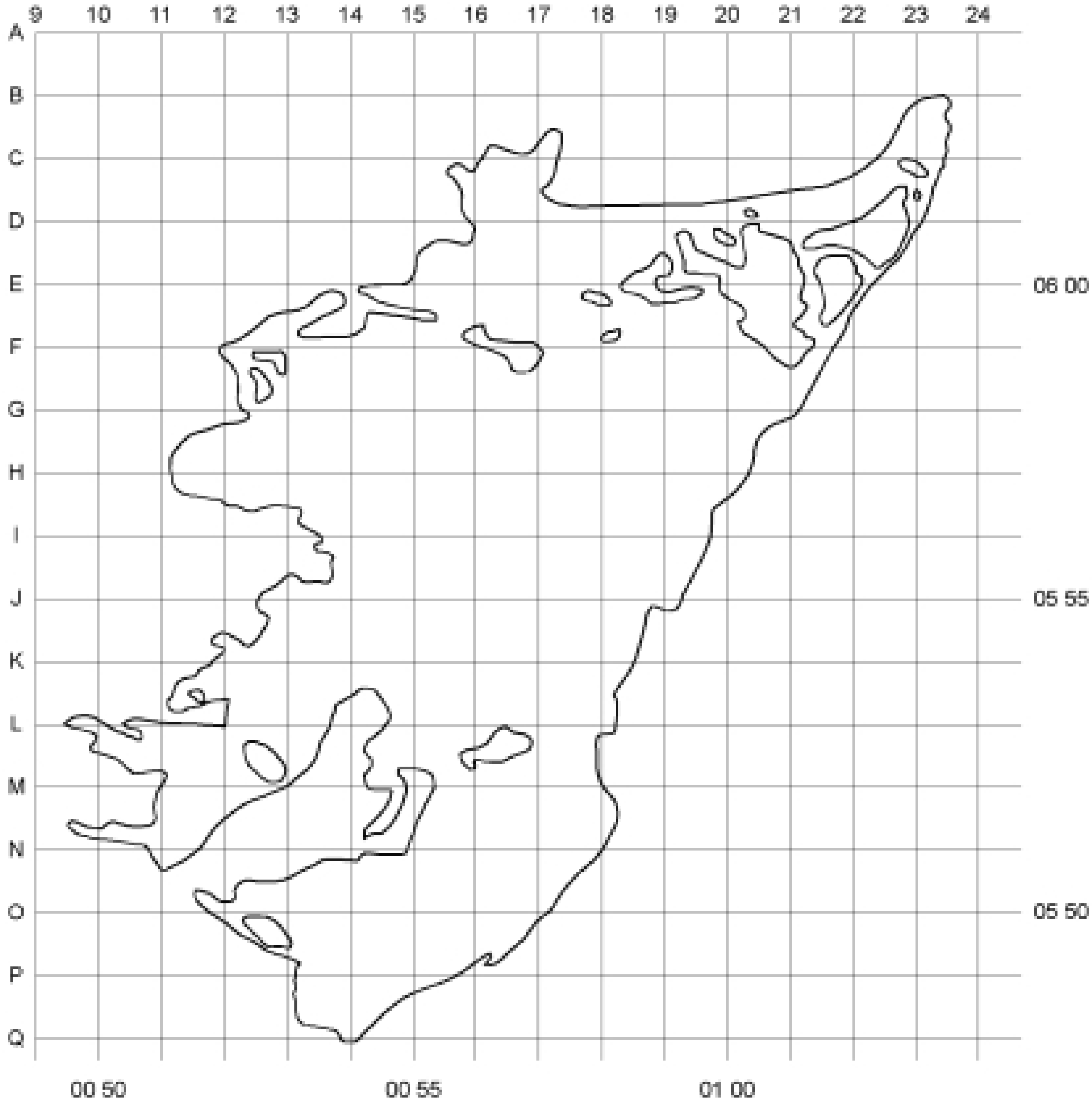


Figure 3 Sampling grid for the Keta Ramsar site

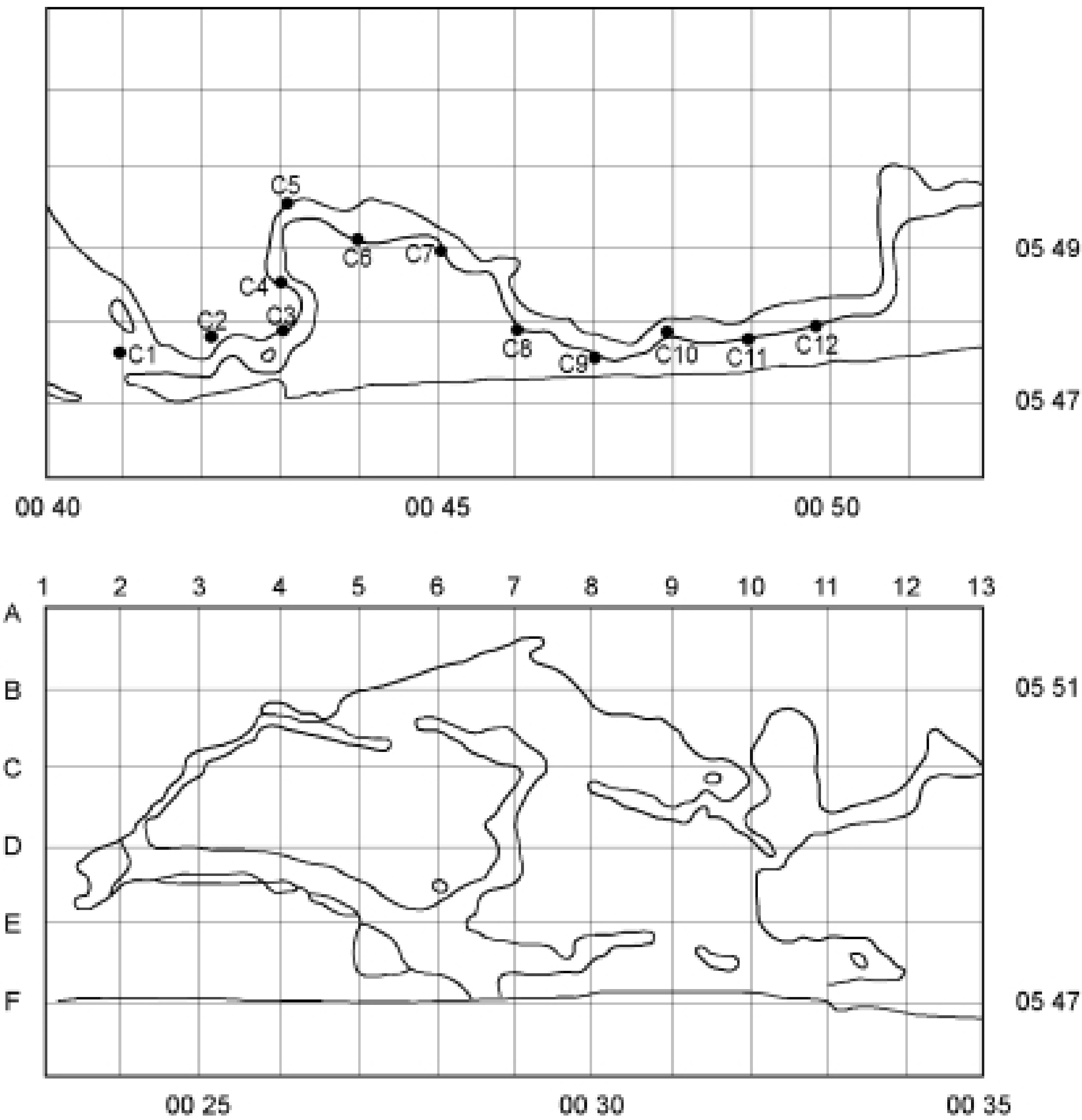


Figure 4 Sampling grid for (top) the Angor channel that connects Keta lagoon to the Volta River and (bottom) the Songor Ramsar site

Table 2 Sites used for wetland vegetation sampling at Keta lagoon

Site code*	Coordinates		Date	Field coordinates		Vegetation sampling	
	N	E		N	E	Phenology	Biomass
KB17	06 03	00 57	16/11	06 03.4	00 56.9	P	
KB23	06 03	01 03	16/11	06 02.9	01 03.0	P	
KC16	06 02	00 56	16/11	06 02	00 55.8	P	B
KC18	06 02	00 58	16/11	06 01.8	00 58.0	P	B
KC20	06 02	01 00	16/11	06 01.4	01 00.0	P	
KC22	06 02	01 02	16/11	06 01.7	01 02.1	P	B
KC23*	06 02	01 03	28/11	06 02.0	01 03.0	P	
KC24	06 02	01 04	16/11	06 02	01 04.0	P	B
KD15	06 01	00 55	16/11	06 00.9	00 55.0	P	
KD22*	06 01	01 03	28/11	06 01.0	01 03.0	P	
KD23	06 01	01 03	16/11	06 00.1	01 02.9	P	
KE14	06 00	00 54	17/11	05 59 8	00 53.9	P	B
KE15*	06 00	00 55	28/11	06 00.2	00 54.9	P	
KE19*	06 00	00 59	28/11	06 00.0	00 59.0	P	
KE20	06 00	01 00	19/11	06 00.0	01 00.0	P	B
KE21	06 00	01 01	19/11	06 00.0	01 01.0	P	
KE22*	06 00	01 02	27/11	06 00.0	01 02.0	P	
KF11	05 59	00 51	17/11	05 59.1	00 51.7	P	
KF16*	05 59	00 56	28/11	05 59.1	00 56.0	P	
KF21	05 59	01 00	19/11	05 59.0	01 00.0	P	
KF22	05 59	01 02	16/11	05 59.1	01 01.7	P	B
KG01*	05 58	00 41	9/12	05 58.1	00 41.0	P	
KG09*	05 58	00 49	6/12	05 59.0	00 49.0	P	
KG12	05 58	00 52	21/11	05 57.9	00 52.0	P	B
KHO8*	05 57	00 47	6/12	05 57.1	00 47.0	P	
KH11	05 59	00 51	17/11	05 57.2	00 51.0	P	
KI 01*	05 56	00 41	9/12	05 56.1	00 41.0	P	
KI09*	05 56	00 49	6/12	05 56.0	00 49.0	P	
KI11*	05 45	00 50.9	6/12	05 56.0	00 50.9	P	
KI12	05 56	00 52	21/11	05 56.6	00 52.1	P	
KI13*	05 56	00 52	21/11	05 56.4	00 52.9	P	
KJ02*	05 55	00 42	9/12	05 55.1	00 42.2	P	
KJ12	05 55	00 52	21/11	05 54.5	00 52.6	P	
KK03*	05 54	00 42	9/12	05 54.0	00 42.0	P	
KK11	05 54	00 51	19/11	05 54.1	00 51.0	P	B

Site code*	Coordinates		Date	Field coordinates		Vegetation sampling	
	N	E		N	E	Phenology	Biomass
KK12*	05 54	00 51	21/11	05 53.9	00 51.0	P	
KK19	05 54	00 59	19/11	05 54.0	00 59.0	P	
KL04*	05 53	00 44	9/12	05 53.1	00 44.0	P	
KL10	05 53	00 50	18/11	05 53.0	00 50.1	P	
KL11*	05 53	00 51	21/11	05 53.0	00 51.0	P	
KL12*	05 53	00 52	19/11	05 53.0	00 52.0	P	
KL14	05 53	00 54	15/11	05 53	00 54.0	P	
KM07*	05 52	00 47	28/11	05 52.0	00 47.0	P	
KM10	05 52	00 50	18/11	05 52.0	00 49.9	P	B
KM11*	05 53	00 51	20/11	05 53.1	00 50.9	P	
KM13	05 52	00 53	15/11	05 52	0053.0	P	B
KM15*	05 52	00 55	20/11	05 52.1	00 55.0	P	B
KM18	05 52	00 58	19/11	05 52.0	00 58.0	P	B
KN06*	05 51	00 46	28/11	05 51.0	00 46.0	P	
KN08*	05 51	00 47	28/11	05 51.0	00 47.9	P	
KN12	05 51	00 52	15/11	05 51.2	00 51.9	P	
KO07*	05 50	00 47	28/11	05 50.0	00 47.0	P	
KO09*	05 50	00 49	28/11	05 50.0	00 49.0	P	
KO11	05 50	00 51	15/11	05 50.1	00 51.0	P	B
KO12*	05 50	00 52	20/11	05 50.0	00 52.0	P	
KO17	05 50	00 57	20/11	05 49.9	00.57.1	P	
KP08*	05 49	00 48	15/11	05 49.0	00 48.1	P	B
KP10	05 49	00 50	15/11	05 50.0	00 49.8	P	
KP12	05 49	00 52	20/11	05 49.3	00 52.2	P	
KP13*	05 49	00 53	20/11	05 49.0	00.52.0	P	
KP16	05 49	00 56	20/11	05 49.0	00 56.1	P	B
KQ03*	05 48	00 42	5/12	05 48.0	00 42.9	P	
KQ05*	05 48	00 45	5/12	05 48.0	00 45.0	P	
KQ09	05 48	00 49	15/11	05 48	00 48.8	P	B
KQ11	05 48	00 51	15/11	05 47.3	00 51.0	P	
KQ13	05 48	00 53	14/11	05 47.5	00 53.1	P	B
KQ15*	05 48	00 55	9/12	05 48.2	00 55.0	P	
KR02*	05 47	00 42	5/12	05 47.2	00 42.0	P	
KR06*	05 47	00 46	5/12	05 47.0	00 46.0	P	
KR08*	05 46	00 48	5/12	05 46.8	00 48.0	P	
KR10*	05 47	00 50	28/11	05 47.0	00 50.0	P	

The coordinates for each site were read from the Ghana 1:50 000 topographical maps and positioned in the field with hand-held GPS recorders.

The sampling undertaken at each site is indicated (P = phenological sampling; B = biomass sampling) along with the date (day/month) they were collected.

* Sites not included in the initial survey and subsequently added for further phenological recordings.

Table 3 Sites used for wetland vegetation sampling at Songor lagoon

Site code	Map coordinates		Date	Field coordinates		Vegetation sampling	
	N	E		N	E	Phenology	Biomass
SA13*	00 51	00 34	26/11	00 51.7	00 34.0	P	
SB04	05 51	00 25	22/11	5 51.0	00 25.0	P	
SB05	05 51	00 26	22/11	5 51.0	00 26.1	P	B
SB06	05 51	00 27	22/11	05 51.3	00 27.1	P	
SB07	05 51	00 28	22/11	05 51.1	00 28.0	P	
SB08	05 51	00 29	22/11	05 51.0	00 29.1	P	
SB09	05 51	00 30	22/11	05 51.0	00 30.0	P	B
SB10	05 51	00 31	22/11	05 50.9	00 31.0	P	
SB11*	05 51	00 32	25/11	05 50.9	00 32.0	P	
SB12*	05 51	00 33	25/11	05 50.9	00 33.0	P	
SB13*	05 51	00 34	26/11	05 50.0	00 34.0	P	
SB14*	05 51	00 35	26/11	05 51.0	00 35.0	P	
SC03	05 50	00 24	22/11	05 58.1	00 24.1	P	B
SCO5*	05 50	00 26	26/11	05 50.1	00 26.0	P	
SC11*	05 50	00 32	25/11	05 50.1	00 32.0	P	
SC12*	05 50	00 33	25/11	05 50.0	00 33.0	P	
SC13*	05 50	00 34	26/11	05 49.9	00 33.9	P	
SC14*	05 50	00 35	26/11	05 50.1	00 34.9	P	
SD01	05 49	00 22	23/11	05 49.0	00 22.0	P	
SD09*	05 49	00 30	26/11	05 49.1	00 3.1	P	
SD10*	05 49	00 31	26/11	05 49.0	00 31	P	
SD11*	05 49	00 32	25/11	05 49.0	00 32.0	P	
SD12*	05 49	00 33	25/11	05 49.1	00 32.9	P	
SD13*	05 49	00 34	26/11	05 48.9	00 34.0	P	
SD14*	05 49	00 35	26/11	05 48.6	00 34.9	P	
SE01	05 48	00 22	23/11	05 48.0	00 22.1	P	
SE02	05 48	00 23	23/11	05 48.3	00 23.1	P	
SE05	05 48	00 26	23/11	05 48.0	00 26.1	P	B
SE06	05 48	00 27	23/11	05 48.0	00 27.0	P	
SE10*	05 48	00 31	25/11	05 48.1	00 31.0	P	
SE11*	05 48	00 32	25/11	05 47.9	00 32.0	P	
SE12*	05 48	00 33	25/11	05 48.0	00 33.0	P	
SE13*	05 48	00 34	26/11	05 48.0	00 33.9	P	
SE13*	05 48	00 35	26/11	05 48.0	00 34.9	P	
SE15*	05 48	00 36	26/11	05 48.0	00 46.0	P	
SE16	05 48	00 37	24/11	05 48.0	00 37.0	P	

Site code	Map coordinates		Date	Field coordinates		Vegetation sampling	
	N	E		N	E	Phenology	Biomass
SF08	05 47	00 29	24/11	05 47.26	00 28.9	P	
SF09	05 47	00 30	24/11	05 47.1	00 29.9	P	
SF10	05 47	00 31	24/11	05 47.16	00 31.0	P	
SF11	05 47	00 32	24/11	05 47.0	00 31.9	P	
SF12	05 47	00 33	24/11	05 47.0	00 33.0	P	
SF13	05 47	00 34	24/11	05 47.1	00 34.1	P	
SF14	05 47	00 35	24/11	05 47.1	00 35.1	P	
SF15	05 47	00 36	24/11	05 47.2	00 36.1	P	
SF16	05 47	00 37	24/11	05 47.2	00 37.0	P	

The coordinates for each site were read from the Ghana 1:50 000 topographical maps and positioned in the field with hand-held GPS recorders.

The sampling undertaken at each site is indicated (P = phenological sampling; B = biomass sampling) along with the date (day/month) they were collected.

* Sites not included in the initial survey and subsequently added for further phenological recordings.

Table 4 Location of transects used for wetland vegetation point and block sampling

Code	Name	Date	Field coordinates		Bearing
			N	E	
1	Blekusu	20/12/96	05 58 59.9	01 01 43.0	300º
2	Tasikome	20/12/96	06 01 47.3	01 02 00.5	170º
3	Tegbi	21/12/96	05 51.59.7	00 57 58.2	250º
4	Fiahor	21/12/96	05 50 48.0	00 53 57.0	150º
5	Alakple	21/12/96	05 51 58.6	00 53 00.7	320º
6	Norlopi	21/12/96	06 01 40.9	00 55 49.0	80º
7	Woe	22/12/96	05 48 51.5	00 56 00.1	10º
8	Totokpoe	22/12/96	05 47 05.5	00 31 00.9	19º
9	Wasakuse	22/12/96	05 51 15.9	00 34 01.4	190º

Table 5 Keta aquatic sampling

Site code	Map coordinates		Date	Field coordinates		Parameter			
	N	E		N	E	C	M	F	S
KC17	06 02	00 57	18/11	06 02	00 57	x	x	x	
KD17	06 01	00 57	18/11	06 01	00 57	x		x	
KD18	06 01	00 58	18/11	06 01	00 58	x		x	
KD19	06 01	00 59	16/11	06 01	00 59	x	x	x	
KD20	06 01	01 00	16/11	06 01	01 00	x		x	x
KD21	06 01	01 01	16/11	06 01	01 01	x	x	x	
KD22	06 01	01 02	18/11	06 01	01 02	x		x	
KE15	06 00	00 55	18/11	06 00	00 55	x	x	x	

Site code	Map coordinates		Date	Field coordinates		Parameter			
	N	E		N	E	C	M	F	S
KE16	06 00	00 56	18/11	06 00	00 56	x		x	
KE17	06 00	00 57	18/11	06 00	00 57	x	x	x	
KE18	06 00	00 58	23/11	06 00	00 58	x		x	
KF13	05 59	00 53	22/11	05 59	00 53	x		x	x
KF14	05 59	00 54	22/11	05 59	00 54	x		x	
KF15	05 59	00 55	18/11	05 59	00 55	x	x	x	
KF18	05 59	00 58	22/11	05 59	00 58	x		x	
KF19	05 59	00 59	23/11	05 59	00 59	x		x	
KF20	05 59	01 00	23/11	05 59	01 00	x		x	
KG13	05 58	00 53	22/11	05 58	00 53	x		x	x
KG14	05 58	00 54	22/11	05 58	00 54	x		x	x
KG15	05 58	00 55	22/11	05 58	00 55	x		x	
KG16	05 58	00 56	22/11	05 58	00 56	x		x	
KG17	05 58	00 57	19/11	05 58	00 57	x		x	x
KG18	05 58	00 58	19/11	05 58	00 58	x	x	x	x
KG19	05 58	00 59	22/11	05 58	00 59	x		x	
KG20	05 58	01 00	17/11	05 58	01 00	x	x	x	
KG21	05 58	01 01	16/11	05 58	01 01	x		x	
KH12	05 57	00 52	22/11	05 57	00 52	x		x	x
KH13	05 57	00 53	22/11	05 57	00 53	x		x	x
KH14	05 57	00 54	22/11	05 57	00 54	x		x	
KH15	05 57	00 55	22/11	05 57	00 55	x		x	
KH16	05 57	00 56	21/11	05 57	00 56	x		x	x
KH17	05 57	00 57	19/11	05 57	00 57	x	x	x	
KH18	05 57	00 58	19/11	05 57	00 58	x		x	
KH19	05 57	00 59	21/11	05 57	00 59	x		x	x
KH20	05 57	01 00	17/11	05 57	01 00	x		x	
KI14	05 56	00 54	21/11	05 56	00 54	x		x	
KI15	05 56	00 55	21/11	05 56	00 55	x		x	x
KI16	05 56	00 56	21/11	05 56	00 56	x		x	x
KI17	05 56	00 57	19/11	05 56	00 57	x		x	
KI18	05 56	00 58	19/11	05 56	00 58	x	x	x	x
KI19	05 56	00 59	21/11	05 56	00 59	x		x	
KJ13	05 55	00 53	21/11	05 55	00 53	x		x	x
KJ14	05 55	00 54	21/11	05 55	00 54	x		x	
KJ15	05 55	00 55	21/11	05 55	00 55	x		x	x
KJ16	05 55	00 56	21/11	05 55	00 56	x		x	x
KJ17	05 55	00 57	19/11	05 55	00 57	x	x	x	x

Site code	Map coordinates		Date	Field coordinates		Parameter			
	N	E		N	E	C	M	F	S
KJ18	05 55	00 58	17/11	05 55	00 58	x		x	
KJ19	05 55	00 59	17/11	05 55	00 59	x		x	x
KK12	05 54	00 52	21/11	05 54	00 52	x	x	x	x
KK13	05 54	00 53	21/11	05 54	00 53	x		x	
KK14	05 54	00 54	21/11	05 54	00 54	x		x	x
KK15	05 54	00 55	21/11	05 54	00 55	x		x	
KK16	05 54	00 56	21/11	05 54	00 56	x		x	
KK17	05 54	00 57	19/11	05 54	00 57	x	x	x	
KK18	05 54	00 58	17/11	05 54	00 58	x		x	
KL13	05 53	00 53	15/11	05 53	00 53	x		x	x
KL15	05 53	00 55	20/11	05 53	00 55	x		x	x
KL16	05 53	00 56	20/11	05 53	00 56	x		x	x
KL17	05 53	00 57	19/11	05 53	00 57	x		x	
KL18	05 53	00 58	16/11	05 53	00 58	x		x	
KM12	05 52	00 52	15/11	05 52	00 52	x		x	
KM16	05 52	00 56	20/11	05 52	00 56	x		x	x
KM17	05 52	00 57	19/11	05 52	00 57	x	x	x	x
KN11	05 51	00 51	15/11	05 51	00 51	x	x	x	
KN15	05 51	00 55	20/11	05 51	00 55	x		x	x
KN16	05 51	00 56	18/11	05 51	00 56	x		x	
KN17	05 51	00 57	19/11	05 51	00 57	x	x	x	
KO13	05 50	00 53	20/11	05 50	00 53	x		x	x
KO15	05 50	00 55	20/11	05 50	00 55	x		x	
KO16	05 50	00 56	20/11	05 50	00 56	x		x	x
KO17	05 50	00 57	14/11	05 50	00 57	x		x	
KP3	05 49	00 43	5/12	05 48 36.4	00 43 07.3	x		x	
KP4	05 49	00 44	5/12	05 48 11.4	00 44 01.6	x		x	
KP13	05 49	00 53	23/11	05 49	00 53	x		x	
KP14	05 49	00 54	20/11	05 49	00 54	x		x	
KP15	05 49	00 55	20/11	05 49	00 55	x		x	x
KP16	05 49	00 56	20/11	05 49	00 56	x		x	x
KQ3	05 48	00 43	5/12	05 47 36.5	00 42 59.7	x		x	
KQ5	05 48	00 45	5/12	05 47 57.2	00 45 02.4	x		x	
KQ10	05 48	00 50	20/11	05 48	00 50	x		x	
KQ11	05 48	00 51	20/11	05 48	00 51	x		x	
KQ12	05 48	00 52	20/11	05 48	00 52	x		x	
KQ14	05 48	00 54	23/11	05 48	00 54	x		x	x
KR1	05 47	00 41	5/12	05 46 42.5	00 40 58.6	x		x	

Site code	Map coordinates		Date	Field coordinates		Parameter			
	N	E		N	E	C	M	F	S
KR2	05 47	00 42	5/12	05 46 52.7	00 42 14.7	x		x	
KR3	05 47	00 43	5/12	05 46 56	00 43 02.5	x		x	
KR6	05 47	00 46	5/12	05 46 56.1	00 46 02.4	x		x	
KR7	05 47	00 47	5/12	05 46 36.0	00 47 00.9	x		x	
KR8	05 47	00 48	5/12	00 46.53.0	00 48 00.4	x		x	
KR9	05 47	00 49	15/11	05 46 44.9	00 49.4	x		x	x
KR10	05 47	00 50	15/11	05 47	00 50	x		x	

The coordinates for each site were read from the Ghana 1:50 000 topographical maps and positioned in the field with hand-held GPS recorders.

The sampling undertaken at each site is indicated (C = water chemistry; M = metals and nutrients; F = fauna [benthos and zooplankton]; S = sediment) along with the date (day/month) they were collected.

Table 6 Songor aquatic sampling

Site code	Map coordinates		Date	Field coordinates		Parameter			
	N	E		N	E	C	M	F	S
SB6	05 51	00 27	25/11	05 51	00 27	x		x	
SB7	05 51	00 28	25/11	05 51	00 28	x		x	
SB13	05 51	00 34	11/12	05 51 09	00 34 08.0	x		x	
SC3	05 50	00 24	08/12	05 50	00 24	x		x	x
SC4	05 50	00 25	08/12	05 50	00 25	x		x	
SC5	05 50	00 26	08/12	05 50	00 26	x		x	x
SC6	05 50	00 27	08/12	05 50	00 27	x		x	x
SC8	05 50	00 29	08/12	05 50	00 29	x		x	x
SC9	05 50	00 30	25/11	05 50	00 30	x		x	
SC10	05 50	00 31	25/11	05 50	00 31	x		x	x
SC12.5	05 50	00 33.5	11/12	05 50	00 33 22.9	x		x	x
SD2	05 49	00 23	08/12	05 49	00 23	x		x	x
SD3	05 49	00 24	09/12	05 49	00 24	x		x	
SD4	05 49	00 25	09/12	05 49	00 25	x		x	x
SD5	05 49	00 26	09/12	05 49	00 26	x		x	x
SD6	05 49	00 27	09/12	05 49	00 27	x		x	x
SD7	05 49	00 28	09/12	05 49	00 28	x		x	
SD8	05 49	00 29	09/12	05 49	00 29	x		x	x
SD9	05 49	00 30	09/12	05 49	00 30	x		x	
SD10	05 49	00 31	25/11	05 49	00 31	x		x	x
SD11	05 49	00 32	11/12	05 49 14.3	00 31 51.7	x		x	x
SE6	05 48	00 27	09/12	05 48 13.9	00 26 53 0	x		x	
SE7	05 48	00 28	09/12	05 48	00 28	x		x	
SE8	05 48	00 29	09/12	05 48	00 29	x		x	

Site code	Map cordinates		Date	Field coordinates		Parameter			
	N	E		N	E	C	M	F	S
SE9	05 48	00 30	09/12	05 48	00 30	x		x	
SE10	05 48	00 31	09/12	05 48	00 31	x		x	
SF9	05 47	00 30							x
SF10	05 47	00 31	11/12	05 47	00 31	x		x	
SF11	05 47	00 32	11/12	05 47 07.8	00 31 58.4	x		x	
SF12	05 47	00 33	11/12	05 47 06.1	00 33 05.9	x		x	

The coordinates for each site were read from the Ghana 1:50 000 topographical maps and positioned in the field with hand-held GPS recorders.

The sampling undertaken at each site is indicated (C = water chemistry; M = metals and nutrients; F = fauna [benthos and zooplankton]; S = sediment) along with the date (day/month) they were collected.

Table 7 Angor channel aquatic sampling

Channel code	Map cordinates		Date	Parameter			
	N	E		C	M	F	S
C1	5 46 42	0 40 58	5 Dec	X		X	
C2	5 46 53	0 42 07	5 Dec	X		X	
C3	5 46 56	0 43 02	5 Dec	X		X	
C4	5 47 36	0 42 59	5 Dec	X		X	
C5	5 48 36	0 43 07	5 Dec	X		X	
C6	5 48 11	0 44 01	5 Dec	X		X	
C7	5 47 57	0 45 02	5 Dec	X		X	
C8	5 46 56	0 46 02	5 Dec	X		X	
C9	5 46 36	0 47 00	5 Dec	X		X	
C10	5 46 53	0 48 00	5 Dec	X		X	
C11	5 46 45	0 49 00	5 Dec	X		X	
C12	5 47 55	5 49 50	15 Nov	X		X	

The coordinates for each site were read from the Ghana 1:50 000 topographical maps and positioned in the field with hand-held GPS recorders.

The sampling undertaken at each site is indicated (C = water chemistry; M = metals and nutrients; F = fauna [benthos and zooplankton]; S = sediment) along with the date (day/month) they were collected.

3.2 Sampling methods

The sampling methods are outlined below with a summary of the field sampling protocols given in appendix 1.

3.2.1 Hydrological and meteorological

The work carried out to describe the hydrological and meteorological conditions at the two sites consisted of both field and office activities. As part of the survey, hydrological, hydrogeological and hydrometeorological data relevant to the study area were acquired from various sources including the Hydro Division of the Architectural and Engineering Services Corporation (AESC), the Ghana Water and Sewerage Corporation (GWSC), Water Research Institute (WRI) and the Meteorological Services Department (MSD). The field visits and measurements were carried out with the view to better describing and analysing the hydrology of the sites and to recommending engineering options necessary to enhance the ecological integrity of the wetland ecosystems.

Field work on all aspects of the study started in November 1996 and was completed by the end of the year. The work carried out for the hydrological aspects of the study of the sites included:

- collection and collation of hydrometeorological and hydrogeological data;
- study of field/topographic sheets covering the relevant areas;
- field measurements, by standard hydrometric techniques of flows into the lagoons, notably the Avu and Keta lagoons which are fed by the Todzie River and the Volta estuary as at time of study;
- measurement of static water levels at selected wells within the study area.

Field measurement of conductivity, salinity and total dissolved solids (TDS) of water collected from the wells by a Hach CO18 meter (model 50150) and establishment of the location of these wells with a Garmin 45 GPS.

3.2.2 Physico-chemical

Field analysis

Over 120 stations were visited at the two sites over the study period. At each station the following parameters were measured: water depth, transparency, pH, water temperature, conductivity, total dissolved solids (TDS), salinity, and dissolved oxygen (concentration and percent saturation). Water depth was measured at most stations by a metre rule with readings rounded up to the nearest centimetre. Transparency was measured with a plain white homemade Secchi disc (30 cm diameter); two readings averaged (disappearance, reappearance) to the nearest centimetre. Hydrogen ion concentration was measured by a pH meter (table 8). Water temperatures were recorded from water taken 20 to 30 cm below the surface, and read by the oxygen meter. Conductivity, TDS and salinity were read using the HACH meter (table 8).

The HACH meter had been calibrated by standard salt solutions in the laboratory before use in the field. Dissolved oxygen was read by an Aqualytic meter, which had been checked for accuracy by cross reference to samples tested by the Azide modification of the Winkler method. All data were recorded in the field on data sheets. The time and date of visit to each station was also recorded.

Table 8 Meters used for taking field measurements of physico-chemical parameters

Parameter	Meter	Range/Accuracy
pH	Hach EC10 Model 50050	+/- 0.02
Conductivity/Salinity/TDS	Hach CO18 Model 50150	Range 1; 0–199.9µS, Range 2; 200–1999µS, Range 3; 2–19.99 mS, and Range 4; 20–199.99mS. Accuracy of all ranges +/- 0.5% of full scale Salinity range 0–80 ppt +/- 0.1% TDS Range 0–19900 mg L^{-1} +/- 0.1%
Dissolved oxygen	Aqualytic OX1 921	Range 0–50mg L^{-1} +/- 0.1 mg L^{-1} or 0–199% +/- 1% temperature -5– 45^{0}C +/- 15%. Temperature compensated probe

Laboratory analysis

All water chemistry parameters were measured at the Water Research Institute laboratory – the only laboratory in Ghana accredited under the GERMP. The methods used all follow the 14th edition of Standard Methods (APHA 1984). Analysis was carried out on 44 samples from the sites for major ions: sodium and potassium by flame emission photometry at 589 and 766.5 nm respectively; calcium and magnesium by EDTA titration; sulphate by the turbidimetric method; and chloride argentometrically. Other analyses included: alkalinity by titration; total phosphate by the stannous chloride method; suspended solids gravimetrically after drying in an oven to constant weight at 105ºC; zinc, lead and copper by Atomic Absorption Spectroscopy using a Perkins-Elmer spectrophotometer at 213.9, 217.0 and 324.7 nm respectively.

Sediment samples were collected from the top 30 cm of the lagoon bottom by digging, from over 50 stations at the two lagoons and were analysed by staff of the Volta Basin Research Project at the Department of Soil Science, Legon. After air drying the bulk samples, the particle size composition was determined by dry sieving through a graded set of sieves for the sand fractions, and by sedimentation for the silt and clay fractions.

3.2.3 Biological

Benthos

At each of the 120 stations in the two lagoons, five sediment cores were taken to examine the benthos. Hand held PVC corers with a core area of 0.00196 m^2 were used. Each core was washed separately through sieves of 300 micron mesh, and all material retained on the sieves removed. The core depths ranged from 5–15 cm depending on substrate type, substrates with large amounts of shell being more difficult to sample (see Piersma & Ntiamoa-Baidu 1995). Each invertebrate sample was placed in a 250 ml container for preservation with 4% formalin to which Rose Bengal at 1 mg per litre had been added. The samples were sorted by eye and by compound low power microscopes and all the organisms found identified and counted.

Zooplankton

Due to the extreme shallowness of many of the stations, plankton nets could not be towed in the lagoons, neither could Schindler traps be deployed. As such, 50 litres of water were collected by bucket (5 times 10 litre buckets) from an area undisturbed by previous sampling and poured through a plankton net. The net had a mesh of 200 microns. Material collected by the net was washed into 60 ml tubes and treated as the benthos above.

Phytoplankton

Water samples for phytoplankton identification and density counting were collected from the 120 stations within the lagoons. As with the zooplankton, 50 litres of water were collected from beneath the water surface and immediately poured through a plankton net (mesh 80 microns), the retained material was placed into a 60 ml tube and preserved with Lugol’s solution (APHA 1984). Twenty-five of the preserved samples were used for species identifications. After an initial cursory examination approximately 10 ml of each sample was boiled in 70% nitric acid to clear all organic materials from the cell walls of the diatomaceous species present. These were then washed in deionised water and centrifuged to remove all remains of the acid. The cleared samples were then mounted in the medium ‘Naphthrax’ and permanent slides made for retention in the International Diatom Herbarium (Curtin University, Perth, Western Australia) and identification using the specialised literature (J John pers comm). Given an absence of taxonomic expertise in the project team it was not possible to treat all 120 samples in this manner.

Chlorophyll

For chlorophyll analysis, between 0.25 and 1.0 litres of water (dependent on the turbidity) were filtered through Whatman GFC paper (nominal pore size 1 micron). After filtration, the paper was placed in 10 ml of 90% methanol and stored on ice. The samples were kept cold for a further 24–26 hours and then analysed with a spectrophotometer at the field base. A HACH field spectrophotometer with a 1 cm wide cuvette was used to measure pigment levels after extraction, with optical density (OD) readings being taken at 750, 664, 647 and 630 nm wavelengths according to the trichromatic method (Jeffrey & Humphrey 1975, APHA 1984) for chlorophyll a, b, c_1 and c_2. The optical density at 750 nm was subtracted from each of the other readings. The chlorophyll concentration (mg L^{-1}) in the extracts was calculated by the following equations and then multiplied by the volume of extract (mL) divided by the volume of the filtered sample (L):

$$\text{Chlorophyll a} = [11.85(OD664) - 1.54(OD647) - 0.08(OD630)]$$

$$\text{Chlorophyll b} = [21.03(OD647) - 5.43(OD664) - 2.66(OD630)]$$

$$\text{Chlorophyll c} = [24.52(OD630) - 7.60(OD647) - 1.67(OD664)]$$

The phaeophytin component in each sample was then determined by acidifying the sample with one drop of 1M HCl and taking a further reading at 665 nm. After subtraction of the reading at 750 nm the concentration of phaeophytin (mg L^{-1}) was calculated by the following equation and then multiplied by the volume of extract (mL) divided by the volume of the filtered sample (L):

$$\text{Phaeophytin} = 26.7[1.7(OD665) - (OD664)]$$

Macrophytes

The aquatic macrophytes at each grid point within the lagoons were collected in five replicate 0.31 x 0.31 m quadrats, giving an area of 0.1 m^2. All above-ground plant material within the quadrats was removed by cutting, placed into plastic bags and returned to the field base. (The same samples were used for collecting macroinvertebrates.) The plant material was initially sun-dried and then oven dried to a constant weight at 70ºC and weighed.

The wetland macrophytic vegetation sampling initially involved species occurrence and phenological recordings being made at each site with above-ground biomass at every other site in the initial surveys. All sites were used to record species presence and dominance whilst only every other site in the initial survey was used for biomass sampling. Tables 2 and 3 list all sites surveyed and whether or not biomass samples were collected.

At each site a species list was made within approximately 50 m radius. The dominant 1–3 species were identified and five 1 m^2 quadrats randomly placed approximately 5 m apart within the area occupied by the dominant species for semi-quantitative recordings of species biomass dominance, ground cover and phenological state. The biomass dominance was recorded in a numeric descending order. The ground cover and proportional estimates of phenological state were recorded on a six-point scale that reflected the percentage ground cover and phenological states, respectively.

Scale	1	2	3	4	5	6
Percentage	1%	2–25%	26–50%	51–75%	76–99%	100%

The phenological recordings included estimates of the proportion (percentage) of plants flowering, fruiting and seeding along with estimates of the proportion of juvenile, mature and senesced plants in each quadrat. These recordings were done on the basis of the six-point scale given above and, where applicable, covered the occurrence of flowering, fruiting, seeding, juveniles, adults and senescence of the dominant species within each quadrat.

Above-ground biomass sampling was confined to the dominant 1–3 plant species at each site. Five replicate 0.25 m^2 quadrats were placed approximately 5 m apart within the area occupied by each species and all above-ground plant material removed by cutting, placing into plastic bags and returning to the field base. The plant material from each bag was cut into smaller pieces, sun-dried and then oven-dried to a constant weight at 70ºC and weighed.

Nine stations, roughly equidistant around the Keta lagoon, were selected for vegetation transects. After locating the transect on the ground with a GPS, a 200 m line (pre-marked at 1 metre intervals) was laid perpendicular to the water's edge. When practicable, the 100 m mark on the line was placed at the water land interface. Two methods were then used for recording presence and absence of vegetation. In the 'point' method, a pole was placed vertically on each meter mark on the line and every plant the pole touched was recorded. In the 'block' method, two observers walking on either side of the line noted all species found in blocks of 1 x 5 m, delimiting the distance away from the line by one metre sticks.

4 Ecological character of Keta and Songor lagoons

4.1 Meteorology and hydrology

4.1.1 Climatic conditions

The climate of the study area lies within the dry Equatorial climatic region of Ghana, which also covers the entire coastal belt of the country. This region is the driest in the country and is referred to as the central and southeastern coastal plains. The coastal lands of Ghana have two clearly defined seasons, the Dry season and the Rainy season. The Rainy season exhibits double maxima, the main one occurring between April and June and the minor one between September and October. June is normally the wettest month in the area. The annual isohyetal pattern of the coastal belt has the minimum in the west outside Accra up and close to Songor lagoon in the east. The prevailing wind direction is from the southwest (the southwest monsoons). This is a characteristic feature for the entire coastal belt of the country. Mean monthly averages of daily wind speed range between 21.1 to 29.0 km h^{-1}. However, high velocity winds (110 km h^{-1}) of short duration have been recorded in Accra. The north east trade winds rarely reach the coast.

Day light and sunshine (hrs) in project area

The day length varies between 11.8 h and 12.5 h in the study area. It reaches its maximum in June and minimum in January. Daily sunshine duration is least in June (4.8 h) when there is maximum cloud cover and maximum in November (8.4 h) with a mean of 6.9 h. The values in table 9 give an idea of the general variation in the hours of sunshine within the study area.

Table 9 Day length (hours) and hours of sunshine within the study area

Day length (hours)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
11.8	11.9	12.1	12.3	12.4	12.5	12.4	12.3	12.2	12.0	11.9	11.8	12.1
Hours of sunshine												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
7.1	7.2	7.2	7.0	6.6	4.8	5.4	6.3	6.7	7.8	8.4	7.8	6.9

Relative humidity

Relative humidity data for the study area are estimated using data at Ada and Keta. Since local variation in relative humidity is not appreciable especially within the same climatic belt, humidity values at Ada and Keta are considered representative of relative humidity for the Keta and Songor Ramsar sites. Generally, relative humidity is high in the mornings and at night, but is at a minimum in the afternoon (table 10).

Temperature

Long-term temperature records are available at the Ada synoptic station. Records at this station give minimum average temperatures between 23ºC and 26ºC whereas the maximum lies between 27ºC and 32ºC. August is normally the coldest month in the area. Records from the Keta observation station indicate that the minimum average temperature is 24ºC, whereas the maximum average is 31ºC.

Table 10 Percent relative humidity at Ada (5-year average) and Keta (14-year average)

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean
Ada													
00:00	89	90	90	88	89	91	94	96	94	91	89	91	81
06:00	90	92	89	91	93	93	95	97	95	93	92	92	93
12:00	71	74	74	76	77	82	81	80	78	75	74	71	76
18:00	83	86	85	84	85	88	90	91	90	88	86	87	87
Keta													
Time	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Mean**
00:90	81	79	77	76	79	82	81	80	78	77	78	78	79
15:00	66	64	63	66	70	75	73	70	69	69	67	66	68

Rainfall

The study area experiences two rainfall maxima with the annual average for different periods ranging from 688 to 855 mm (table 11). Rainfall occurs between March/April to July and September–October. The low rainfall gives rise to stream flow mainly in the Rainy season only. Between November and April, the numerous small streams that drain the area dry up; over the last decade even the Todzie River dried into a series of pools in its lower reaches.

Rainfall in the greater Keta basin area was estimated using available records at Keta, Anyanui, Sogakope, Dabala, Anyako, Atiavi, Anloga, Adina, and Afiadenyigba. Rainfall records in the study area were reliable up to the 1980s. However, after this period, there are a lot of gaps in the data; only the stations at Keta and Ada have consistent data. Wakuti (1968) carried out an extensive analysis of rainfall in the study area and concluded that the variation in annual totals was small. Hence, for the southern section where the annual rainfall was about 900 mm, isohyets of the average monthly rainfall were not necessary. The arithmetic mean was considered adequate. In the present estimate, therefore, the arithmetic mean of the monthly rainfall is computed to give the mean basin rainfall for the Keta basin. This is presented in table 11 and illustrated in figure 5. Because Keta station has a long record, the variation in rainfall over various time frames was examined and this is also presented in table 11. It is clear from this presentation that between the mid-1970s and the early 1990s the mean annual rainfall has been low. Therefore the upper range of annual rainfall of 910 mm is on the high side.

Long records of rainfall data are available for the Ada synoptic station. From the data, the following pattern of rainfall is observed. The maximum rainfall occurs in June with the major season itself beginning from March/April. There is also a minor season between September and October. The mean monthly variation is depicted in figure 5. A summary of the rainfall statistics for various time periods is presented in table 11. Whereas the long-term mean annual rainfall is 891.6 mm, the mean between the mid-1970s and the early 1990s falls below this long-term mean by over 23%.

Pan evaporation

Evaporation from the Keta and Songor areas was estimated using direct measurements of pan evaporation from Ada and Tema. It is recognised that both stations lie in the same climatic belt. It was observed that there is a decrease in evaporation from Tema to Ada. This difference notwithstanding, Ada and Tema records were close enough to be averaged to give the evaporation for the study area. The mean pan evaporation for the study area is presented in table 12 and illustrated in figures 5 and 6.

Table 11 Rainfall (mm) in the general study area and long-term rainfall in the Keta Ramsar site

General study area											
Station	**Keta**	**Anyanui**	**Sogakope**	**Dabala**	**Anyako**	**Ataivi**	**Anloga**	**Adina**	**Afiadenyigba**	**Mean**	**STD**
Period	**1913–1992**	**1955–1960**	**1953–1975**	**1954–1980**	**1955–1981**	**1957–1985**	**1957–1981**	**1956–1968, 1973–1981**	**1956–1981**		
Jan	10.6	12.2	21.8	14.2	10.4	6.4	12.0	8.7	5.1	11.3	4.6
Feb	22.6	1.4	21.3	18.1	28.9	22.3	22.5	28.3	34.2	22.2	8.7
Mar	56.1	116.8	87.2	68.7	71.0	61.7	50.7	73.4	65.6	72.3	18.6
Apr	99.2	173.1	111.4	103.8	105.3	97.3	124.8	130.4	118.3	118.2	22.2
May	155.2	227.3	136.4	178.7	129.0	140.6	156.7	216.2	130.1	163.4	34.6
Jun	187.5	228.2	211.4	194.2	222.1	246.4	306.4	284.2	248.8	236.6	37.3
Jul	64.7	93.4	51.6	52.1	61.4	81.3	66.1	68.2	49.8	65.4	13.6
Aug	19.9	32.2	22.2	25.6	26.2	17.7	14.5	66.0	17.5	26.9	14.7
Sep	49.8	16.5	57.9	43.8	49.2	45.0	40.8	54.9	25.1	42.5	12.8
Oct	88.3	143.2	102.2	108.3	78.7	87.6	88.0	128.9	74.7	100.0	21.9
Nov	34.1	29.4	61.5	68.1	29.4	35.7	32.6	41.6	30.5	40.3	13.7
Dec	12.8	13.9	16.4	8.9	10.8	7.7	7.8	12.0	8.5	11.0	2.8
Total	800.8	1087.5	901.3	884.4	822.3	849.5	923.0	1112.9	808.0	910.0	
Mar–Jun	498.0	745.5	546.5	545.4	527.4	546.0	638.6	704.2	562.7	590.5	
%	0.6	0.7	0.6	0.6	0.6	0.6	0.7	0.6	0.7	0.6	
Sep–Nov	192.2	221.2	243.7	245.7	183.5	185.9	175.9	291.5	147.8	209.7	
%	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.3	0.2	0.2	

Keta Ramsar site (mm)														
Period		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total**
1913–1991	Mean	10.8	23.2	57.5	103.0	157.2	189.9	67.2	21.6	51.7	89.5	35.5	13.6	800.8
	STD	19.8	32.7	48.1	57.3	79.1	134.6	84.5	45.7	64.0	69.3	34.0	21.8	
	CV	1.8	1.4	0.8	0.6	0.5	0.7	1.3	2.2	1.2	0.8	1.0	1.7	
1915–1945		11.9	24.6	56.4	106.0	173.4	166.6	70.4	20.5	52.2	105.7	48.4	18.8	855.0
1946–1975		12.6	21.4	56.8	113.6	154.6	261.0	56.3	22.9	45.0	89.6	26.5	7.7	825.8
1976–1991		6.4	16.4	58.6	79.1	146.0	136.9	83.3	23.3	64.1	62.8	20.9	6.2	687.5

Table 12 Pan evaporation (mm) in the study area

Station	Period of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Tema	1972–1980	146.9	162.1	194.1	183.7	173.6	143.3	150.2	133.6	148.0	172.2	176.0	148.8	1932.5
Ada	1961–1967	125.0	135.0	175.0	180.0	160.0	125.0	130.0	140.0	150.0	180.0	155.0	130.0	1785.0
	Mean	135.9	148.5	184.6	181.8	166.8	134.2	140.1	136.8	149.0	176.1	165.5	139.4	1858.7
	Ada Rain(mm)	9.2	21.2	65.7	110.5	170.7	235.6	63.3	19.3	53.2	85.3	42.4	15.1	
	(1915 to 1991)													

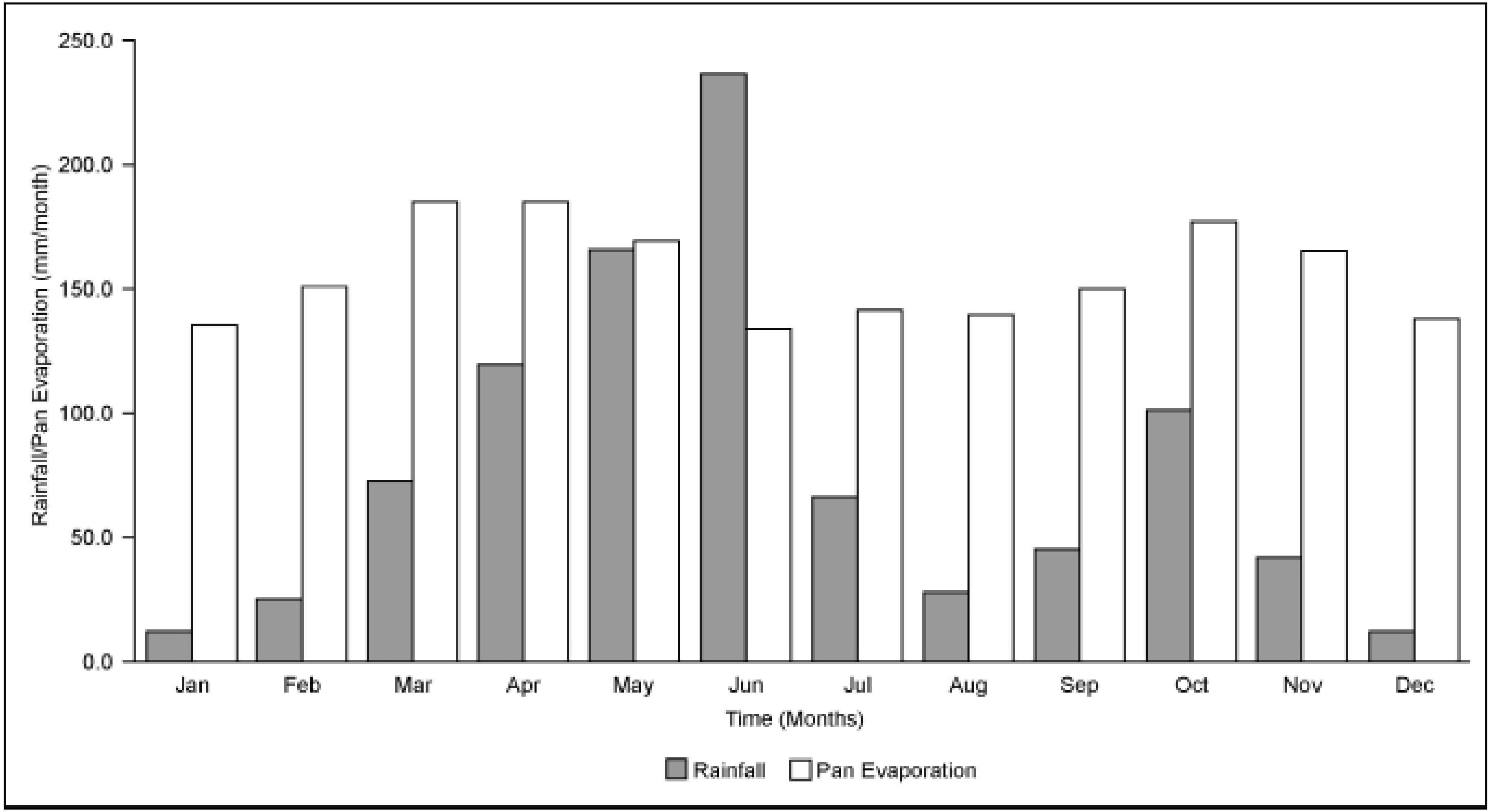


Figure 5 Distribution of rainfall and evaporation at Keta Ramsar site

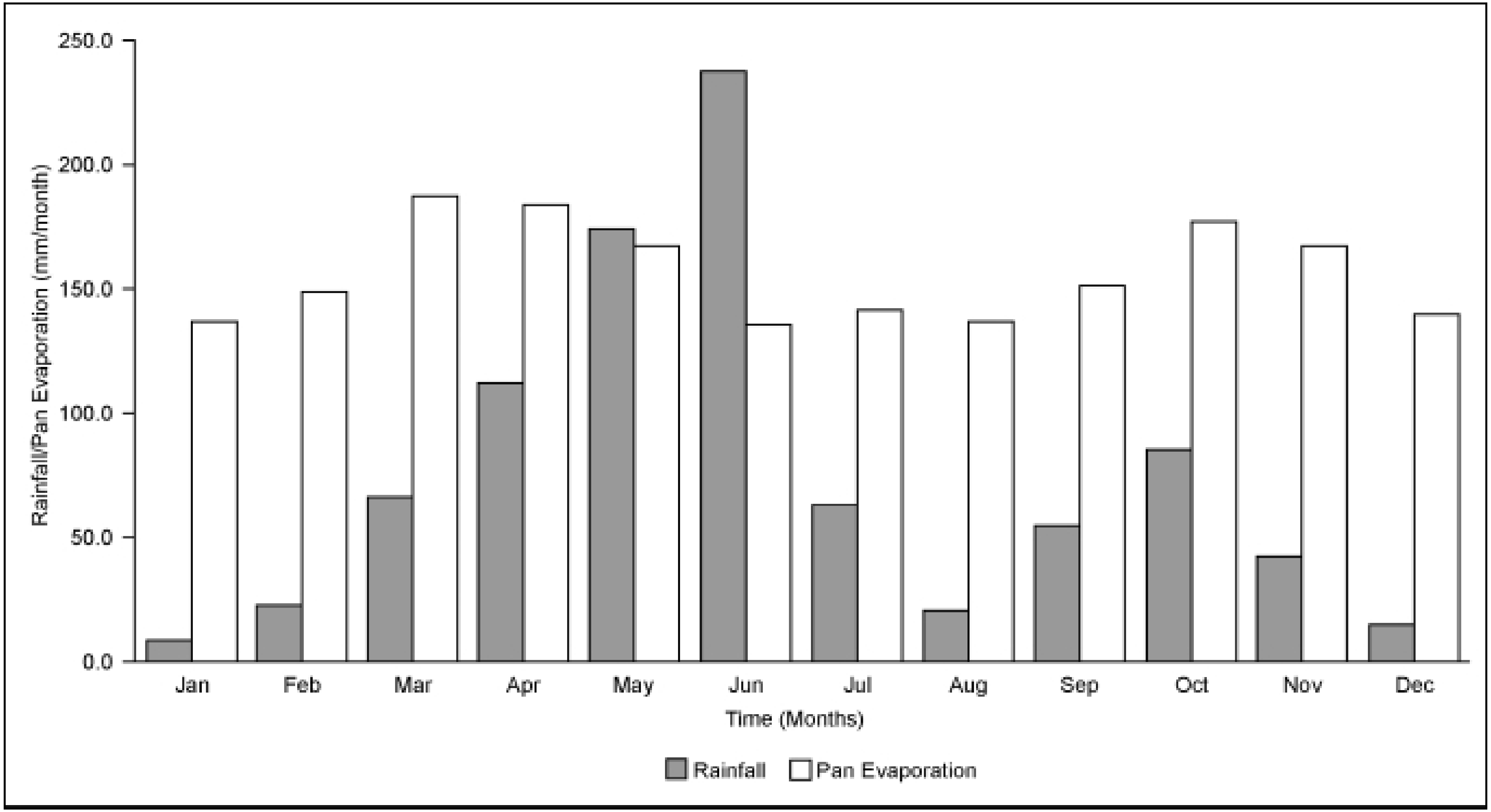


Figure 6 Distribution of rainfall and evaporation at Songor Ramsar site

4.1.2 Hydrological conditions

Keta catchment

In general, stream flow in the area is seasonal, and corresponds to the seasonal variation in rainfall. A few coastal streams drain the area above the Keta lagoon. The major streams apart from the Volta River include the Todzie River, which discharges into the Avu lagoon just north-west of Keta lagoon, and the Belikpa River, which discharges directly into the Keta lagoon. Belikpa River has a relatively small catchment area of less than 300 km^2. Alpen Consult et al (1992) reported that the freshwater end of all these coastal streams is about 25 km (minimum) from Keta, thus making it impracticable to develop them into surface water sources within a reasonable and economic distance.

Volta River

The Volta River is the largest drainage system in the country, with a total drainage area of 379 000 km^2 at Akosombo. It is an international river. It flows along the eastern boundary of the Greater Accra Region and is dammed at Akosombo and Kpong to provide electricity. The reservoir, which is a potential source of raw water supply to a number of towns, provides water for Accra and parts of the Eastern Region. The mean annual flow at Senchi before the construction of the dam was 36.6 x 10^9 m^3 (1160 m^3 s^{-1}).

After the construction of the dams, the river had an annual runoff depth varying between 30 mm and 240 mm and a mean annual flow of 1100 m^3 s^{-1} downstream of the Kpong dam. The highest recorded flood on the Volta River was 14 200 m^3 s^{-1} in 1963. Water abstraction downstream of the Akosombo dam at Kpong is the major development and takes about 0.01% of the yield of the river.

Todzie runoff

Annual runoff of the Todzie River is highly variable. Over the period 1957 to 1968, the minimum annual runoff (1958) was 79 x 10^6 m^3 whereas the maximum was 587 x 10^6 m^3 (1963). The mean for the period was 345 x 10^6 m^3. The Todzie River has a catchment area of 2200 km^2. However, the area commanded by the gauging stations Todzienu and Tove is slightly lower and totals 2120 km^2. The mean annual flow at Todzienu on the Todzie River is estimated at 11 m^3 s^{-1} with a reliable yield (50 year return period) of about 0.05 m^3 s^{-1}. The 100-year flood is estimated at about 140 m^3s^{-1}. In view of the monthly and annual variability in the flow, Todzie River could significantly contribute to flooding in the Keta lagoon as has been reported in earlier studies. The estimated capacity of the Keta lagoon when there is no inflow is about 360 x 10^6 m^3. The mean annual flow on the Todzie is presented in figure 7. As expected, the peak flows occur in June and October while the low flows occur between November and April. The one-day flow measurement carried out on this stream in mid-November was 2.81 m^3 s^{-1}. This is low compared with a mean of 6.6 m^3s^{-1} for November for the period 1957 to 1968. However, for the same period the mean annual flow varied between 2.5 m^3 s^{-1} and 18.5 m^3 s^{-1}. The highest peak flow recorded on the Todzie River was 215 m^3 s^{-1} in 1968. Between 1964 and 1990, the data were not continuous, but the average discharge for November for that period was 7.1 m^3 s^{-1}.

Rivers Aka and Belikpa

These two small rivers have a combined catchment area of 700 km^2 and drain into Keta lagoon. They are situated north of the Keta Ramsar site. They discharge their water through culverts crossing the highway at Afife and Atiteti. There are no historic records of flows on these rivers. However, rainfall data and their distribution are known in the catchments and that can give an appreciation of the flow regime from these streams.

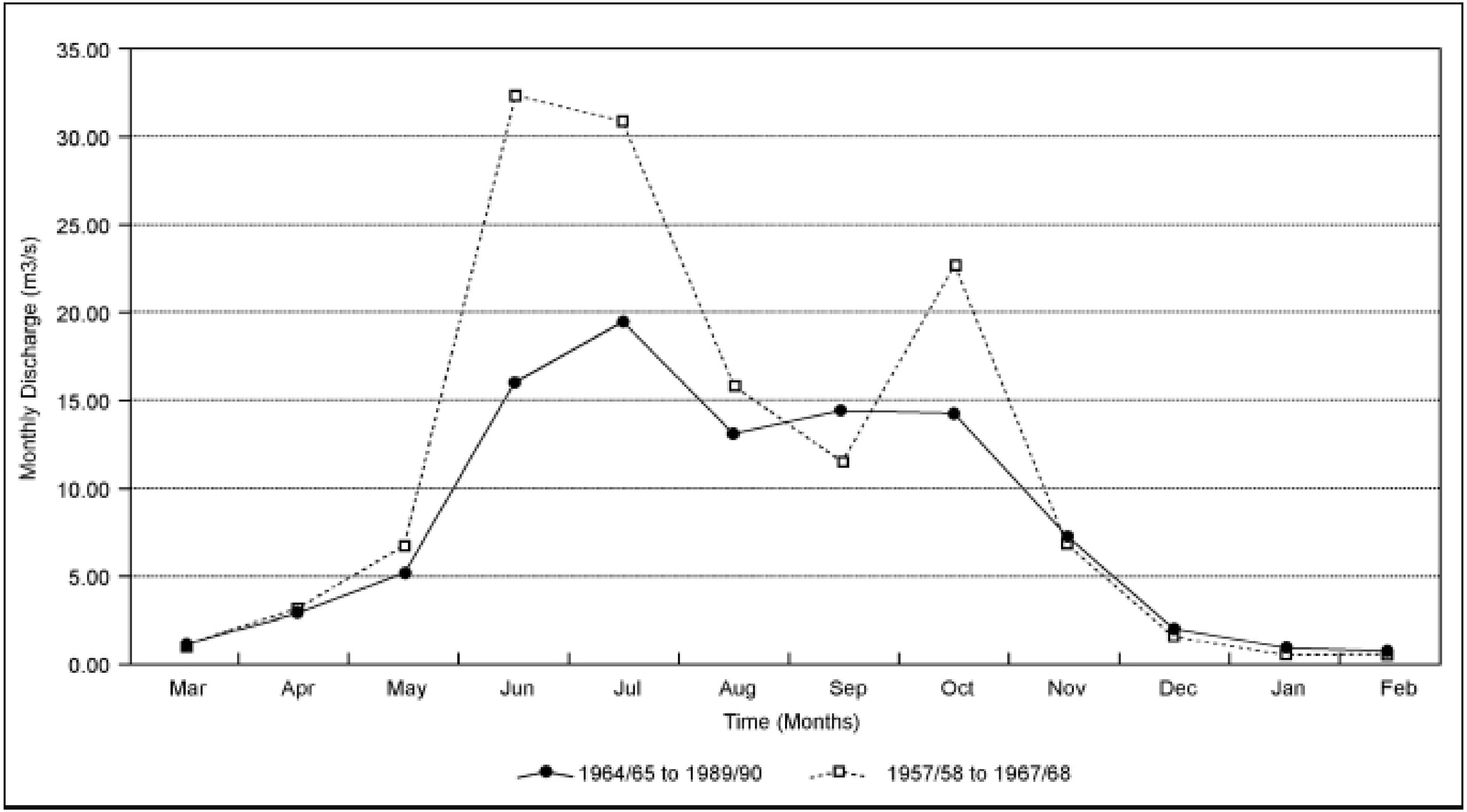


Figure 7 Monthly discharge on Todzie at Todzienu ($m^3 s^{-1}$)

They are known to dry out between December and April each year. By analogy to the Todzie catchment, runoff coefficients have been transferred to these catchments and estimates of runoff made. For a wet year, the estimated runoff from the two catchments is 100 x 10^6 m^3 (based on an annual rainfall of 1300 mm and a runoff coefficient of 11%).

Aka has an area of 420 km^2 and Belikpa 280 km^2. The runoff for June in rainy months could be as high as 25% of the annual runoff. The combined flow of the two streams could be as high as 25 x 10^6 m^3, Aka being 5.8 m^3 s^{-1} and Belikpa 3.8 m^3 s^{-1}.

Variation in water levels

Most of the hydrological data available for the study area after 1968 are water levels at a few gauging stations within the basin. On the Volta River, water releases through the penstocks for power production are available. There are gaps in the hydrometeorological data, especially after 1980. However, some water level measurements were carried out at selected stations in the lower Volta basin, including part of the study area.

Before 1964, records on the Volta at Sogakope showed that water levels increased from 1.4 m in the Dry season to about 6.6 m in September or October. After the construction of the Akosombo dam, however, water level records were uniform at this station, the slight fluctuations being from the operation of the hydropower station and rainfall downstream of the dam. Between 1990 and 1992, variation in water levels at Anyanui had a maximum value of 0.5 m within a year.

Available lagoon water levels for the Keta lagoon indicate that the lowest water levels were reached in March, April, or May with the highest levels occurring in July. This observation is for the period between 1970 and 1980. Between 1988/89 to 1991, water levels records show that high lagoon water levels were observed between July and November. Because the period is short, however, it cannot be conclusively stated that there is a change in the occurrence of the peak floods.

Daily gauge heights at the staff gauge on the Avu lagoon at Avuto between 1989 to 1992 indicated that the highest water levels occurred in July (0.9 m) and the lowest in April (0.2 m). On the Volta River at Agordome, the minimum water levels occur in March or April and the maximum in September or October, with a variation in level of between 0.5 to 0.73 m. Since the filling of the Volta dam at Akosombo in 1965 the mean annual rainfall was below average from 1983 to 1985, resulting in very low water levels in the lake which resulted in power rationing in 1984.

Changes in flow regime

The regulated flow in the Volta began when Akosombo and Kpong hydro-power plants were commissioned in 1965 and 1984 respectively. This has created a new flow regime between Kpong and Ada, resulting in a progressive growth of a sandbar at Ada, which restricts flood discharge (into the sea) and tidal movement into the river. The resulting change in fauna and flora encouraged the growth of disease vectors such as schistosomiasis carrying snails, and created changes in the flow regime between the interconnecting creeks and streams between the Lower Volta River and the Avu–Keta basin, including Avu, Keta and Angaw lagoons.

In the early 1990s, the Volta River Authority dredged the estuary. Whilst the dredging has controlled vector snails by admitting some amount of saline water into the river, salinity levels have been slightly altered in the lower reaches of the river. Salinity studies carried out under the feasibility study for the scheme (Ada–Keta District Water Supply Scheme Feasibility Study for the Master Plan, GWSC) indicate a decreasing trend in salinity from the estuary at Ada Foah, with water at Sogakope being almost unaffected by the incursion of saline water from the estuary.

The dredging activities currently being undertaken in the Angor channel connecting Keta lagoon to the Volta River will increase its flood carrying capacity in both directions (ie from the lagoon to the Lower Volta and vice versa). Since the floods originating from the Todzie River occur in June and those on the Volta in September/October, it is necessary to have a large carrying capacity in the channel. The measured flow in this channel during the current field survey gave a flow of 2.5 $m^3 s^{-1}$, at a time when the water was flowing from the lagoon to the Volta River.

Water balance of the Todzie–Aka Basins

The individual components of a water balance for the Keta basin are presented to give a general idea of the water flow situation. The average annual rainfall in the Todzie–Aka Basins varies from 1400 mm in the north to about 910 mm in the south. Pan evaporation is 1780 mm per year. The combined runoff from all basins in Ghana is estimated at 196 mm per annum. The evaporation data presented for the study area give an annual value of 1859 mm. Rainfall at selected stations in the Keta basin is 910 mm per annum. Thus, on the whole, evaporation far exceeds rainfall. Recharge occurs mainly in the months of June and July and to a lesser extent in September and October. There is a net flow of seawater into the lagoon as a result of the tidal effects, especially along the narrow sand dune edge along the coast.

Groundwater resources

The upper geologic strata consisting of the tertiary rocks on the gravelly base and the more recent sediments seem to favour occurrence of groundwater in areas where they show prominence. These occur mostly towards the south-eastern and north-eastern parts of the study area where two shallow limestone aquifers and a deep limestone aquifer exist.

Freshwater has been obtained from this deep limestone aquifer at depths of between 80 and 300 m at the inland and coastal areas respectively. In the Keta area, the only piped system is in this deep limestone aquifer. Shallow hand dug wells in the Recent deposits along the coastal area also provide some of the water requirements of the people, although these sources are potentially at risk of contamination from surface wastes and saline intrusion.

Potential well fields exist around Agbosome, Afiadenyigba and Nagopo, however, these high yielding boreholes stand the high risk of saline intrusion. They also require high pumping heads, which translate into high operational costs. As there is no clear knowledge of the seawater/freshwater boundary for the limestone aquifer, it is believed that continued pumping from the aquifer may increase the risk of salinity.

Songor catchment

In general, stream flow in the area is seasonal, and corresponds to the seasonal variation in rainfall. A few coastal streams drain the area above the Songor lagoon.

Rivers

The Sege River has a catchment area of about 75 km^2 and drains the north-western part of the Songor lagoon. There are no records of flow on this river because it is not gauged, but based on a 12% recharge, the estimated mean annual flow depth is about 100 mm. The other major stream draining into the Songor lagoon flows through Hwakpo. It has a catchment area of about 50 km^2 and flows from north to south. As mentioned already, all these streams are seasonal.

Other water sources

There are other seasonal streams in the study area some of which have dams or dugouts constructed on them for water supply purposes. None of these small streams is gauged and so there are no records of flow available. The total area that drains into the Songor lagoon is estimated at 240 km^2.

The Songor lagoon is the biggest lagoon in the Songor Ramsar site. The water body covers an area of 115 km^2 and it extends for about 20 km along the coast and 8 km inland behind the narrow sand dune. The lagoon, together with the surrounding floodplain, has extensive shallow water mudflats and islands suitable for feeding and roosting of seashore birds. Apart from the Songor lagoon, there are other small lagoons including Kadza, Truku and Kunye. There are no water level records for these lagoons.

Variation in water level

There are no staff gauges on Songor lagoon and therefore no records of lagoon water levels. It is, however, expected that since this lagoon has no perennial inflowing streams, it will dry much faster than Keta lagoon will. Data for Keta lagoon indicate that the lowest water levels were reached in March, April, or May with the highest levels occurring in July. This observation is for the period between 1970 and 1980.

During the field work, it was learnt that the lagoon normally dries out in the Dry season and the sand dune near Lolonya is broken using a bulldozer to allow sea water to flow into the lagoon at high tide. It is subsequently closed and the water evaporates under natural conditions throughout the year. Salt is then harvested by the various communities and the cycle is repeated. For this reason the lagoon water is hypersaline most of the time. Vacuum Salt Works Industries currently undertakes salt mining in the area and is responsible for the temporary opening of the lagoon to the sea.

Part of the brine in the lagoon is pumped by Vacuum Salt Works Industries and properly managed to ensure that they mine salt all year round by diverting floodwater from the catchment away from their saltponds. The other part of the lagoon, which is not managed, mixes with freshwater from the catchment and undergoes natural evaporation until it dries out completely. The salinity in the lagoon therefore increases progressively from the beginning of the Dry season until the time it dries out.

Groundwater resources

Complex crystalline basement rocks dominate the hydrogeological setting of the Accra Plains which includes the study area. Semi-confined and confined aquifers occur beneath the water table. It is difficult to locate large quantities of groundwater because of the lithology and structure of the basement rocks which include granitic gneiss and schistose lithologies. These are impermeable and have limited storage capacity within their matrix. It is the pattern of fracturing that controls the accumulation of groundwater. Where the fractures are unidirectional, interconnected ground water bodies do not form. Isolated water fill the cracks resulting in only limited groundwater potential.

Groundwater in the region occurs mainly in confined fractured reservoirs. The mean thickness of the water bearing formation of the crystalline rock unit is about 3 m, occurring between depths of 10 and 13 m below the ground level.

Apart from the crystalline basement rocks, other hydrogeological units found in the Accra Plains include Recent and Eocene sand, gravel and sandstone of the Accraian formation which occur in the vicinity of Accra. Shallow and fresh ground water bodies exist in lowland parts of the Recent and Eocene deposits. The main aquifers occur in the sandy and gravelly beds. The

Accraian formation has an insignificant groundwater potential, although small supplies can be obtained in hand-dug wells in the jointed and fractured portions of the formation.

4.2 Bathymetry and sedimentology

4.2.1 Basin morphometry

Both the Keta and Songor lagoons have the shape of a plate, characterised by the shallowness of both water bodies, and their ephemeral nature. Due to the extremely low gradients, which in the case of the Keta lagoon are in the order of 1:20 000–100 000, minor changes in water level have significant effects on the water area. Table 13 gives some morphometric parameters for the Keta lagoon. At the time of taking measurements, the natural portions of the Songor lagoon were dry and the areas under salt production were subject to artificial manipulation. Further, the natural shape of the basin has been modified by salt exploitation.

The flat nature of the lagoon bottom for both Keta and Songor, coupled with the strong land and sea breezes, gives rise to a phenomenon that can be termed 'wind creep'. When this happens, the force of the wind is sufficient to push/pile the water for several tens of metres in areas that would otherwise be dry. This has importance to several species of invertebrate, eg *Typmanotonus,* that feed in these areas when they are flooded. The water depth is often in the range of millimetres.

The hypsographic curves presented in figure 8 illustrate the shallow nature of Keta lagoon. Less than 5% of the total area is deeper than 40 cm. The bulk of the water volume is in areas that are under 30 cm.

Table 13 Summary of morphometric parameters for Keta lagoon

Morphometric parameter	
Max length	24 km
Max width	12 km
Water area*	69.30 km^2
Max area	271.75 km^2
Volume*	5 560 267 m^3
Max depth*	0.75 m
Mean depth*	0.08 m

*At time of measurement (January–February 1995)

4.2.2 Sediments

The sediments of the lagoons are predominantly sands, silts and clays. The larger material is usually relict shells or shell fragments (see Piersma & Ntiamoa-Baidu 1995 for description and ecological significance of these larger particles). Figure 9 presents a map of the distribution of sand, silt and clay in the Keta lagoon. Sand predominates in most of the samples. Samples taken in the lower portion of the lagoon, ie sampling sites KN–KQ, had a large clay fraction. This may be a result of the extensive stands of *Typha* that are found in this region. Further analysis was carried out on the sediment samples using PRIMER software (figures 10 & 11). For Keta lagoon there are a group of sites that are clustered together (KI15, KG17, KI16, KP15 AND KF16). These form a swathe that corresponds to the edge of the area of influence of flood waters from the Volta as seen from Landsat imagery.

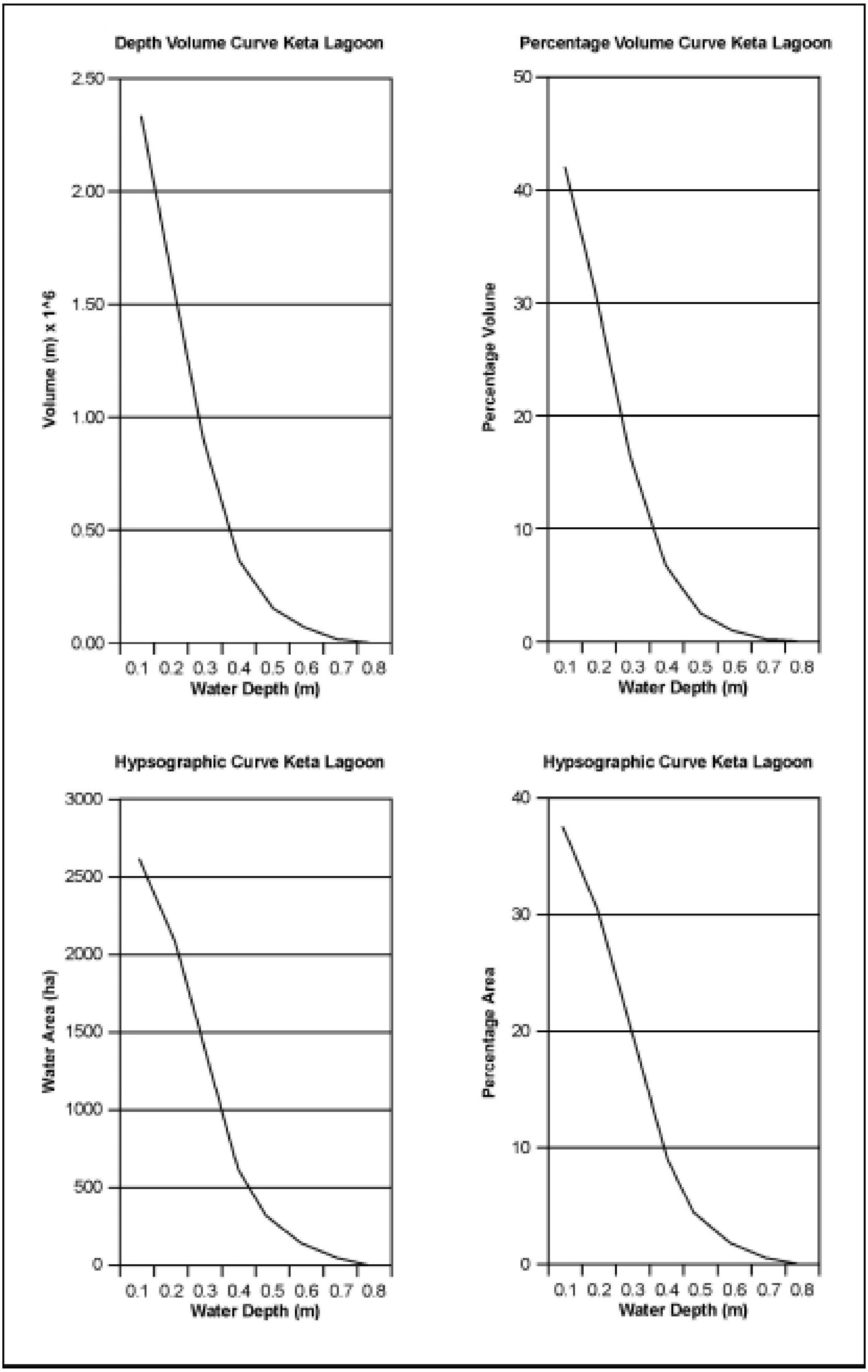


Figure 8 Hypsographic curves for the Keta lagoon

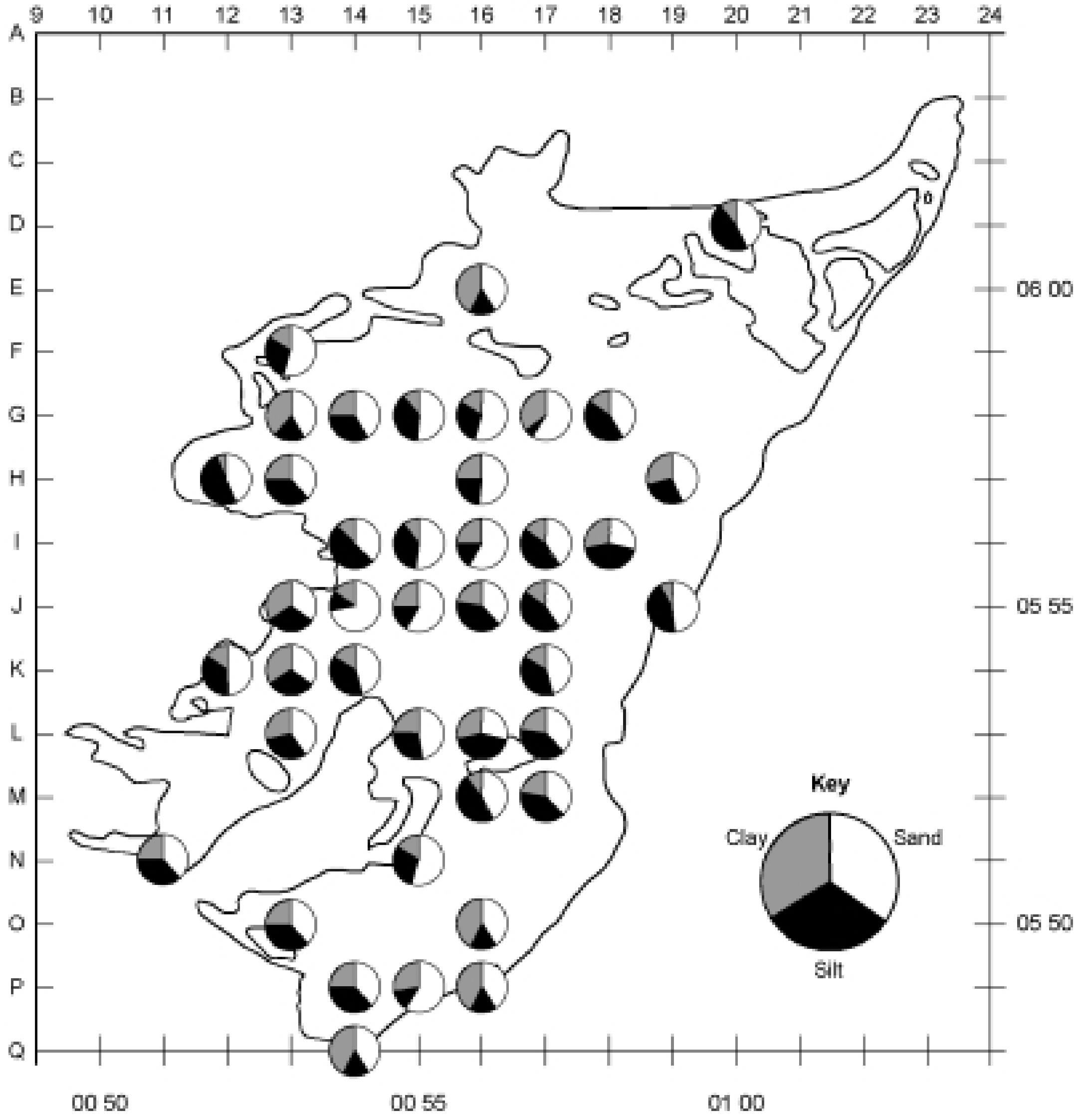


Figure 9 Map of sediments in the Keta lagoon

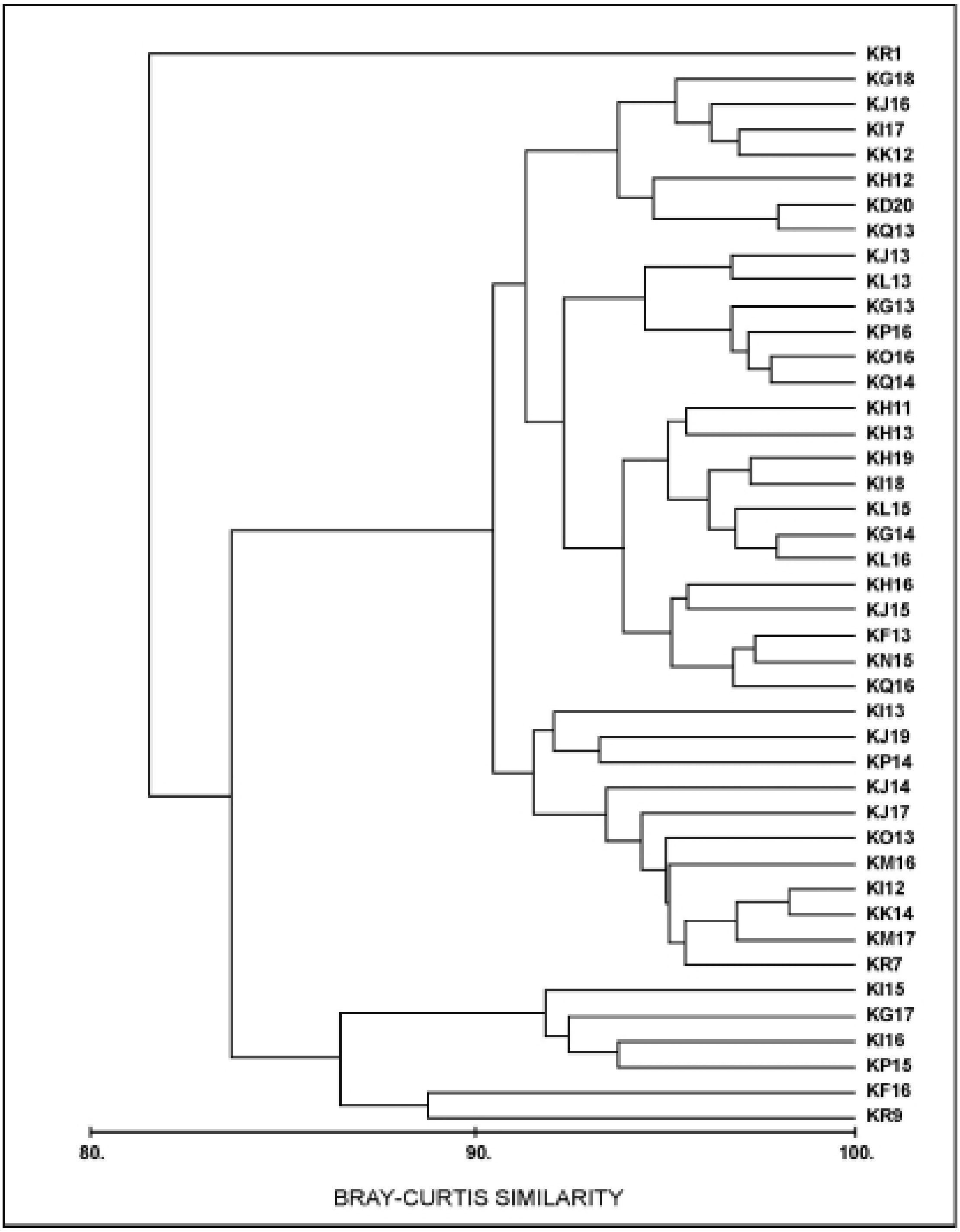


Figure 10 Cluster analysis of sediments in the Keta lagoon

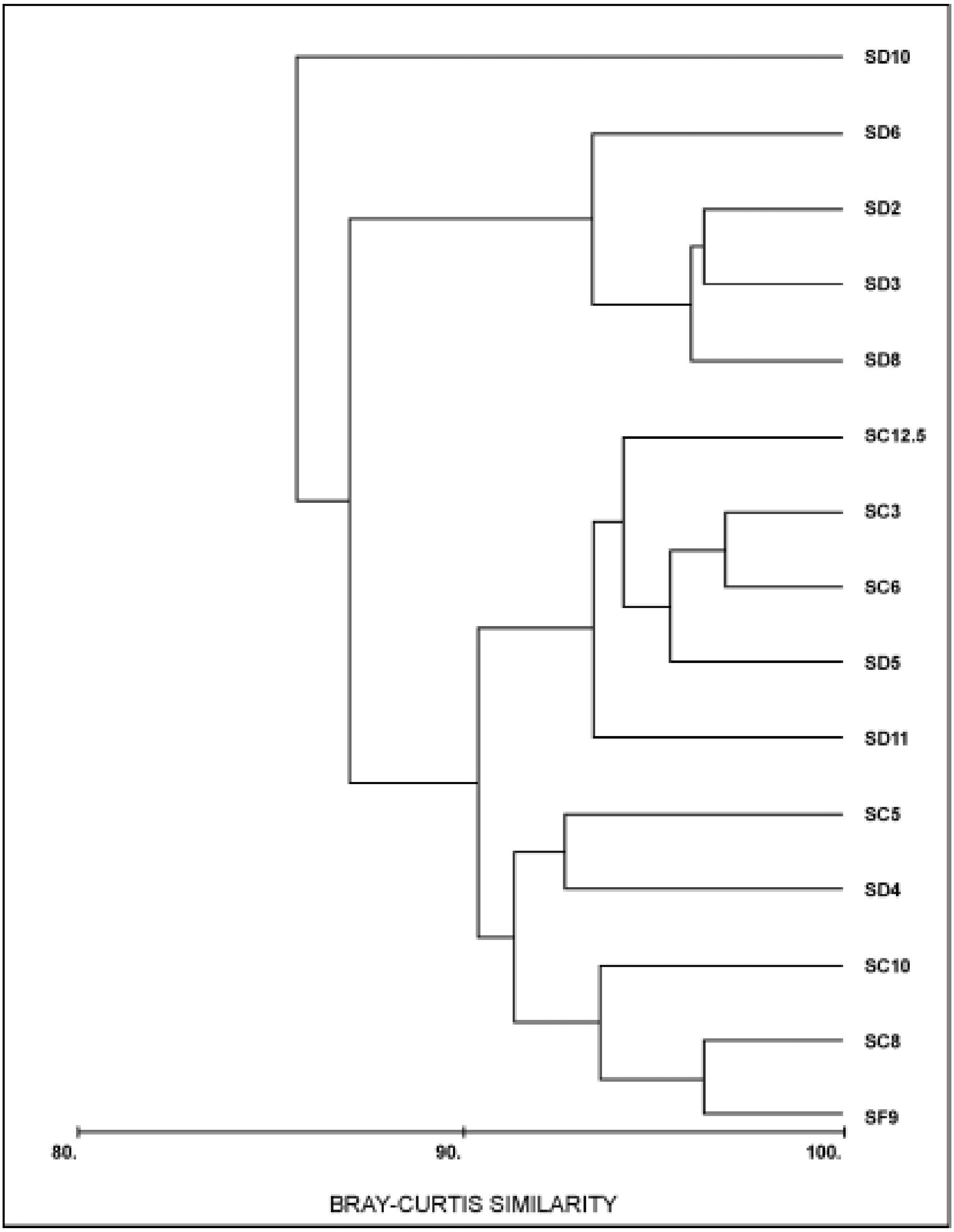


Figure 11 Cluster analysis of sediments in the Songor lagoon

The cluster analysis separates three types of sediments for Songor lagoon (figure 11). These are sandy sites to the north and west of the lagoon, muddy sites in the eastern part of the lagoon and very muddy sites in the coastal area around the middle of the lagoon. Many of the samples taken in Songor had the characteristic smell of hydrogen sulphide. The sediments had a high organic carbon content, and dried to a brick-like consistency.

4.3 Limnology

4.3.1 Physical water parameters

pH

The pH of the water did not show any clear trends between sampling stations at each site, between the two Ramsar sites and the two sampling periods. This lack of pattern is probably due to the fact that wind induced mixing would lead to a very homogeneous water mass and the fairly high carbonate content of the water would have effectively buffered any pH changes that could have resulted from biotic activity.

Temperature

Temperature in these shallow lagoons was always high. Tables 14 and 15 give the relationship between temperature and time of day and temperature with depth (see also figure 12).

Table 14 Relationship between water temperature (^{o}C) in the lagoons and time of day

Time	Mean temp. ^{o}C	Standard deviation	n	Range	
				Minimum	Maximum
08:00	28.5	0.14	2	28.4	28.6
09:00	29.3	0.21	10	28.4	29.8
10:00	30.4	0.35	13	29.0	33.3
11:00	32.1	0.21	7	30.2	36.1
12:00	31.6	0.14	12	30.4	34.5
13:00	31.6	3.04	9	30.2	35.2
14:00	31.6	0.40	8	30.8	32.5
15:00	31.6	0.78	10	30.9	32.7
16:00	30.4	0.64	9	28.2	32.4
17:00	30.0	–	1	–	–

Table 15 Relationship between water temperature (^{o}C) and depth in the lagoons

Depth (cm)	Mean temp. ^{o}C	Standard deviation	n	Range	
				Minimum	Maximum
<25	34.0	2.1	5	30.7	35.2
25–50	31.4	1.6	14	28.5	33.1
>50–75	30.7	1.0	32	28.4	32.0
>75–100	30.6	2.2	29	28.2	31.6
>100	29.9	1.0	8	28.6	32.3

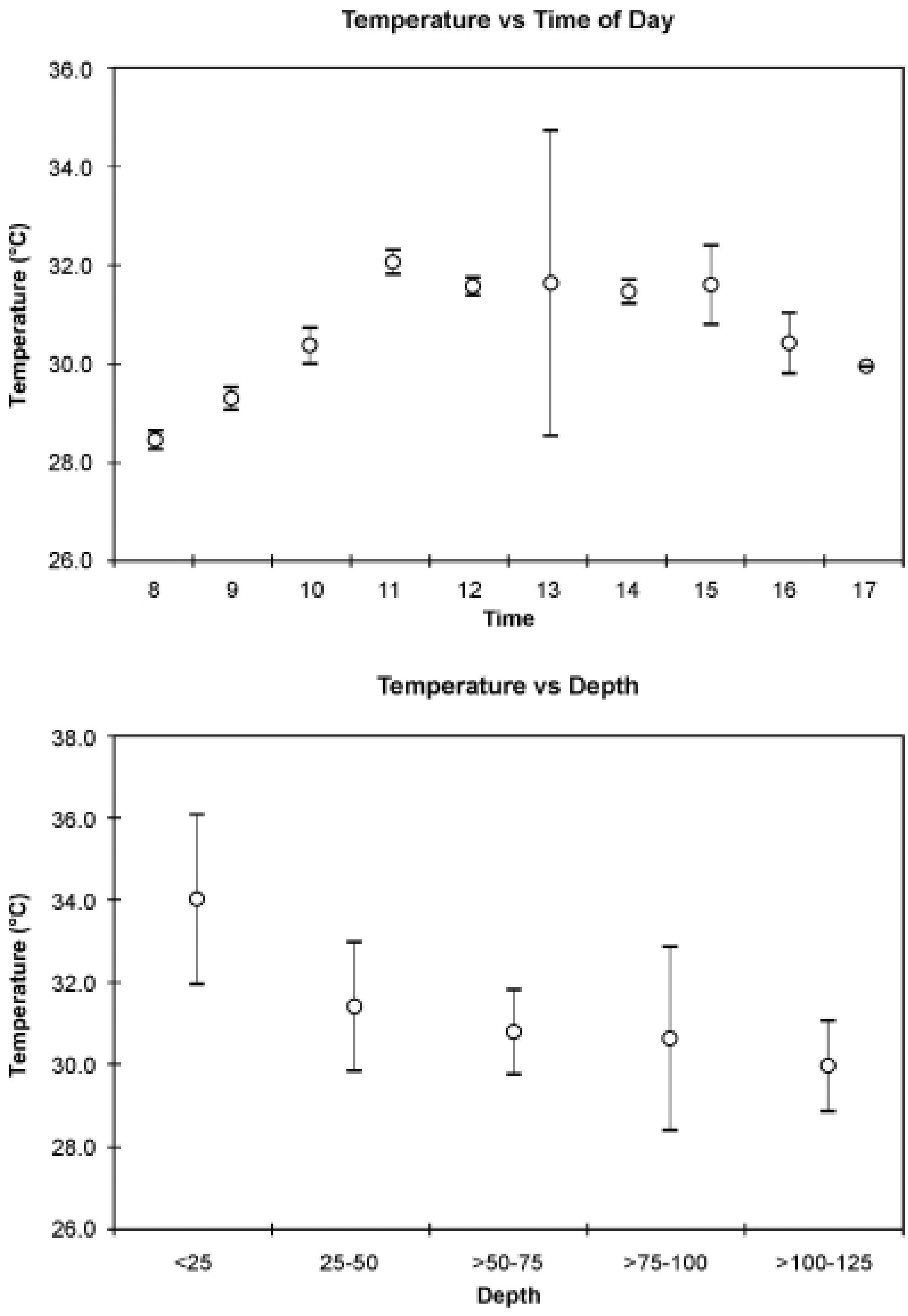


Figure 12 Water temperature in Keta lagoon

The water was warmest just after noon, with about a 4ºC rise in temperature from dawn. Surface temperature decreased with the depth of the water present, but even where the water was deepest, mean temperature was still over 30ºC. There was very little temperature difference between the surface and bottom. This is not surprising given the very shallow nature of the lagoon.

The values for Songor are very similar with sampling being carried out between 08:50 and 17:15 hours. The mean temperature was 30.2ºC with a range of 28.2–31.8ºC (n = 22).

Transparency and suspended solids

The water in the two lagoons was basically without true colour. However, due to the strong wind action and the shallow nature of the lagoons, the transparency was often reduced to less than 10 cm. This has implications on the primary productivity of the lagoons. The high levels of suspended solids could explain the comparative lack of filter feeding invertebrates in the lagoons. The transparency was reduced in areas where there was a large clay fraction in the sediment and high in areas where there were submerged aquatic plants.

4.3.2 Chemical water parameters

Data on the chemical properties of the water are presented in appendix 2.

Conductivity/salinity/total dissolved solids

The values are within the expected range for coastal lagoons in Ghana, ie values range from almost freshwater to hypersaline values (from under 2 mS cm^{-1} to over 80 mS cm^{-1}). The presence of hypersaline subsurface water was noted in several areas such as the areas around Adina and most of the Songor lagoon. Freshwater seepages occurred on both the landward and seaward facing sides of the coastal sand dunes and in the case of the Songor lagoon, these were the sites with obvious signs of aquatic life.

Dissolved oxygen

In other water bodies in Ghana, with similar morphometric parameters as Keta and Songor lagoons, it is common to find that the water column is super-saturated with oxygen. This is not the case in these two lagoons. The reason for this may be because of the absence of significant algal mats on the sediment. Tables 16 and 17 present the change of oxygen with time and depth in Keta lagoon.

Table 16 The relationship between dissolved oxygen content in Keta lagoon and time of day

Depth (cm)	Dissolved oxygen mg L^{-1}	Standard deviation	n	Range	
				Minimum	Maximum
08:00	24.0	15.5	2	13	35
09:00	22.6	13.2	11	6	45
10:00	27.8	18.4	13	2	70
11:00	14.3	7.9	7	1	24
12:00	23.8	7.5	11	14	39
13:00	29.8	13.4	9	17	56
14:00	26.5	5.4	8	20	35
15:00	28.8	5.7	10	19	40
16:00	38.2	19.7	9	22	85
17:00	34.0	–	1	–	–

Table 17 The relationship between dissolved oxygen and depth of water in Keta lagoon

Depth (cm)	Dissolved oxygen mg L^{-1}	Standard deviation	n	Range	
				Minimum	Maximum
<25	39.0	15.5	5	13	53
25–50	27.1	8.6	14	13	41
>50–75	22.3	9.3	31	1	45
>75–100	29.4	17.8	24	2	85
>100	26.0	13.1	8	6	45

Two trends can be seen, the first is a general inverse ‘U’ shaped curve for the change with oxygen with time of day. This is compounded by the fact that oxygen in the water column is the result of both wind action and photosynthesis. The drop in mean concentrations is the result of the daily lull in wind action that occurs around this time. Previous work on the lagoon has shown that the surface waters usually are oxygenated throughout the night. The second trend is the decrease in mean oxygen levels with increase in depth. This trend supports the premise that wind action is the driving factor for oxygen in these lagoons.

Major ions

Sodium and chloride dominate the ionic composition of the water of these two lagoons. This is to be expected given the proximity of the lagoons to the sea. Table 18 presents average values and the range for Keta lagoon, with comparative proportions shown in figure 13.

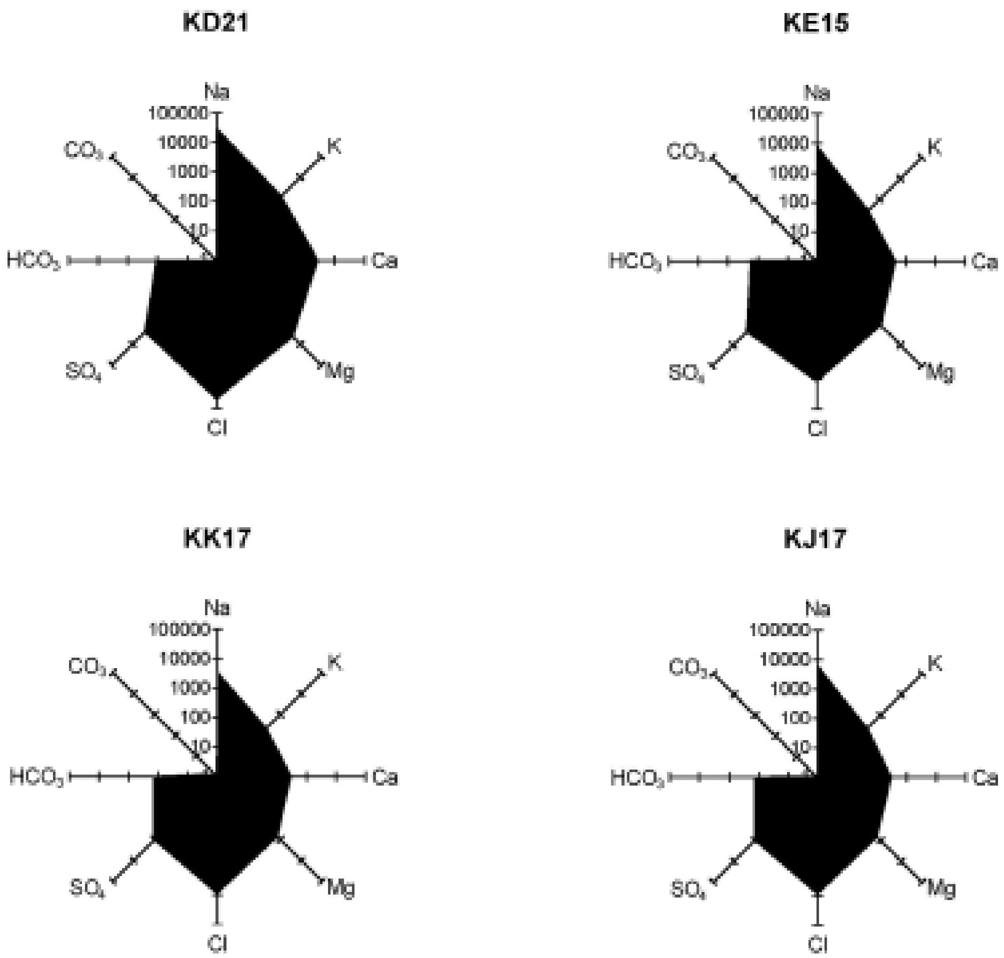


Figure 13 Major ions in Keta lagoon (mg L^{-1})

Table 18 Concentrations of major ions (mg L^{-1}) in water collected from Keta lagoon

	Mean	Standard deviation	n	Min	Max
Sodium	4373	1788	17	855	6900
Potassium	231	178.	17	36	885
Calcium	384	422	17	78	1987
Magnesium	873	642	17	133	2888
Chloride	10207	8527	17	815	41300
Sulphate	1212	522	17	300	2460
Alkalinity	310	714	17	98	3080

Metals

Industrial development in the two catchments is low and there are no mineral deposits with a high metal content in the catchment. As a result the trace metal content in the water of the lagoons was usually below the limits of detection for the methods used (table 19). This is a positive sign. For logistic reasons sediment samples were not analysed for trace metals.

Table 19 Concentrations of metals (mg L^{-1}) in water collected from Keta lagoon

Site	Zinc	Lead	Copper
KC17	0.09	<0.03	<0.03
KD19	0.04	<0.03	<0.03
KD21	0.04	<0.03	<0.03
KE15	0.04	<0.03	<0.03
KE17	0.06	<0.03	<0.03
KF15	0.04	<0.03	<0.03
KG17	0.04	<0.03	<0.03
KG18	0.04	<0.03	<0.03
KG20	0.07	<0.03	<0.03
KH17	0.05	<0.03	<0.03
KI18	0.04	<0.03	<0.03
KJ17	0.04	<0.03	<0.03
KK17	0.06	<0.03	<0.03
KM12	0.06	<0.03	<0.03
KM17	0.05	<0.03	<0.03
KN11	0.06	<0.03	<0.03
KN17	0.04	<0.03	<0.03

4.3.3 Channel chemistry

Figure 14 presents data on the pH, temperature, total dissolved solids and the dissolved oxygen content of twelve sites along the Angor channel to Keta lagoon, from the Volta estuary to the Srogbe bridge. The clearest trend is that of an increase in dissolved solids from the Volta estuary. There is also a sudden rise in temperature in the vicinity of the lagoon. The pH of the water follows no clear trend – more work would be needed for this to be explained.

There is a general decrease in the dissolve oxygen content from the Volta estuary to the lagoon. This could be the result of change from a lotic to a lentic water body, but could also be the result of inflow of low oxygen water to the channel from the lagoon. Sites C3 and C4 are adjacent to mangrove areas that could contribute significant amounts of organic matter reducing the amount of water in the water column.

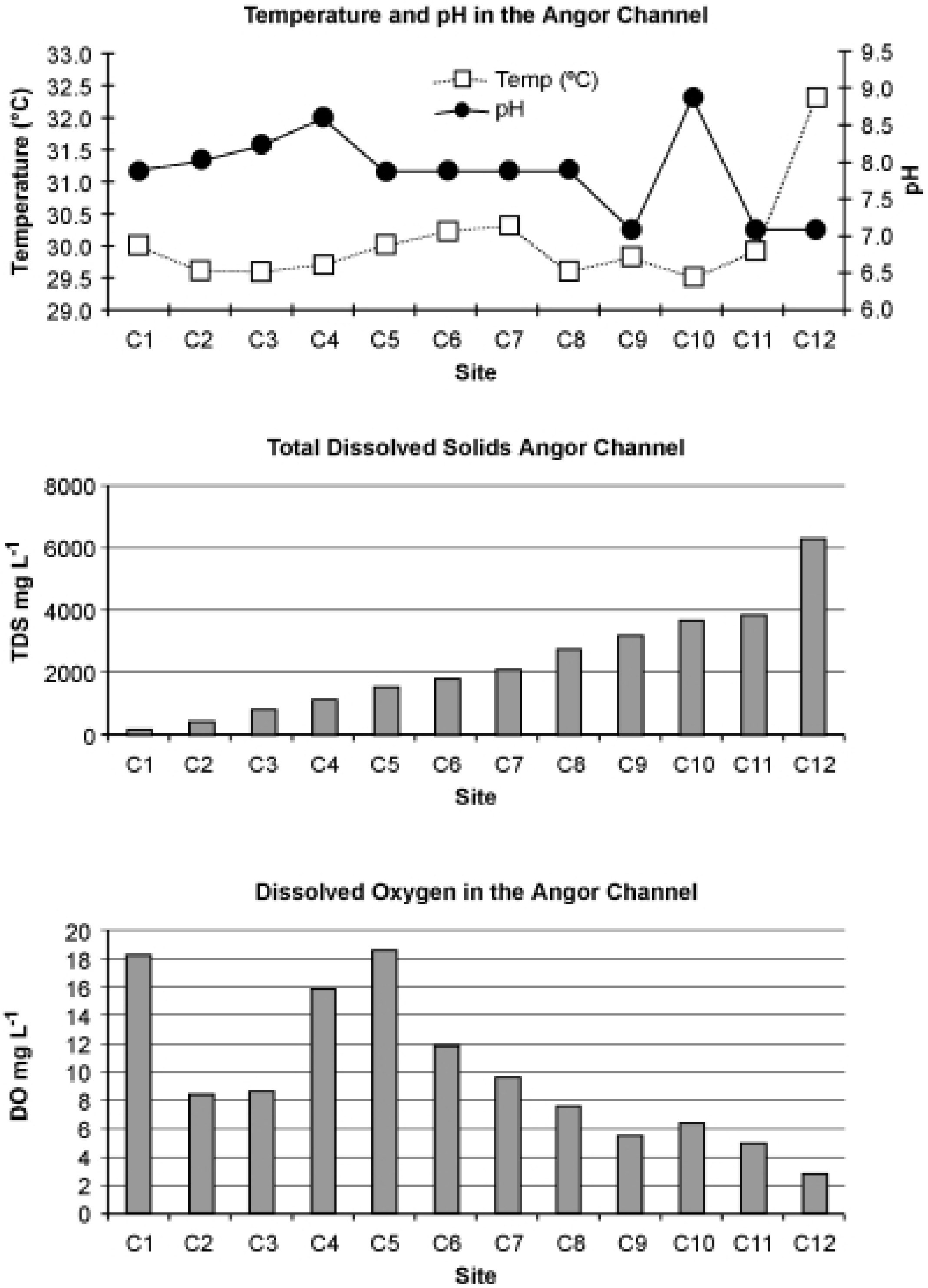


Figure 14 Water chemistry in the Angor channel

4.3.4 Temporal changes in water chemistry

Data on four parameters are presented here: water depth, pH, dissolved oxygen and salinity (figure 15). The second set of samples were taken five months after the first set in order to get as wide a time lag within the reporting limits of this study. The samples were taken just at the beginning of the Rainy season and help give a clearer picture of the situation on the ground. As would be expected water levels had fallen. This fall is all due to evaporation. The pH of the water fell at most of the sites, but by amounts that were not significant. The dissolved oxygen content of the water increased at most of the sites. This is to be expected given that water levels had fallen and epibenthic algae could now play a role in production processes. At most sites the salinity of the water increased. Again, this would be expected with the increasing concentration of ions with fall in water depth due to evaporation.

4.4 Aquatic ecology

4.4.1 Phytoplankton

Diversity

The phytoplankton in the 25 samples that were used for species identification consist primarily of benthic diatoms that have been dislodged from the bottom of the lagoons, plus a few true planktonic diatom species (table 20). These species are typical of shallow lagoons and most likely make a significant contribution to the primary production. Some blue-green alga species made up the remainder of the biomass. Both lagoons harboured diatoms characteristic of high salinity close to seawater or even higher. The only freshwater or brackish water species present were found in the samples from the Angor channel connecting Keta lagoon to the Volta. The two lagoons are characterised by separate diatom assemblages, although many species are common to both. The shallower Songor lagoon contained more benthic algal species.

Whilst the complete set of samples was not analysed, the initial identifications provide an indicative list of species. Further analysis of all samples and a time series of samples would provide more information on the effect of changing water depths and salinity on the primary production of the lagoons, and the relative importance of the benthic algal mats. A complete analysis of species present in the samples will require considerable more investment of time with taxonomic expertise required. For the purpose of an initial characterisation of the two lagoons this was not considered essential.

Chlorophyll

The chlorophyll concentrations are presented for each of the aquatic sampling sites in appendix 3. They are given as chlorophyll *a*, *b* and *c*. The concentrations in Keta ranged from undetectable to 145 $\mu g\ L^{-1}$ with a mean of $20 \pm 21\ \mu g\ L^{-1}$ and in Songor lagoon from undetectable to 86 $\mu g\ L^{-1}$ with a mean of $24 \pm 19\ \mu g\ L^{-1}$. In Keta chlorophyll *a* was generally present in greater concentrations than *b* or *c* whereas in Songor chlorophyll *b* was more prevalent in some, but not all sites. These figures suggest that the lagoons are highly productive (see comparable values in Finlayson et al 1984 for freshwater tropical lakes), although a time series of data is required to actually ascertain the level of primary production.

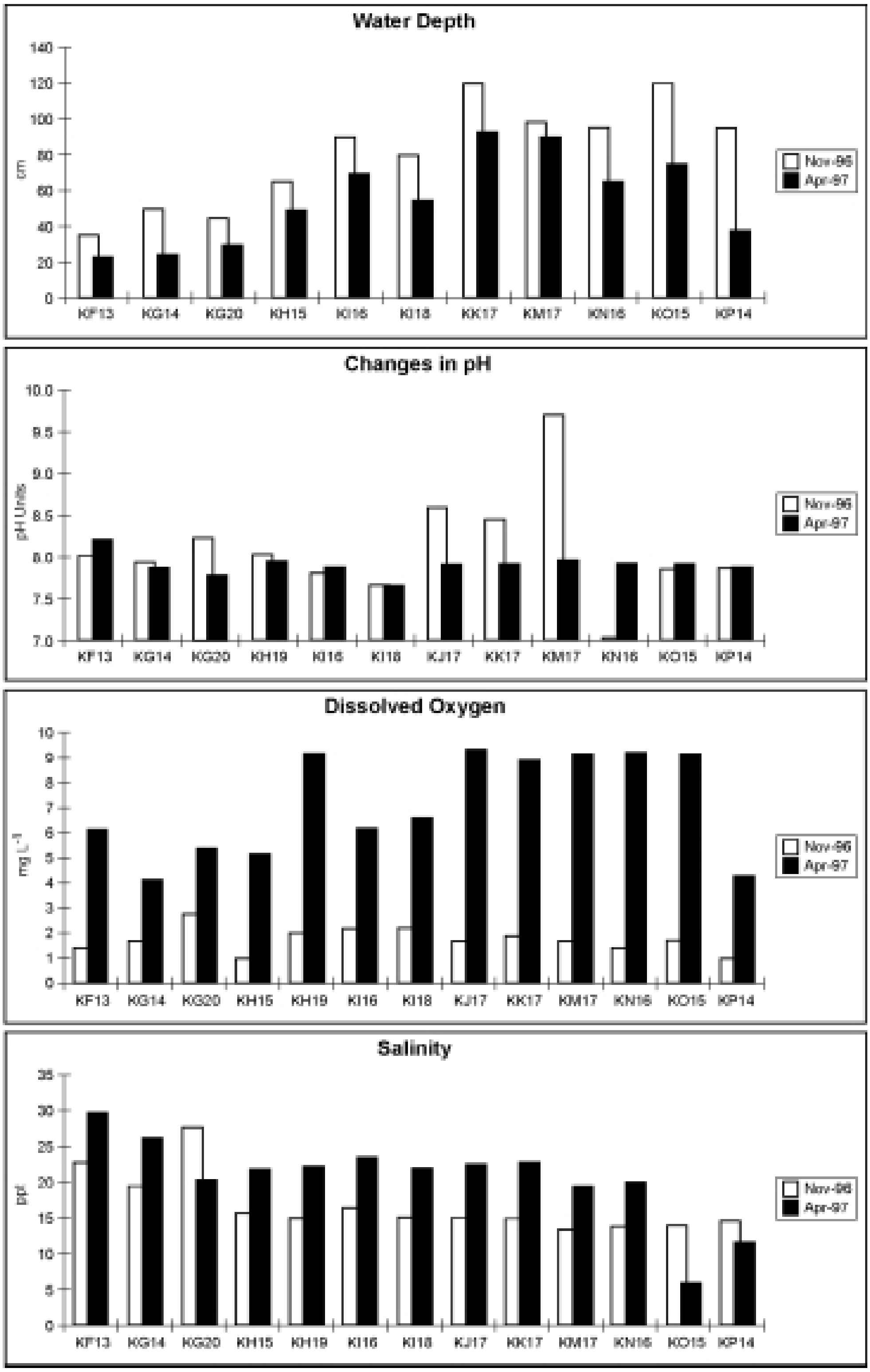


Figure 15 Temporal changes in water chemistry in the Keta lagoon

Table 20 Diatoms species in 25 samples collected from Keta and Songor lagoons

Keta lagoon	Songor lagoon
Actonoptychus spendens	*Actinocyclus octonarius*
Amphora coffeaeformis	*Amphora coffeaeformis*
Amphora holsatica	*Amphora ventricosa*
Amphora ovalis	*Bacillaria pacillifer*
Amphora ventricosa	*Campylodiscus clypeus* var. *bicostata*
Campylodiscus clypeus var. *bicostata*	*Chaetoceros* sp.
Chaetoceros sp.	Cocconeis disculus
Cocconeis disculus	*Cocconeis scutellum*
Cyclotela meneghiniana	*Cyclotela meneghiniana*
Cymbella pusilla	*Cymbella pusilla*
Diploneis ovalis	*Diploneis smithii*
Diploneis smithii	*Diploneis suborbicularis*
Entomoneis paludosa	*Entomoneis paludosa*
Gyrosigma acuminatum	*Fallacia auricula*
Gyrosigma balticum	*Gyrosigma acuminatum*
Gyrosigma eximium	*Gyrosigma eximium*
Hyalodiscus subtilis	*Gyrosigma nodiferum*
Mastogloia pumila	*Gyrosigma scalproides*
Navicula durrenbergii	*Gyrosigma spencerii*
Navicula maculata	*Mastogloia liatungensis*
Nitzschia compressa var. *oblonga*	*Mastogloia pumila*
Nitzschia obtusa	*Navicula* sp.
Nitzschia scalaris	*Navicula trivalis*
Pleurosigma elongatum	*Navicula yarrensis*
Rhopaloida gibberula	*Nitzschia granulata*
Surirella sp.	*Nitzschia panduriformis*
Tabularia tabulata	*Nitzschia scalaris*
Thalassiosira lacustris	*Ioephora martyi*
Thalassiosira weissflogii	*Pleurosigma elongatum*
Tryblionella apiculata	*Pleurosigma salinarum*
Turpsinoe americana	*Rhopaloida gibberula*
	Stauroneis spicula
	Tabularia tabulata
	Thalassiosira hyperborea
	Thalassiosira lacustris
	Thalassiosira weissflogii
	Triblionella victoriae
	Tropidoneis pusila
	Turpsinoe americana

(information supplied by Dr J John)

4.4.2 Zooplankton

Diversity

As would be expected from temporary waters with extremes of salinity and temperature, the zooplanktonic diversity in the two lagoons was not high. The situation was further complicated by the shallow nature of the waters sampled, leading to the appearance of several epibenthic species in the water column. Samples have been sent to taxonomic experts for further identification. Three main groups were found in the plankton sampling: Ostracods, Copepods and Amphipods.

Abundance and distribution

Zooplankton were found in all parts of the lagoon. Table 21 below gives an indication of the numbers and where they were found in the lagoon. As these are data from single samples, they should be treated with care due to the extremely patchy nature of zooplankton.

Table 21 Zooplankton in the Keta and Songor lagoons (numbers per 50 litres)

Site	Ostracod	Copepod	Amphipod	Site	Ostracod	Copepod	Amphipod
Keta							
KD 17	0	22	1	KL 18	0	0	400
KD 18	0	1	0	KM 16	0	150	0
KD 19	0	90	1	KM12	0	12	0
KD 20	0	10	0	KN 15	0	275	0
KD 22	0	1	0	KN 16	0	12	0
KE 18	0	6	18	KN 17	0	64	0
KF 13	0	2	0	KO 13	0	313	0
KF 14	4	113	0	KO 14	0	33	25
KF 15	0	5	0	KO 16	0	26	0
KF 19	0	48	0	KO 17	0	13	0
KF 20	1	3	0	KP 13	0	83	10
KF18	0	240	0	KP 14	0	3	0
KG 13	0	12	2	KQ 10.5	0	55	0
KG 14	0	23	0	KQ 14	0	0	4
KG 15	0	32	0	KR 10	0	61	0
KG 16	1	57	0				
KG 17	0	14	0	**Songor**			
KG 19	0	61	0	SB 13	8	9	0
KG 20	0	800	0	SB 6	0	0	1
KH 14	0	1	0	SB 7	0	0	1
KH 15	0	5	0	SC 10	0	0	9
KH 17	0	31	0	SC 3	0	1	0
KH 18	0	62	3	SC 9	0	2	0
KH 20	0	200	0	SD 10	0	0	1
KI 14	29	3	0	SD 11	12	0	0
KI 17	26	0	0	SD 4	0	1	0
KJ 17	0	24	0	SD 9	1	0	0
KJ 18	9	9	0	SE 11	41	8	0
KJ 19	0	35	0	SE 7	1	0	1
KK 17	0	50	0	SF 10	4	0	0
KL 15	1	39	0	SF 11	20	6	0
KL 16	6	155	0	SF 12	60	4	0
KL 17	0	13	0	SF 9	5	0	1

4.4.3 Benthos

Diversity

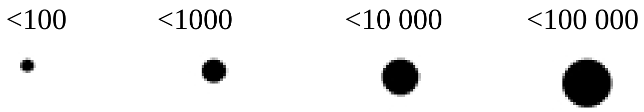
An assessment of the species richness of the benthos is based on the data shown in appendix 4. The presence of the commoner macroinvertebrate species is given in table 22. The fauna is dominated by three groups of organisms: annelids, molluscs and crustacea. For this type of waterbody, the insecta seemed under represented. This may be due to the large numbers of fish that are found in the lagoons.

Table 22 Presence of common macroinvertebrates at the Songor and Keta sites

	Songor Lagoon	Keta Lagoon
Annelida		
Polychaetes		x
Boccardiella		x
Brachidontes		x
Capitellid		x
Eunice		x
Glycera		x
Nereis		x
Notomastus	x	x
Dipsio africana	x	x
Oligochaetes	x	x
Mollusca		
Bolinus cornutus	-	x
Brachydontes niger	-	x
Congeria ornata	-	x
Corbula trigona	x	x
Gastrana multangula	-	x
Hydrobia accrensis	-	x
Loripes aberrans	-	x
Melanoides tuberculata	x	x
Neritina adansoniana	-	x
Pachymelania byronensis	-	x
Tellina nymphalis		x
Tivela tripla	-	x
Tympanotonus fuscata	x	x
Crustacea		
Urothoë grimaldi	x	x
Excirolana latipes	x	x
Parapenaeopis atlantica	-	x
Penaeus kerathurus	-	x
Penaeus notialis	-	x
Callinectes amnicola	x	x
Cardisoma armatum	x	
Ocypode africana	x	x
Sersarma huzardi	-	x
Uca tangeri	-	x

Abundance and distribution

The abundance and distribution of the main macro-zoobenthic species are presented in a series of maps (figures 16–42) based on the data presented in appendix 5. A summary of the data is given in tables 23 and 24. In the Keta lagoon, the most commonly encountered species was the mollusc *Tivela*, followed by the gastropod *Tympanotonos* which occurred in 61 and 58 of the sites sampled. At Songor, polychaetes were the most common species. The numbers of macro-zoobenthos reached remarkable numbers at some sites, oligochaetes were found in numbers exceeding 70 000 per m^2. The numbers of invertebrates at Songor per square metre were much less than at Keta. The scale used for the diagrams is as follows:



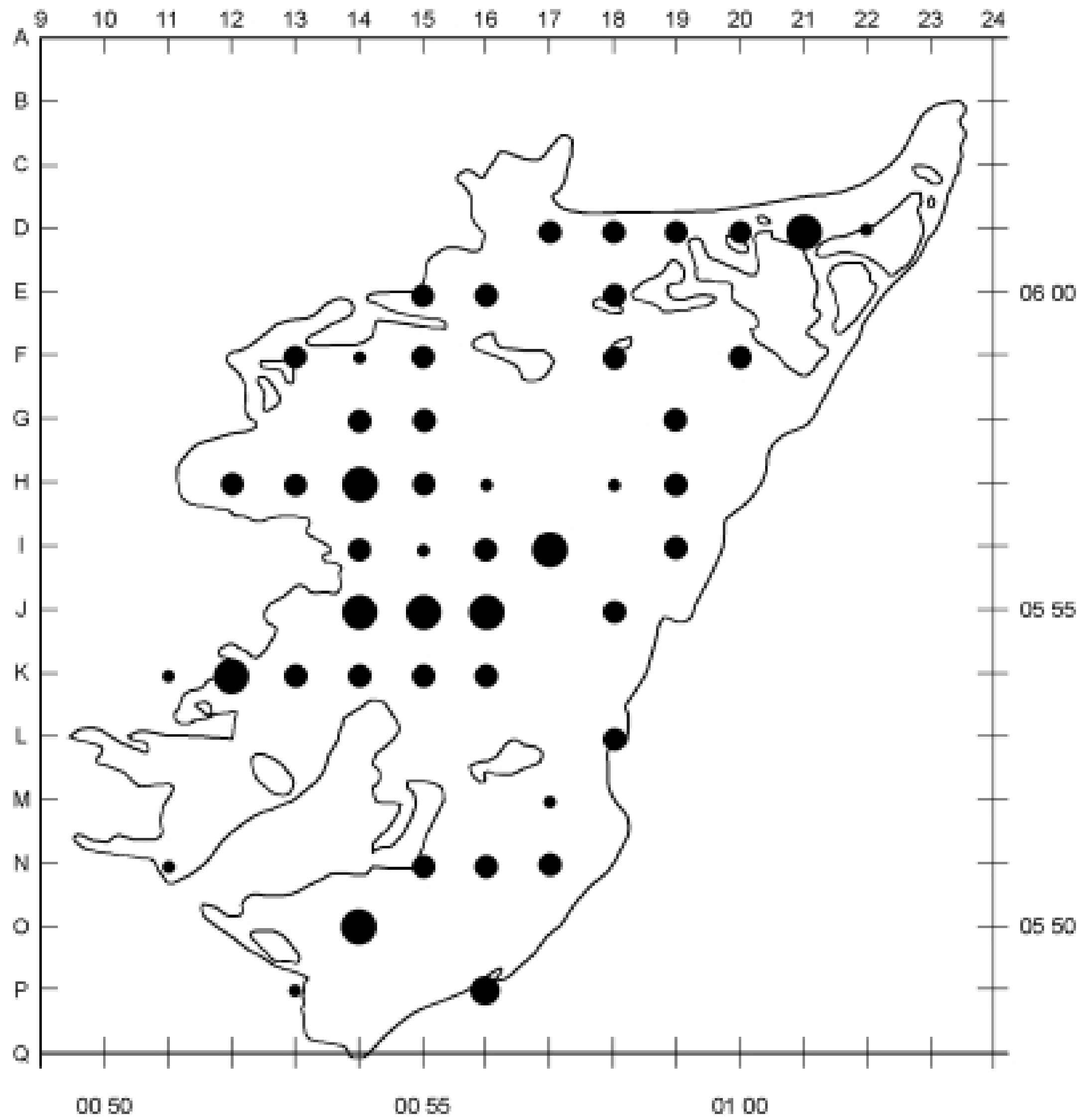


Figure 16 Distribution of *Boccardielia* in Keta lagoon

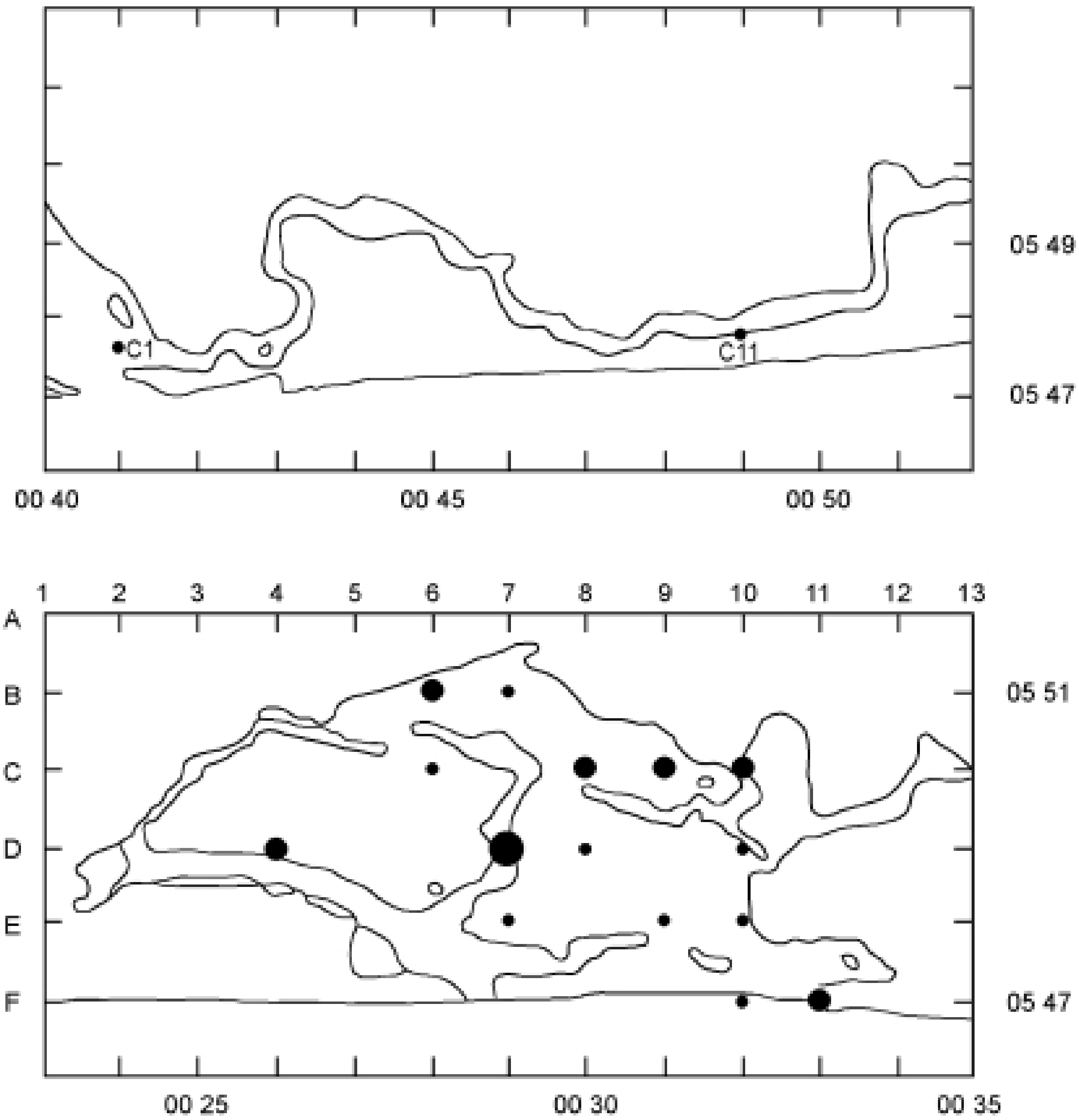


Figure 17 Distribution of *Boccardielia* in (top) the Angor channel connecting Keta lagoon to the Volta River, and (bottom) in Songor lagoon

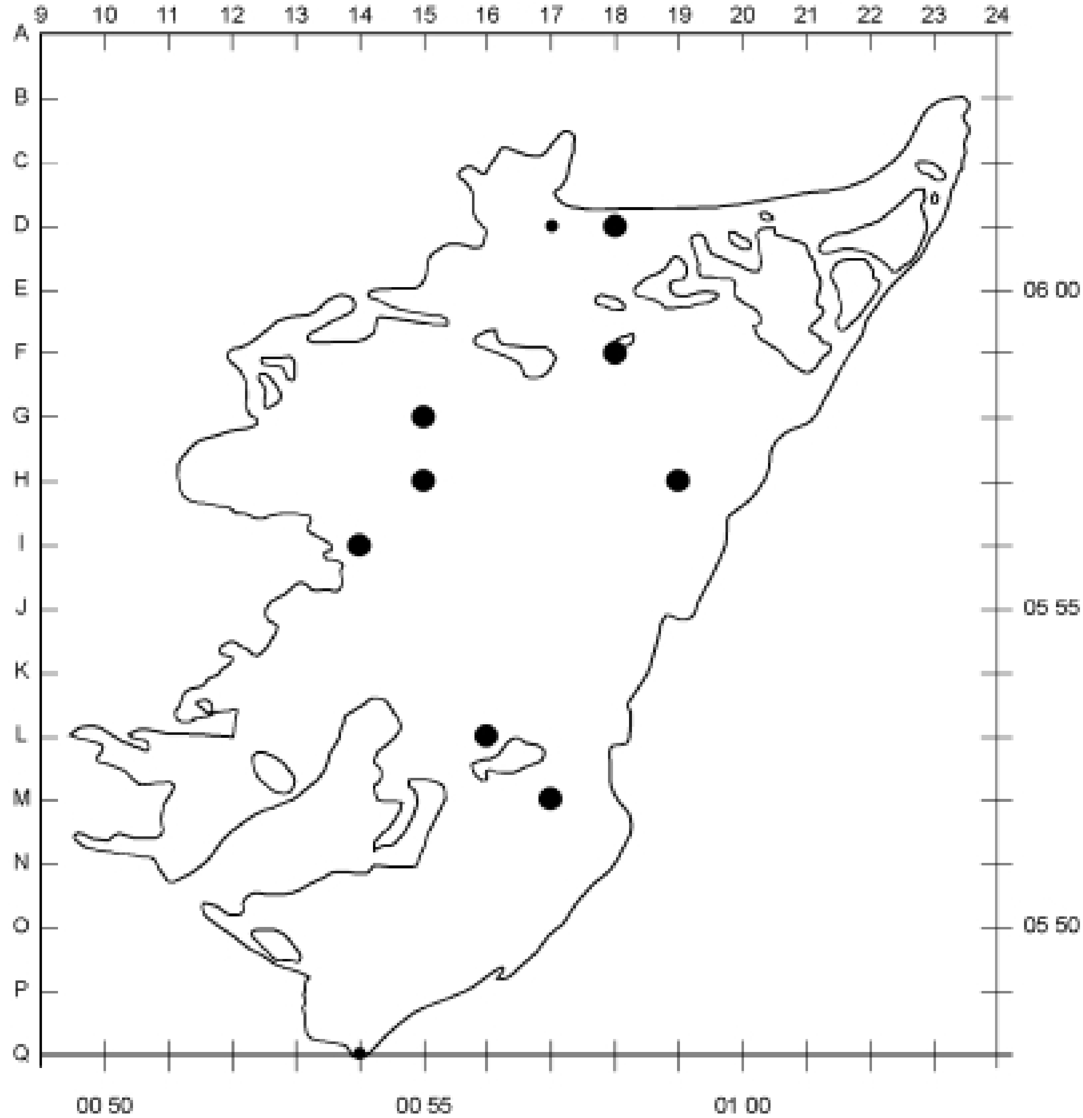


Figure 18 Distribution of *Capitellids* in Keta lagoon

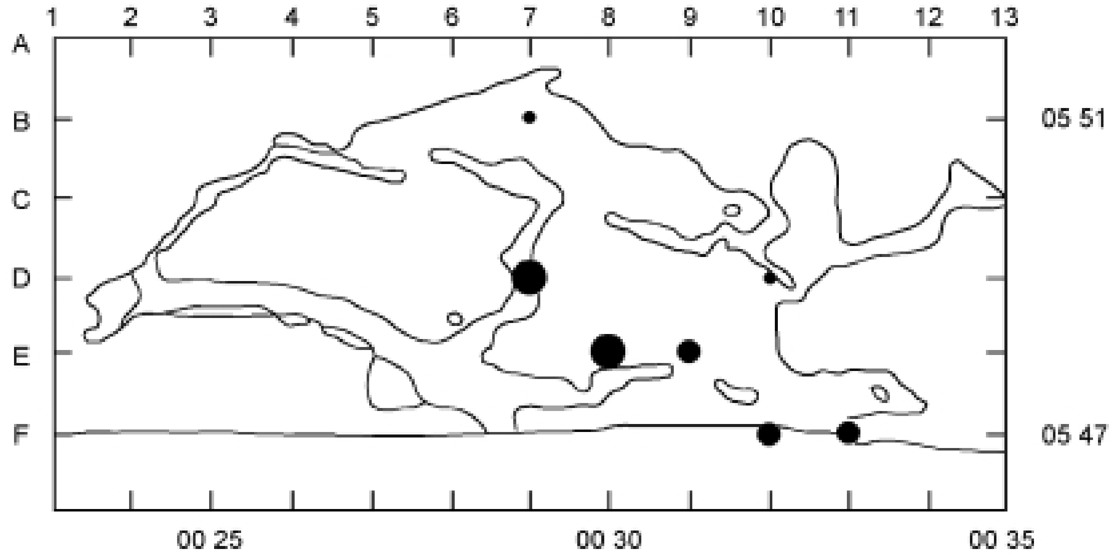


Figure 19 Distribution of *Capitellids* in Songor lagoon

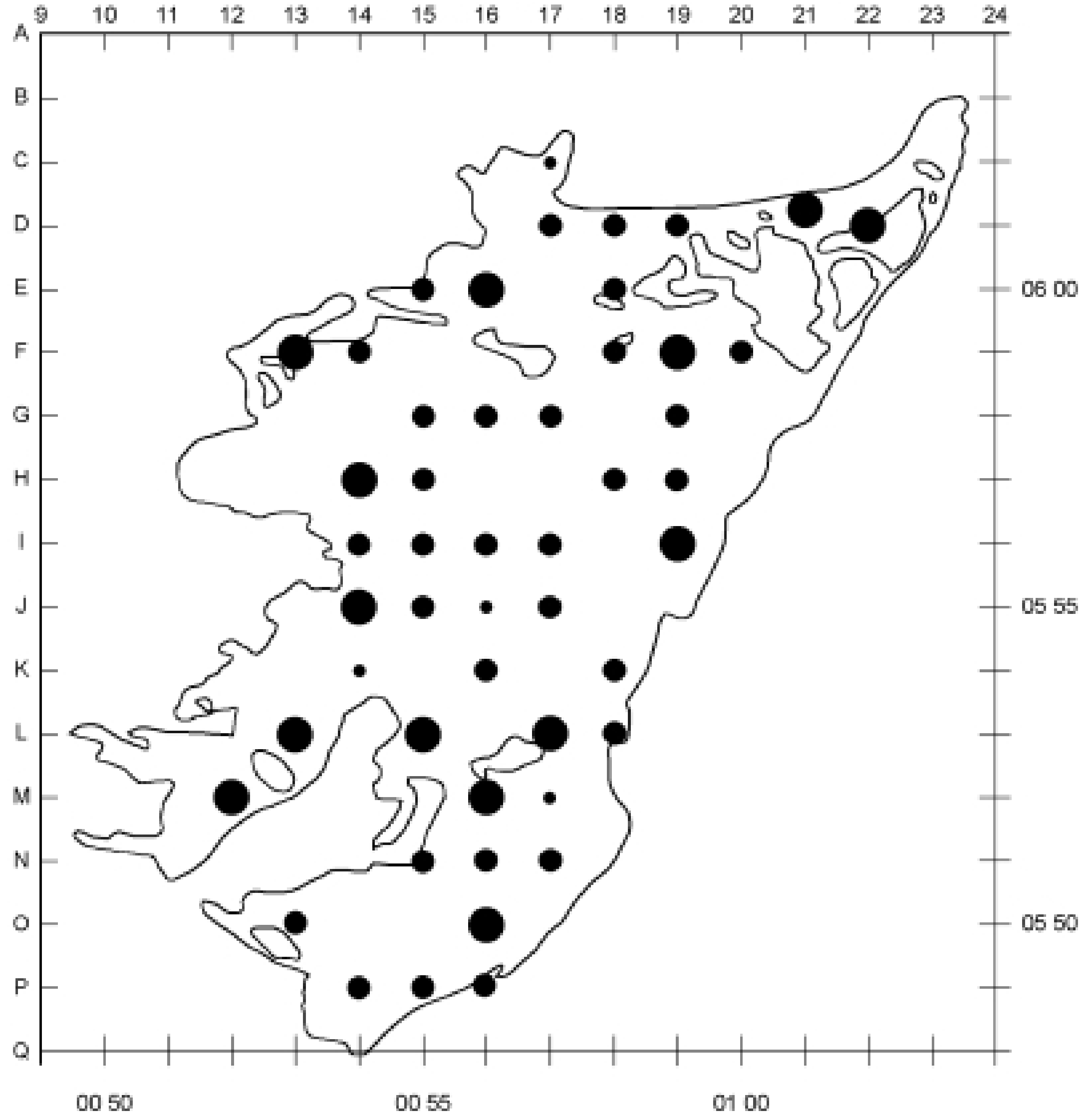


Figure 20 Distribution of *Nereis* in Keta lagoon

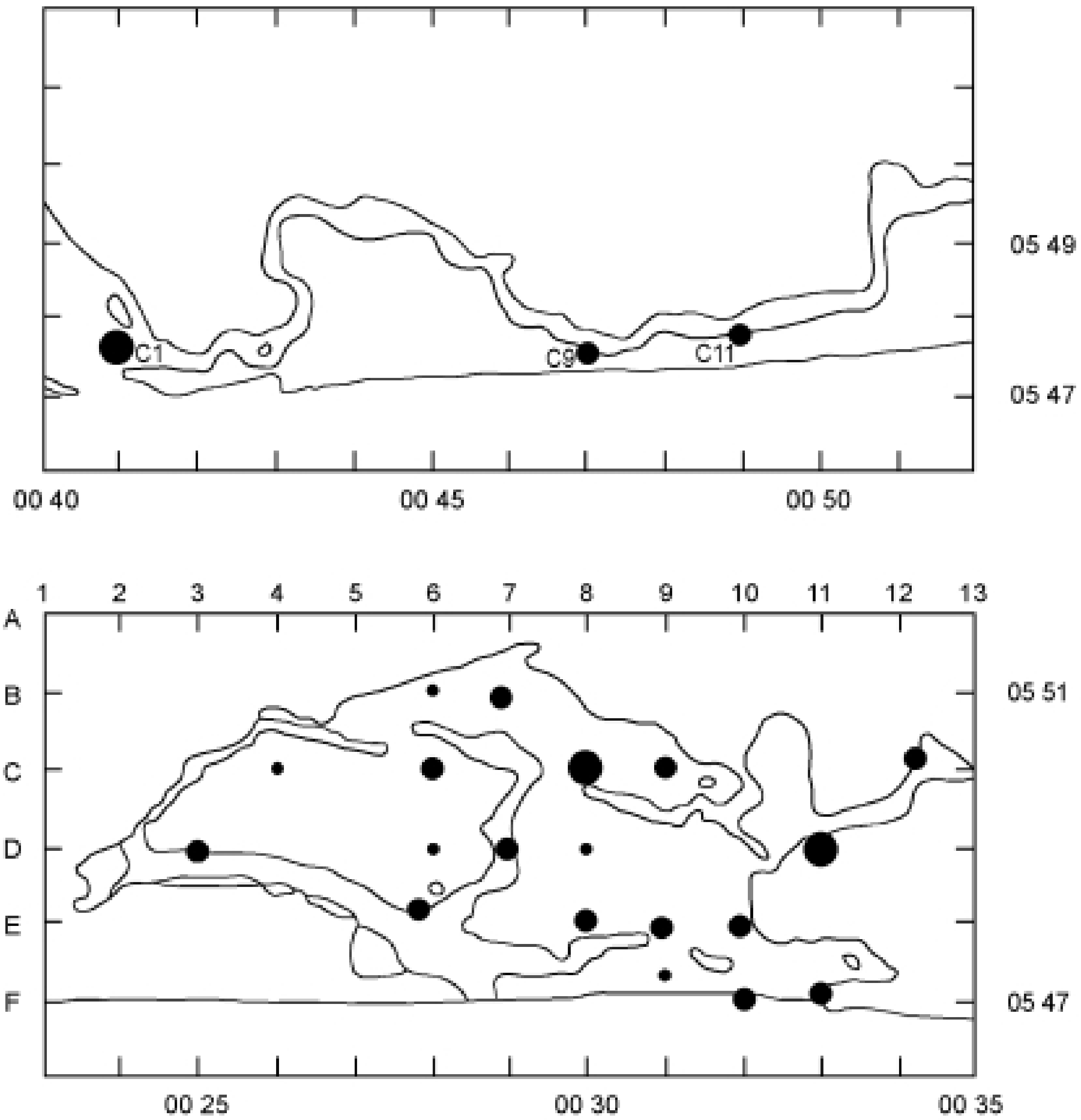


Figure 21 Distribution of *Nereis* in (top) the Angor channel connecting Keta lagoon to the Volta River, and (bottom) in Songor lagoon

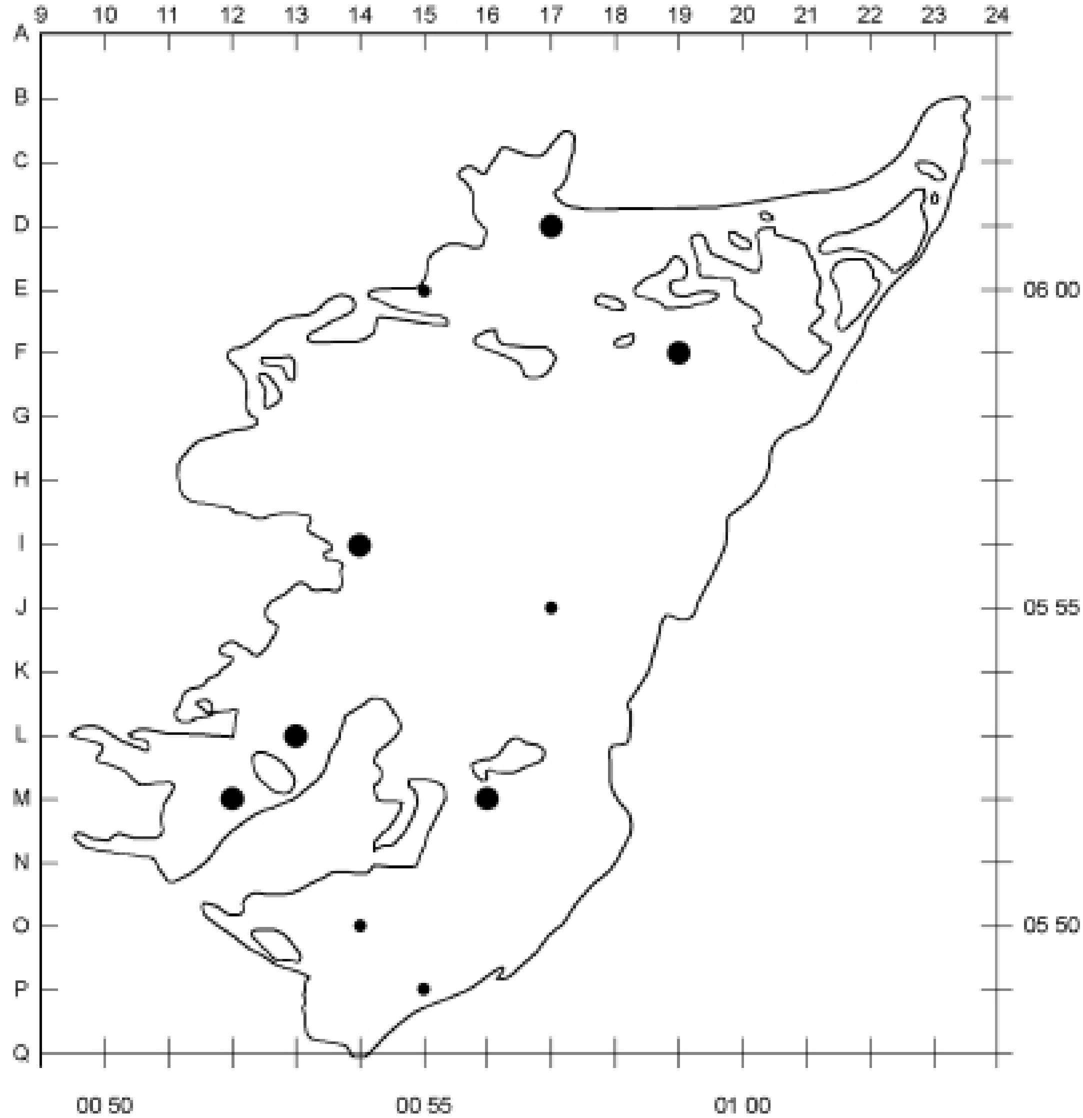


Figure 22 Distribution of *Gylcera* in Keta lagoon

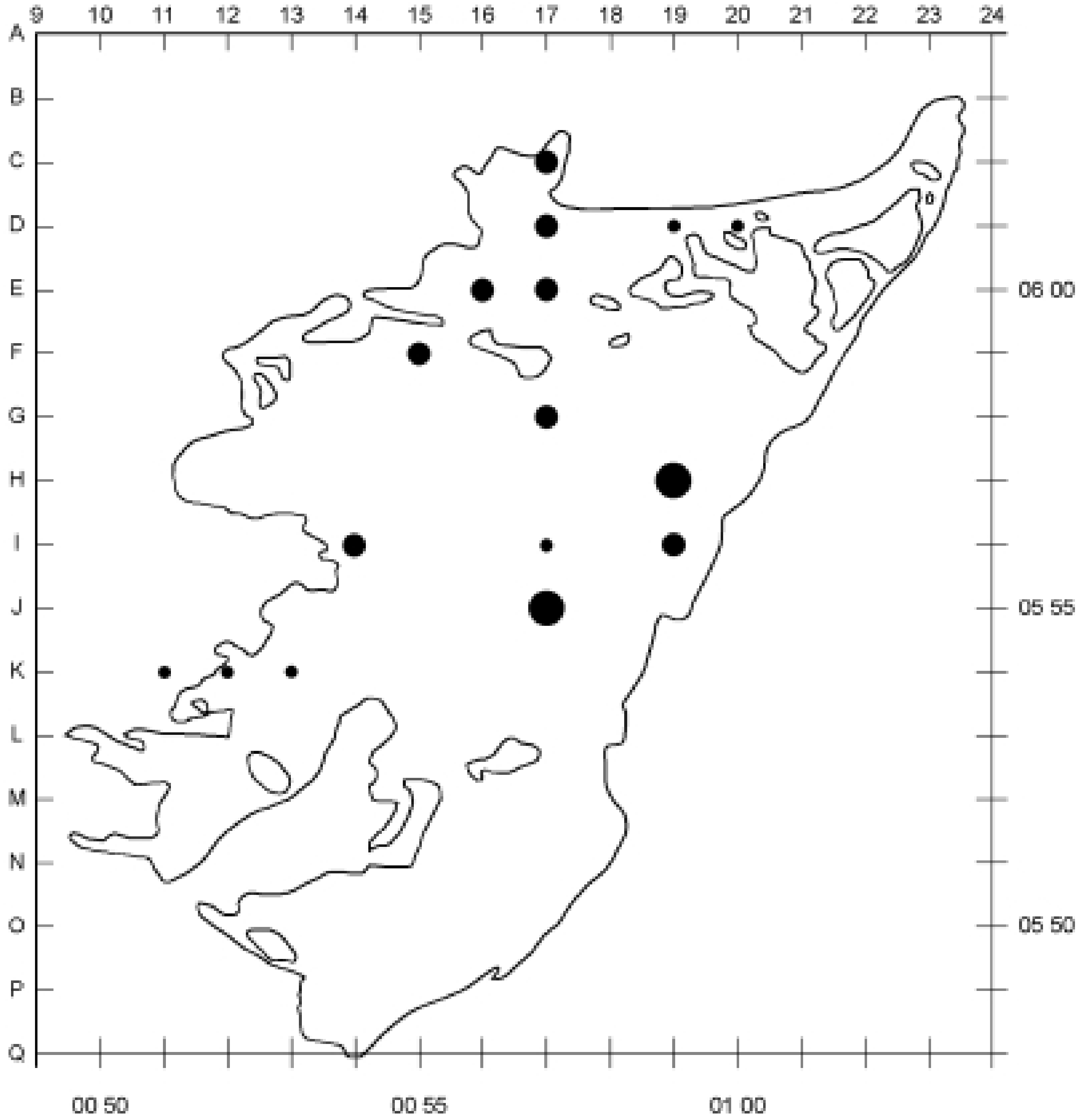


Figure 23 Distribution of *Notomastus* in Keta lagoon

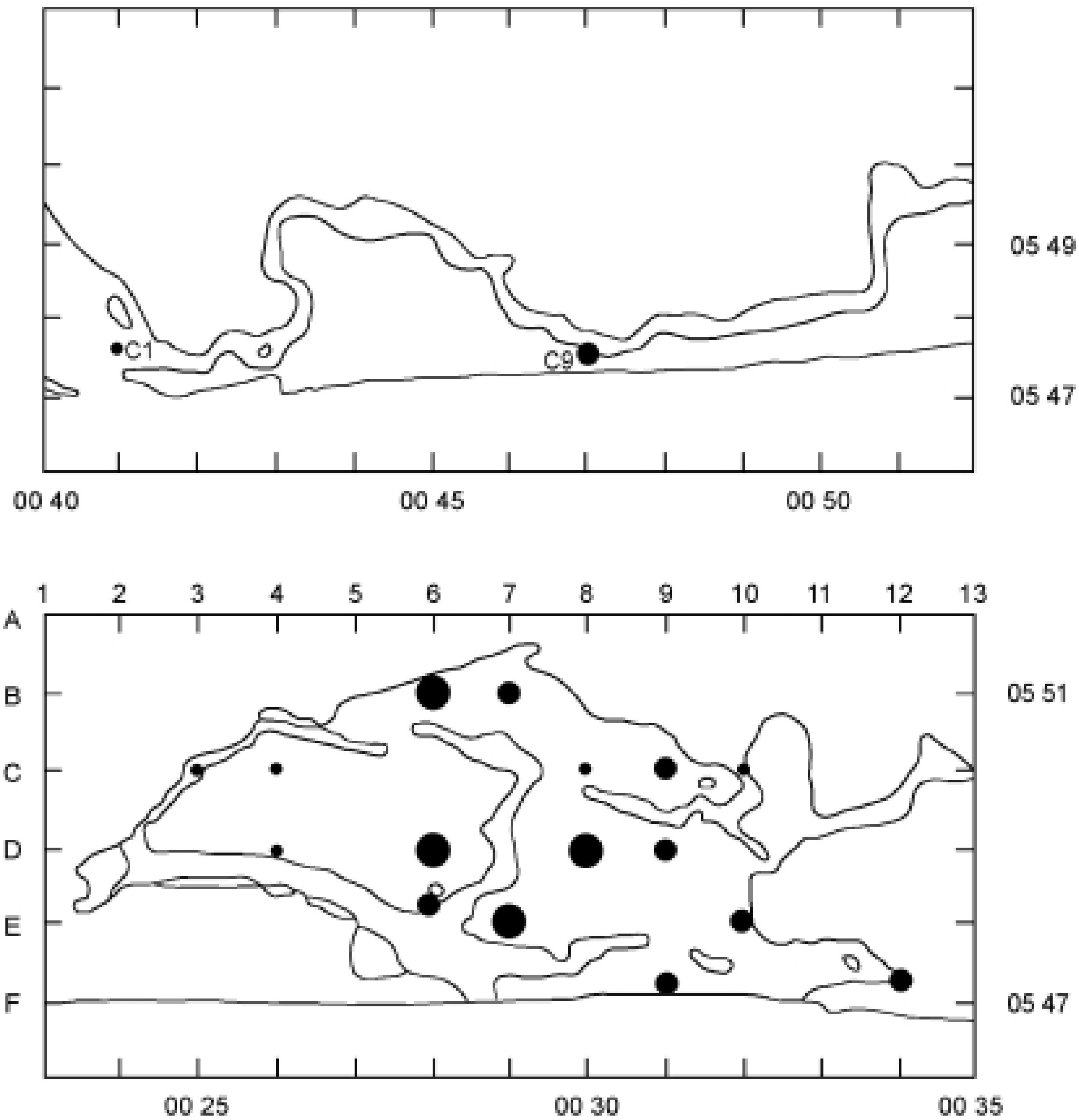


Figure 24 Distribution of *Notomastus* in (top) the Angor channel connecting Keta lagoon to the Volta River, and (bottom) in Songor lagoon

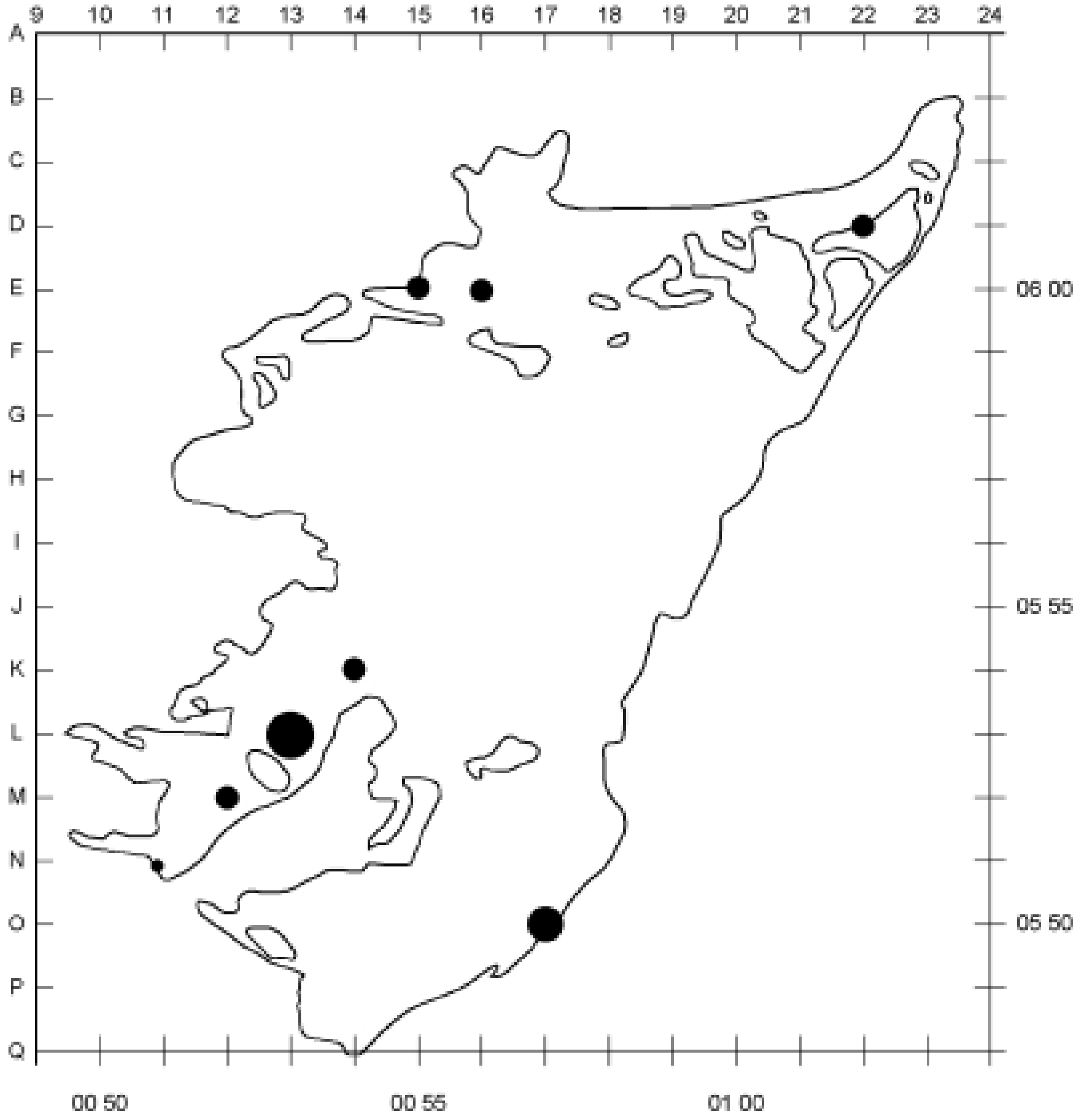


Figure 25 Distribution of *Oligochaetes* in Keta lagoon

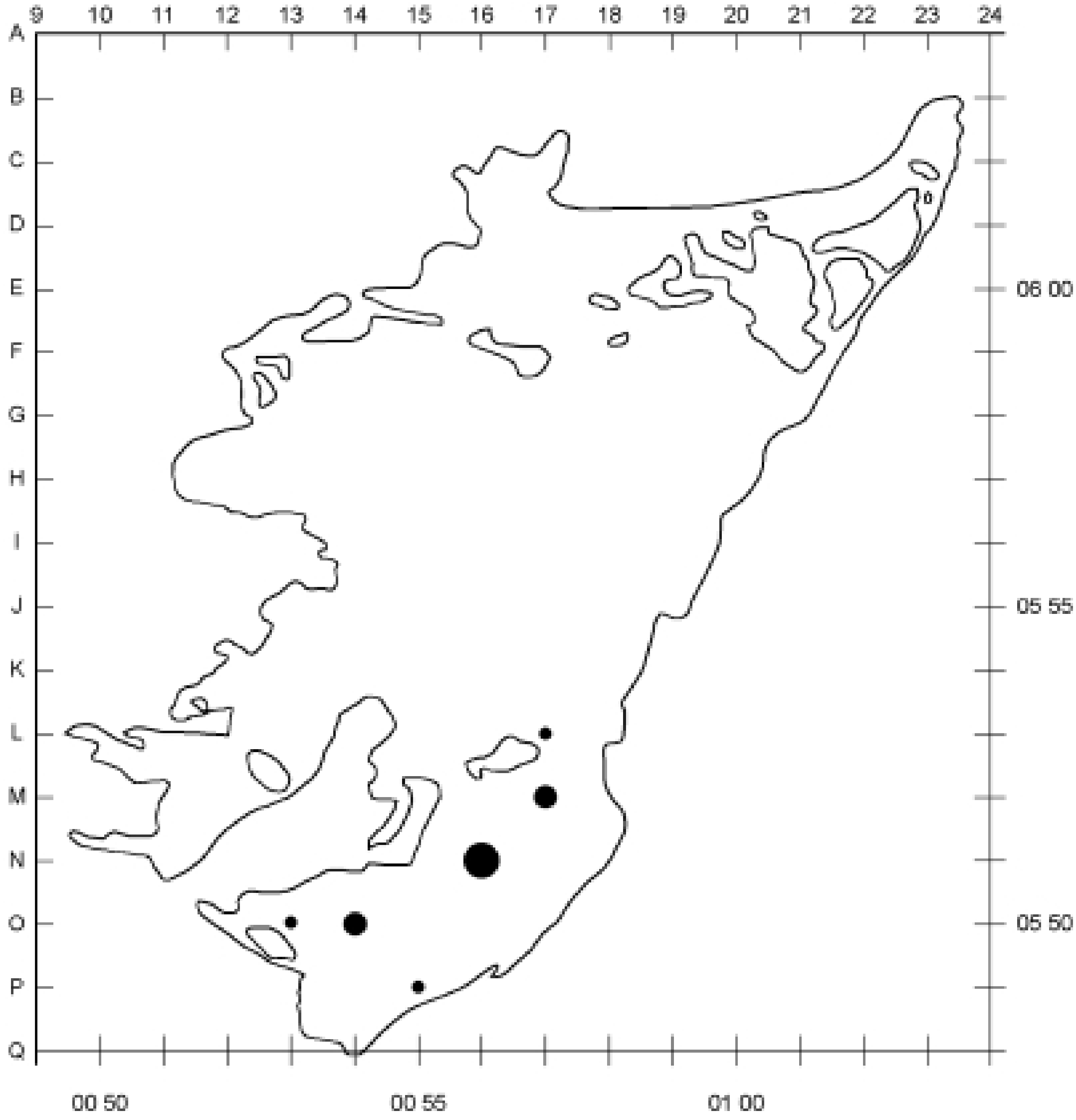


Figure 26 Distribution of *Brachidontes* in Keta lagoon

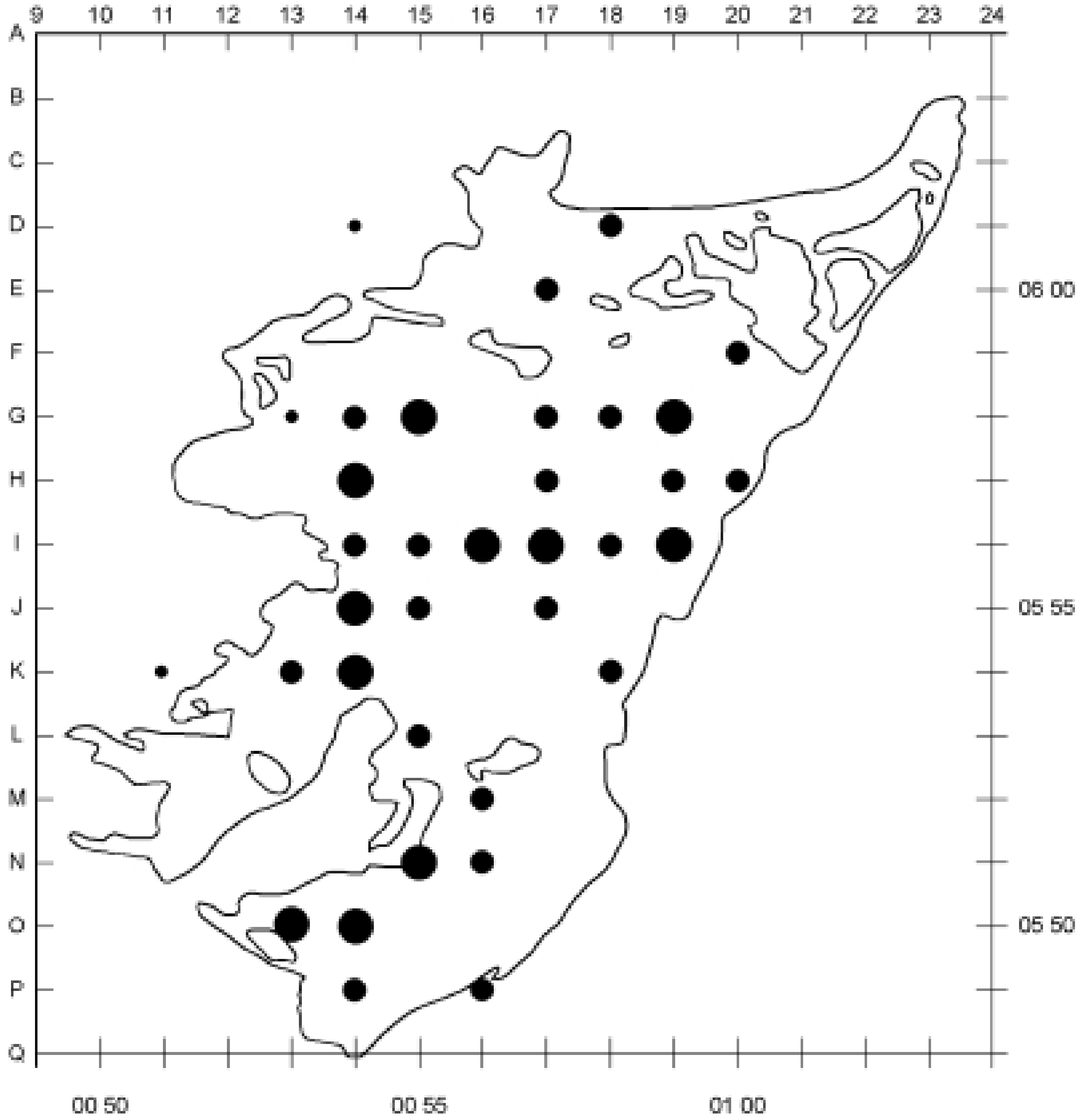


Figure 27 Distribution of *Corbula* in Keta lagoon

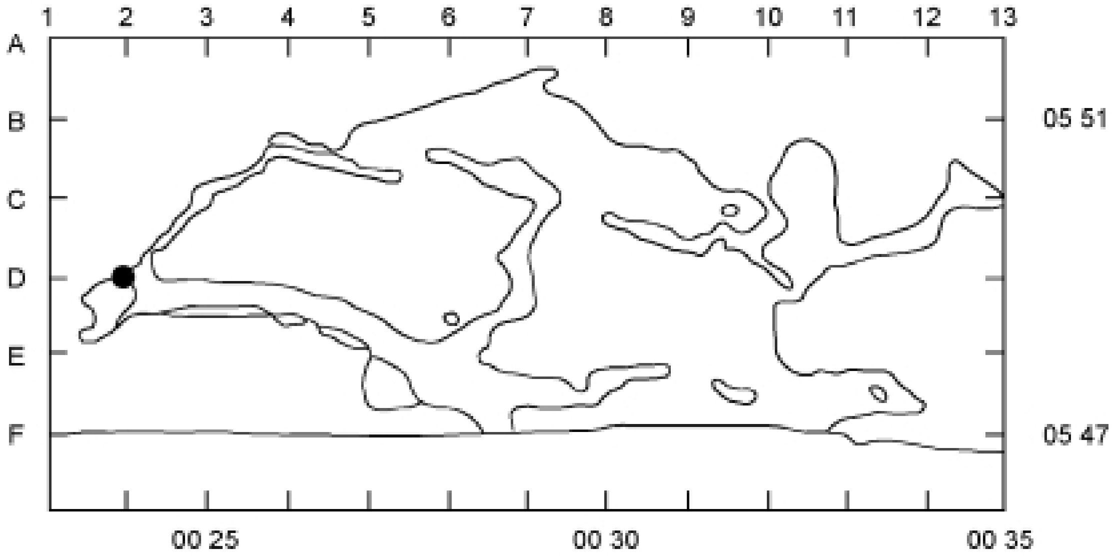


Figure 28 Distribution of *Corbula* in Songor lagoon

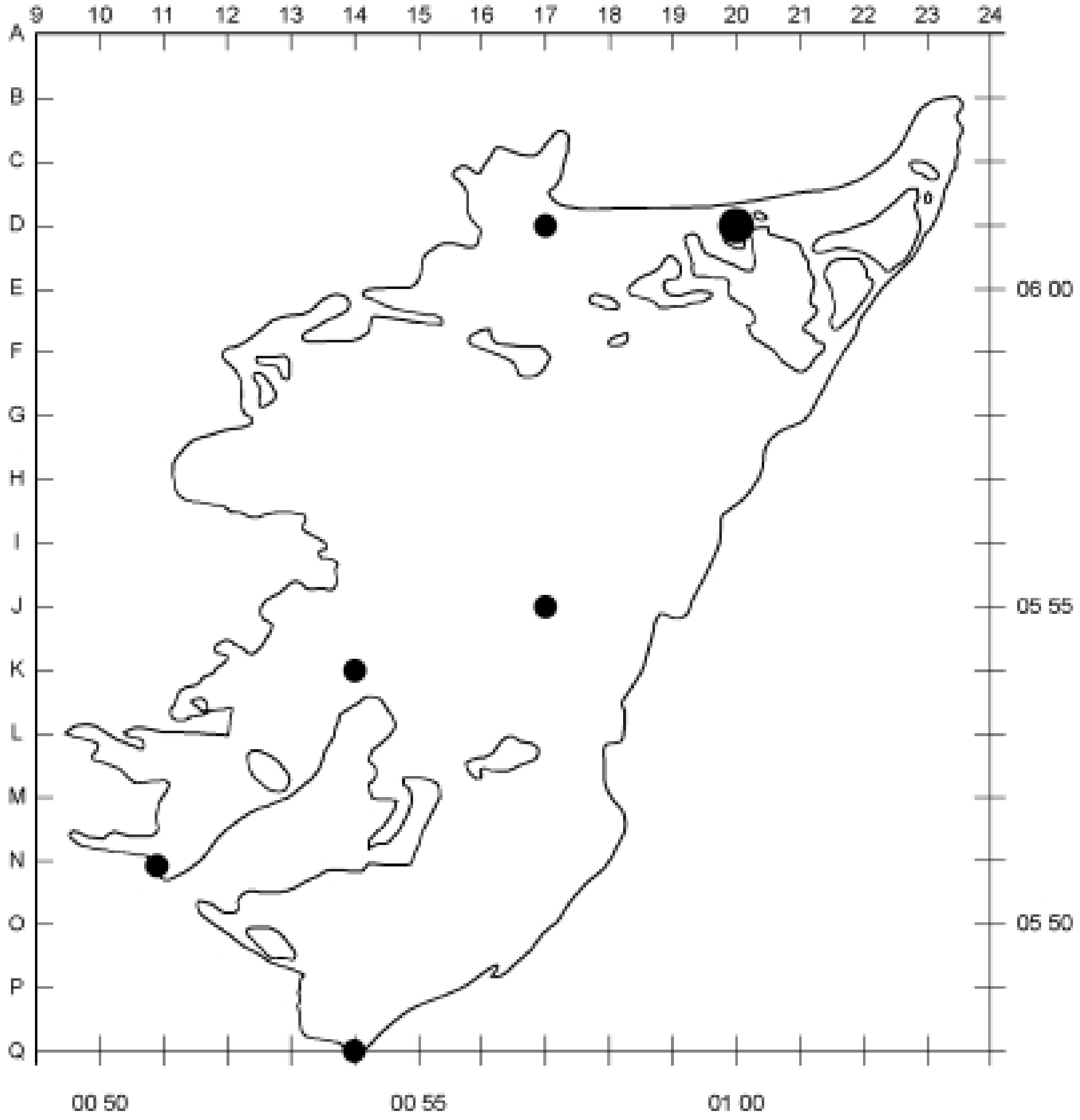


Figure 29 Distribution of *Hydrobia* in Keta lagoon

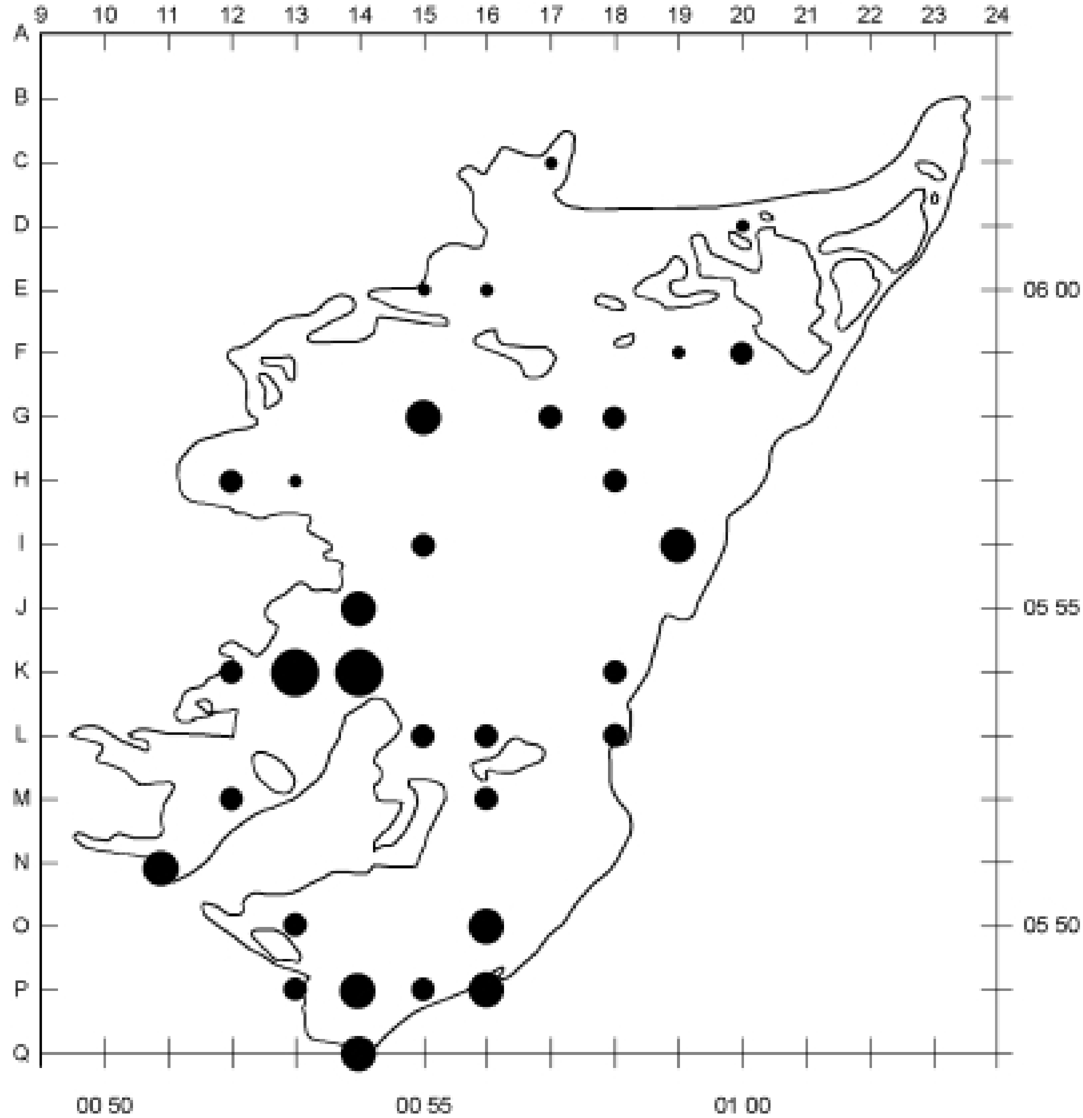


Figure 30 Distribution of *Melanoides* in Keta lagoon

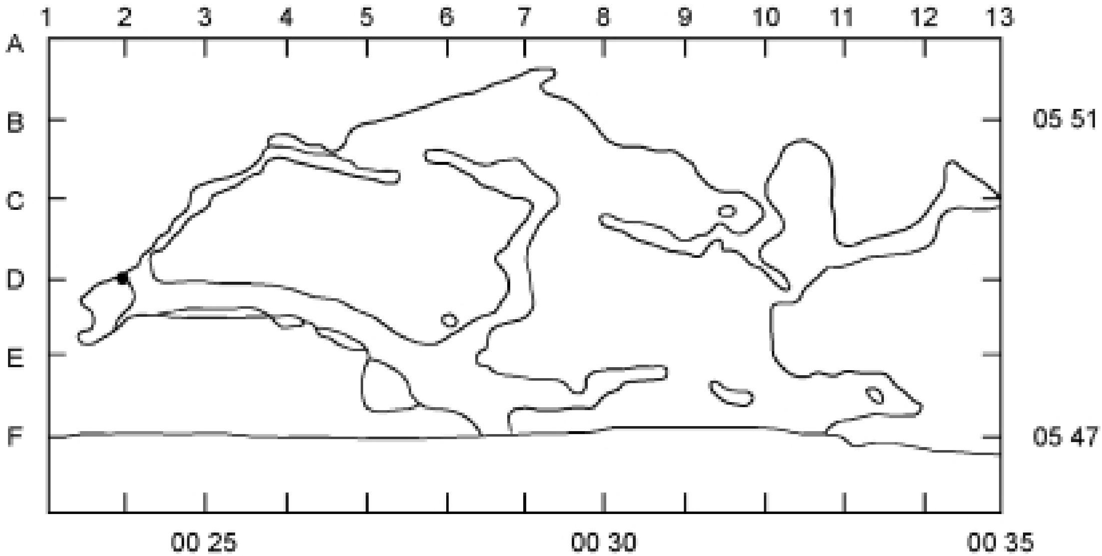


Figure 31 Distribution of *Melanoides* in Songor lagoon

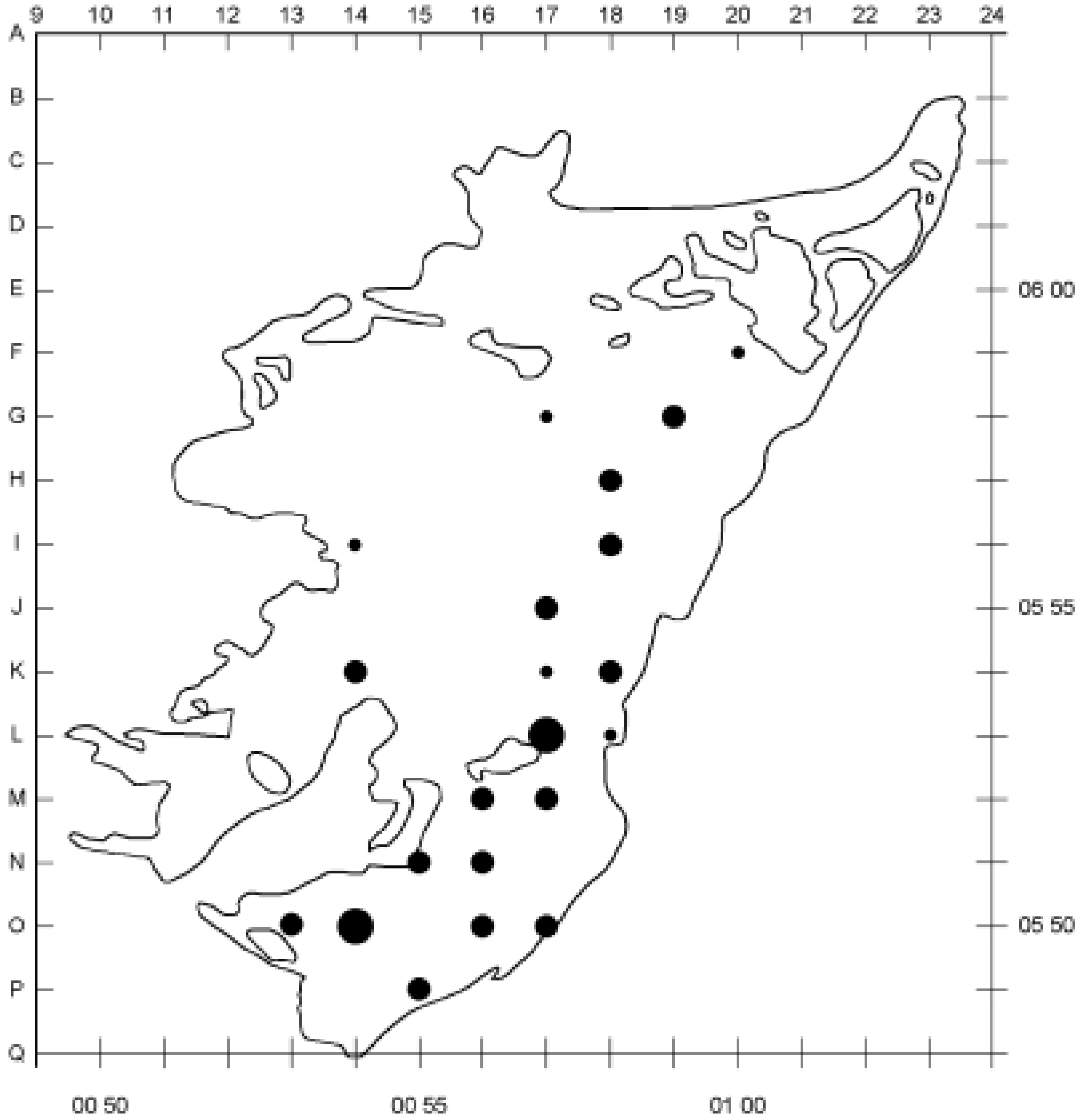


Figure 32 Distribution of *Nerita* in Keta lagoon

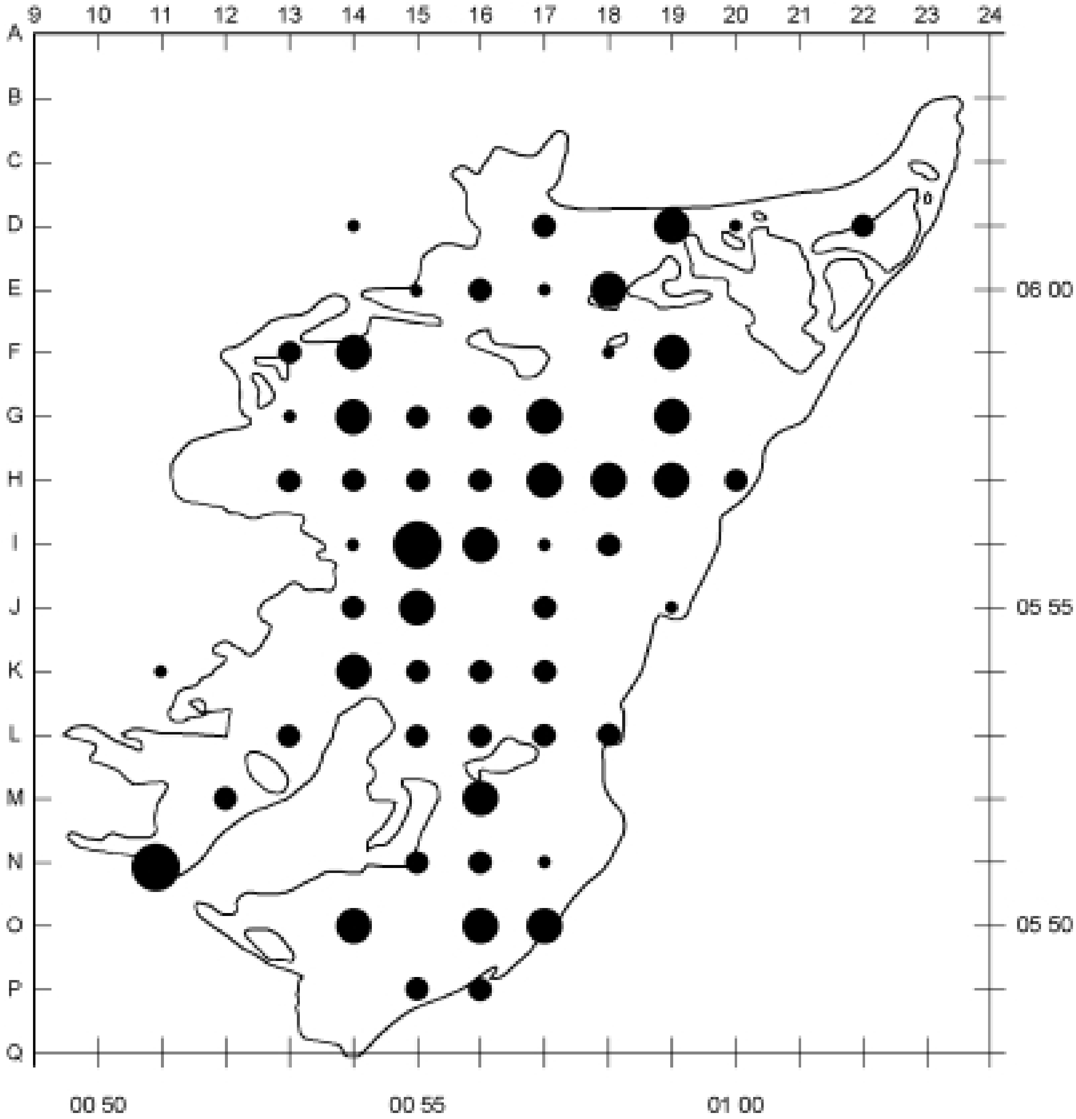


Figure 33 Distribution of *Tivela* in Keta lagoon

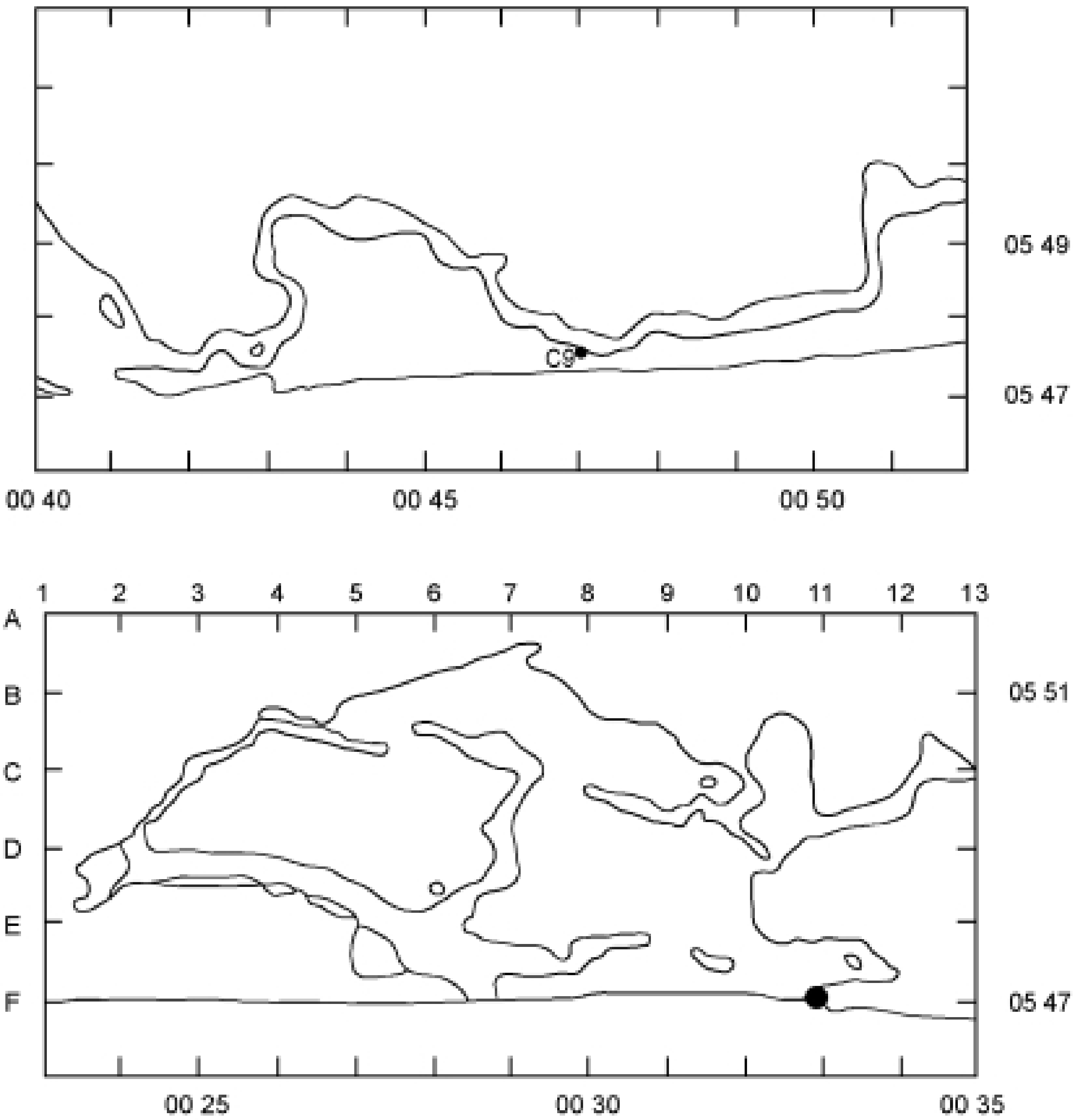


Figure 34 Distribution of *Tivela* in (top) the Angor channel connecting Keta lagoon to the Volta River, and (bottom) in Songor lagoon

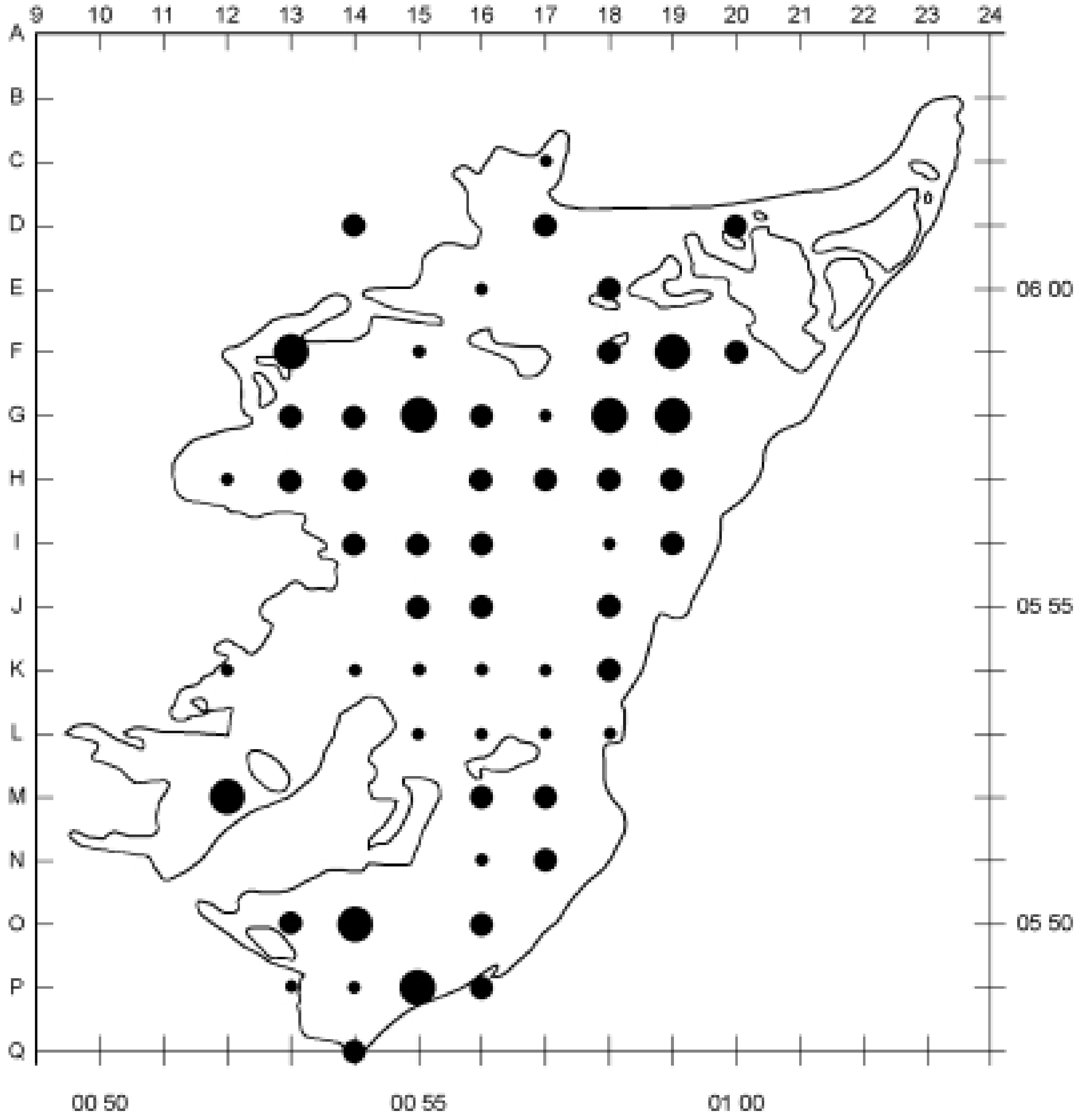


Figure 35 Distribution of *Tympanotonos* in Keta lagoon

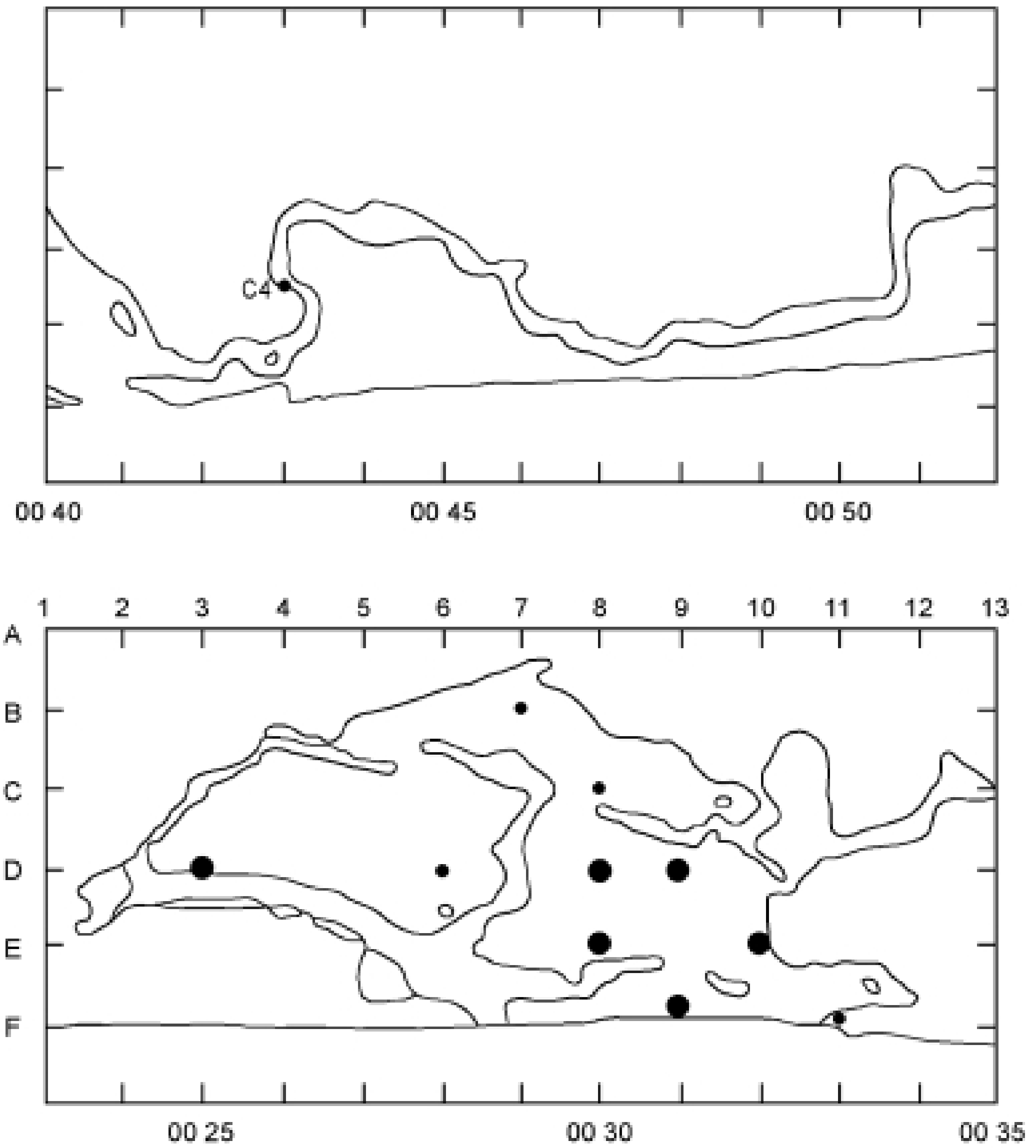


Figure 36 Distribution of *Tympanotonos* in(top) the Angor channel connecting Keta lagoon to the Volta River, and (bottom) in Songor lagoon

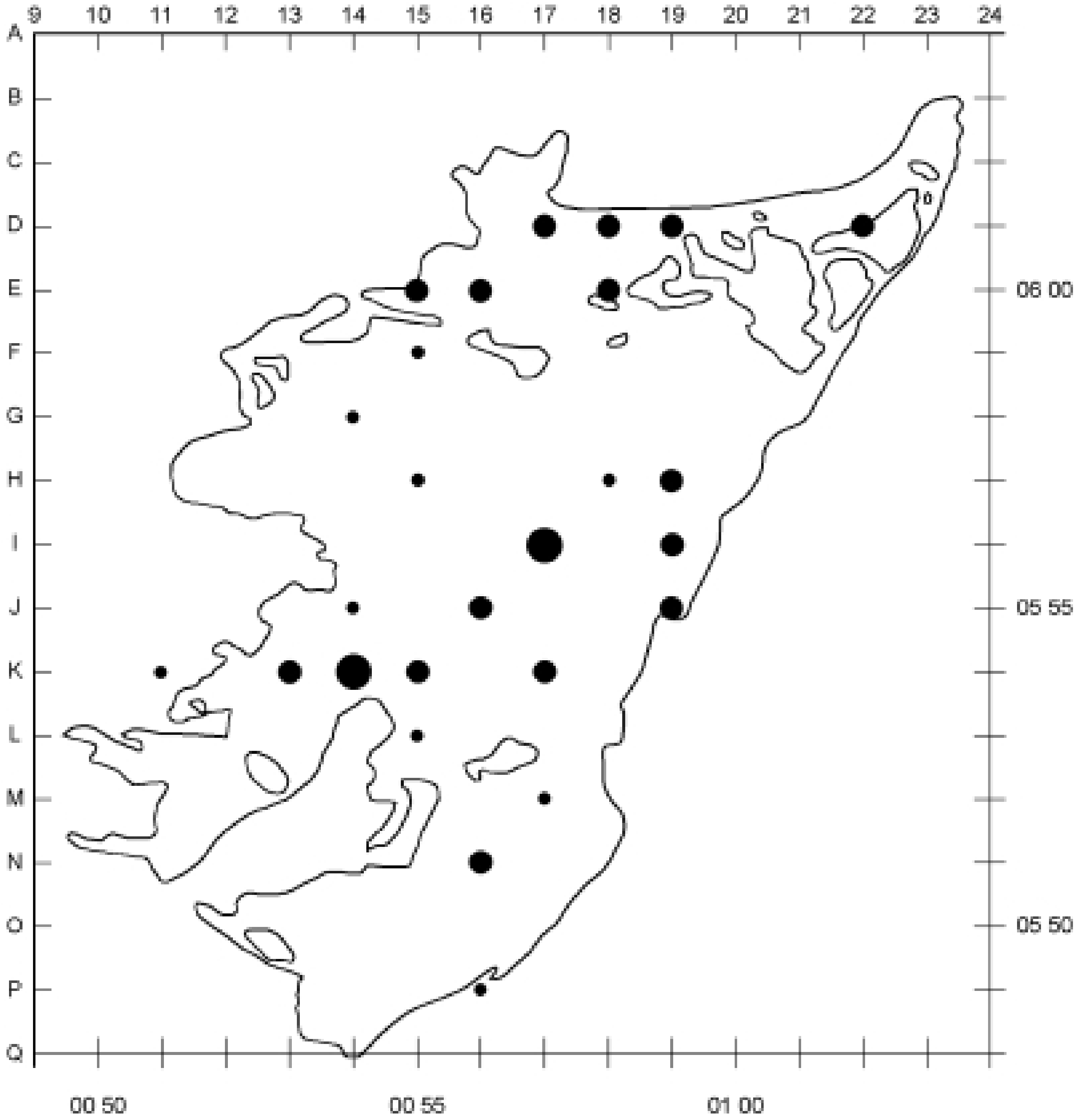


Figure 37 Distribution of *Eunice* in Keta lagoon

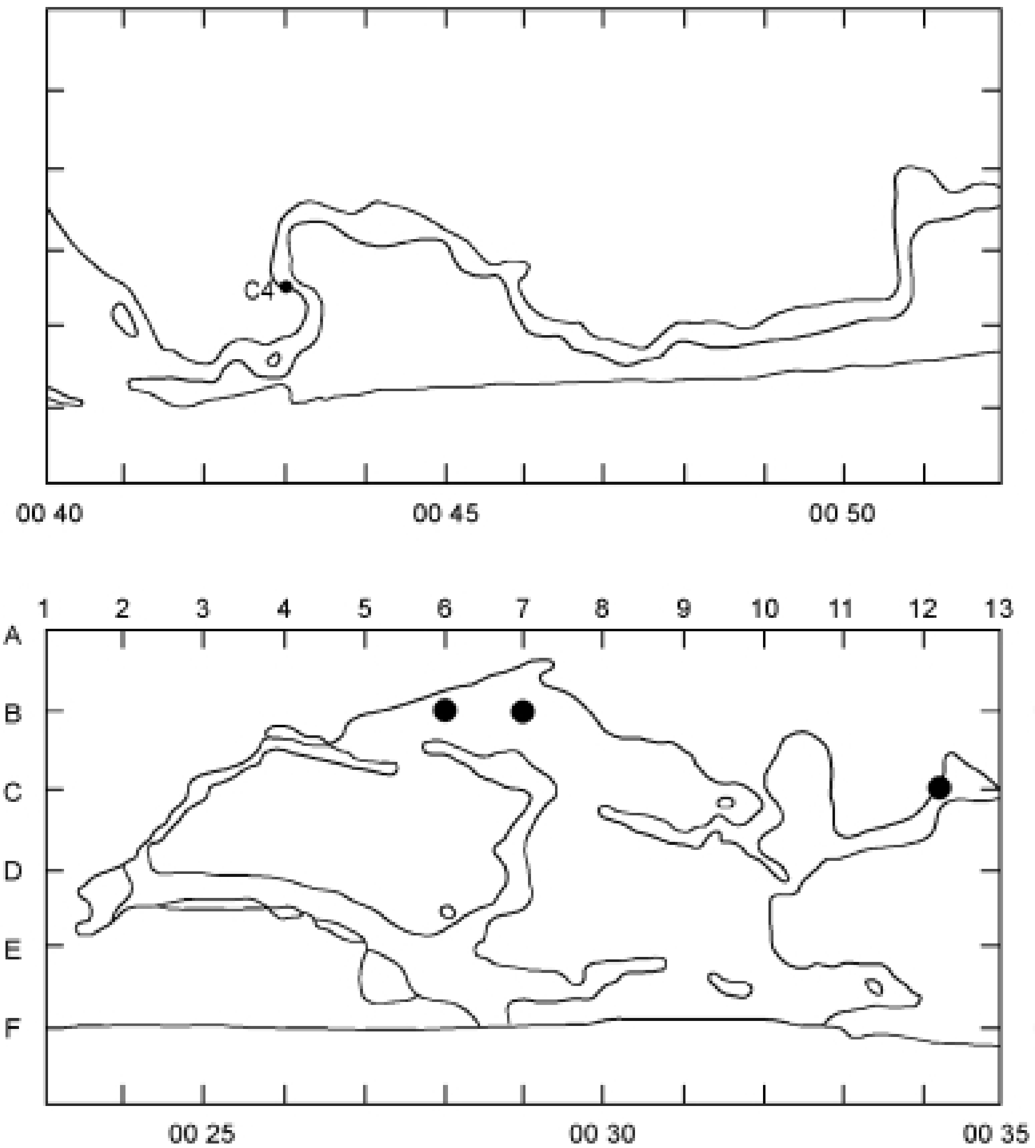


Figure 38 Distribution of *Eunice* in (top) the Angor channel connecting Keta lagoon to the Volta River, and (bottom) in Songor lagoon

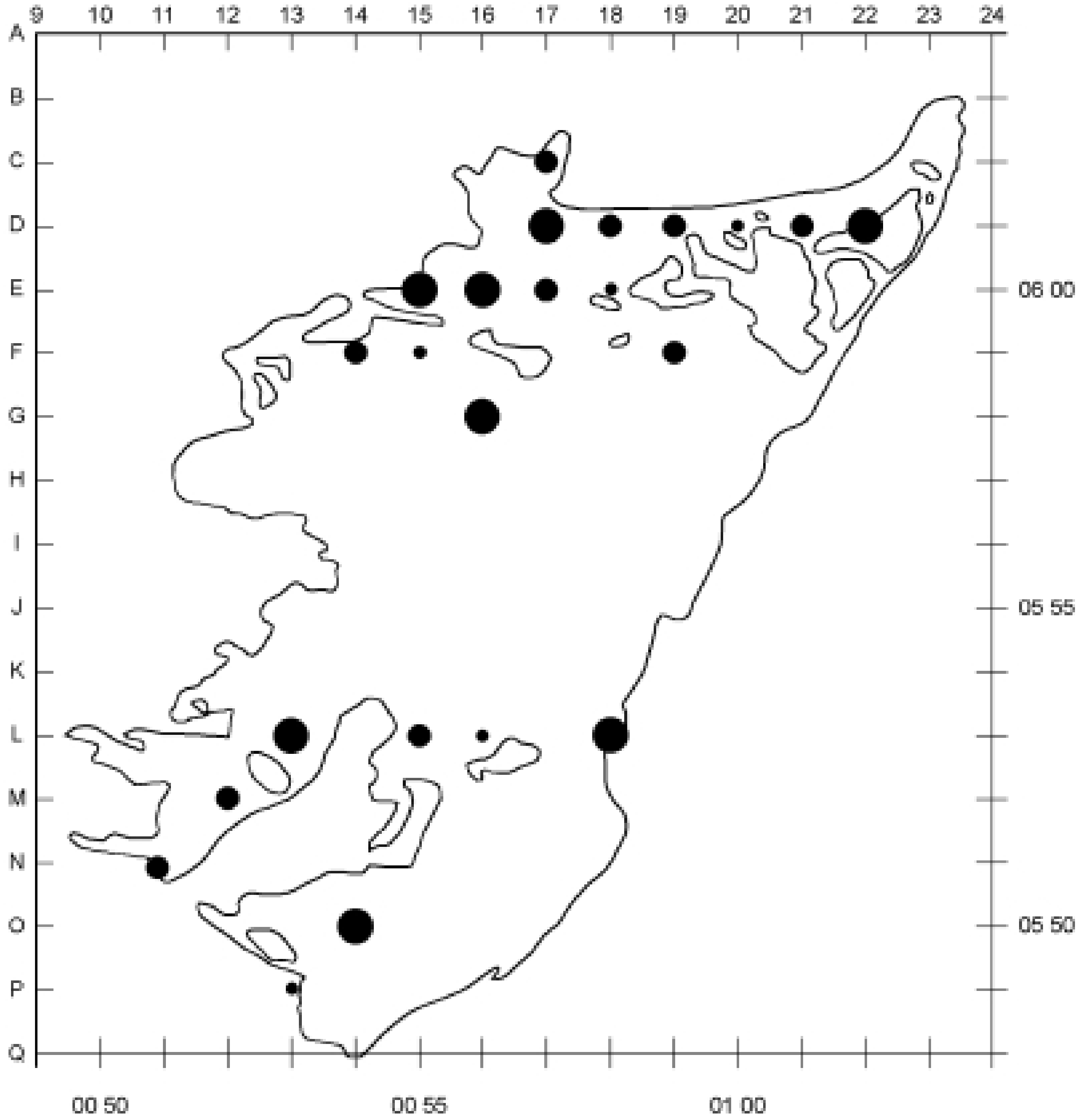


Figure 39 Distribution of *Urothoe* in Keta lagoon

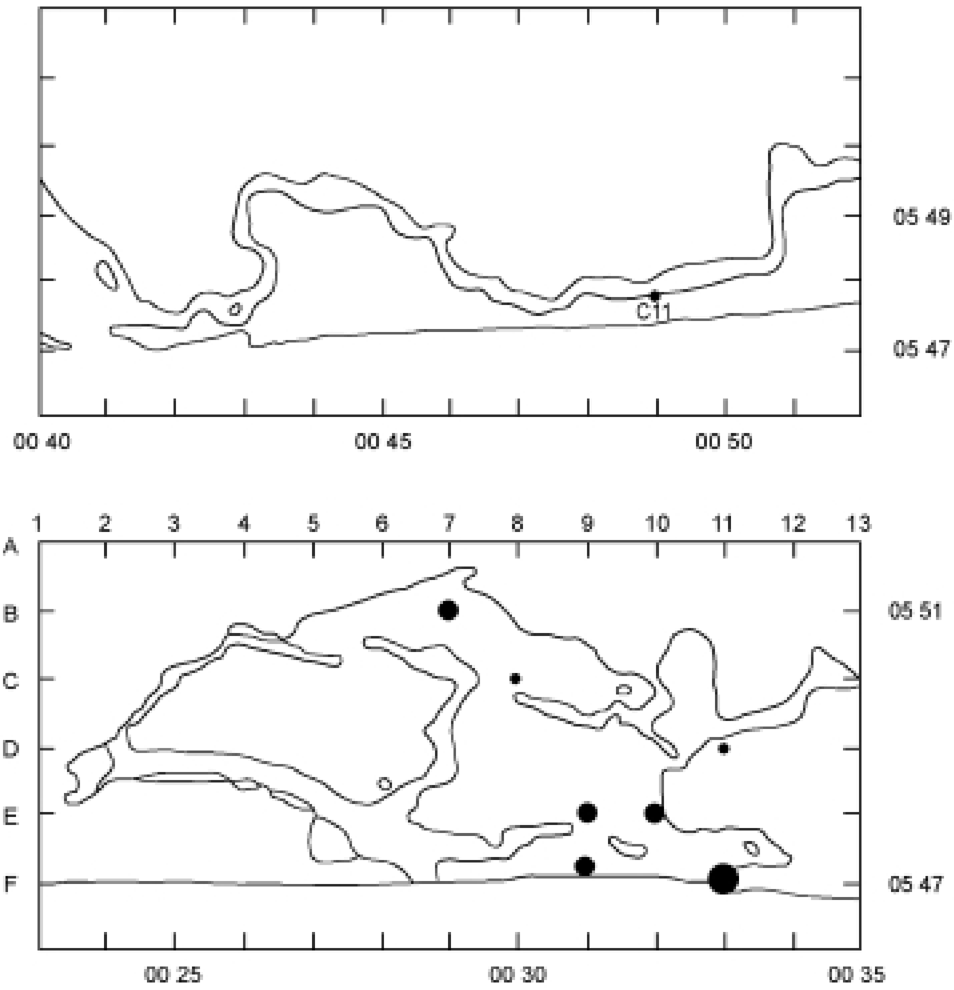


Figure 40 Distribution of *Urothoe* in (top) the Angor channel connecting Keta lagoon to the Volta River, and (bottom) in Songor lagoon

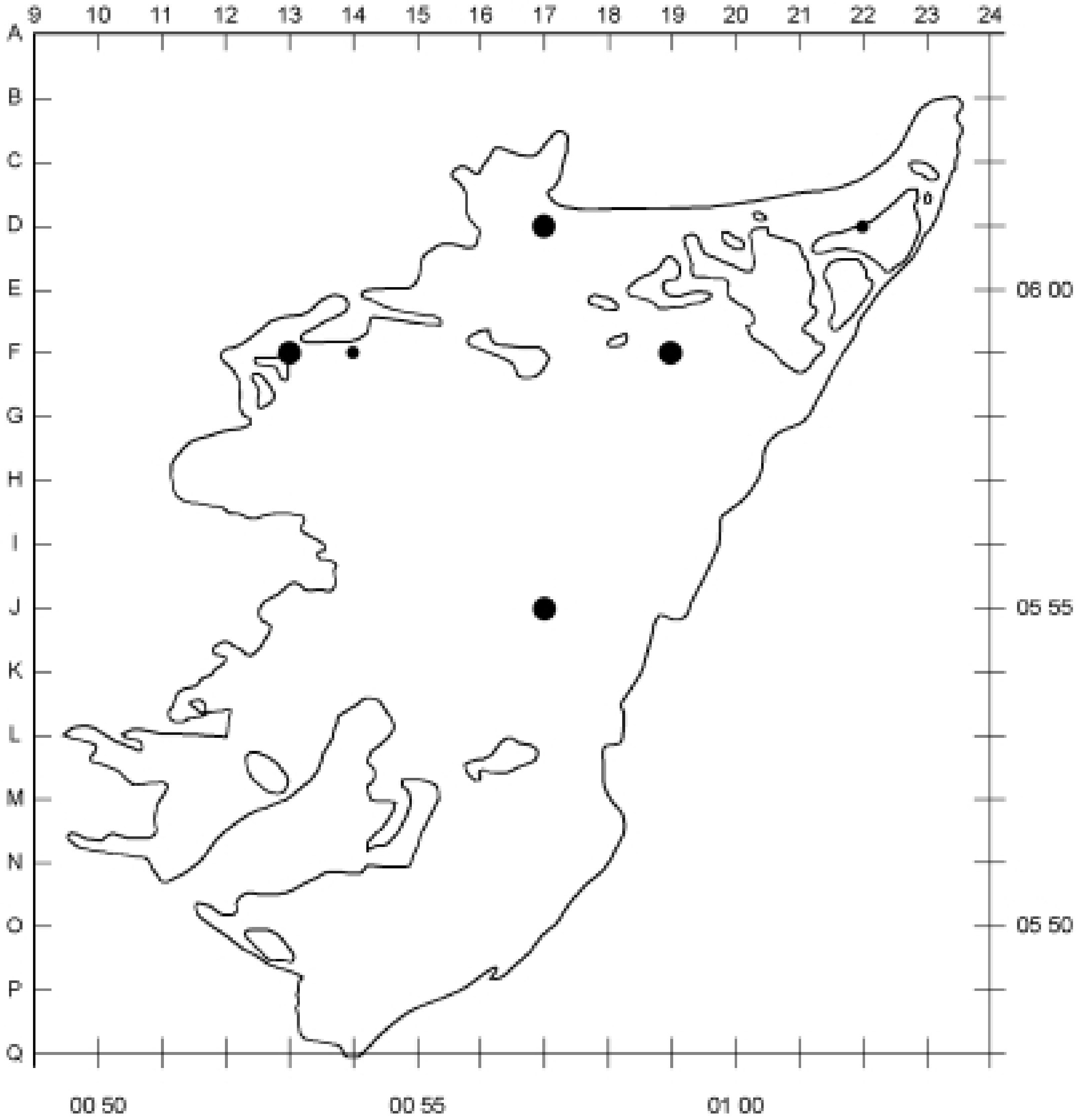


Figure 41 Distribution of *Dipsio* in Keta lagoon

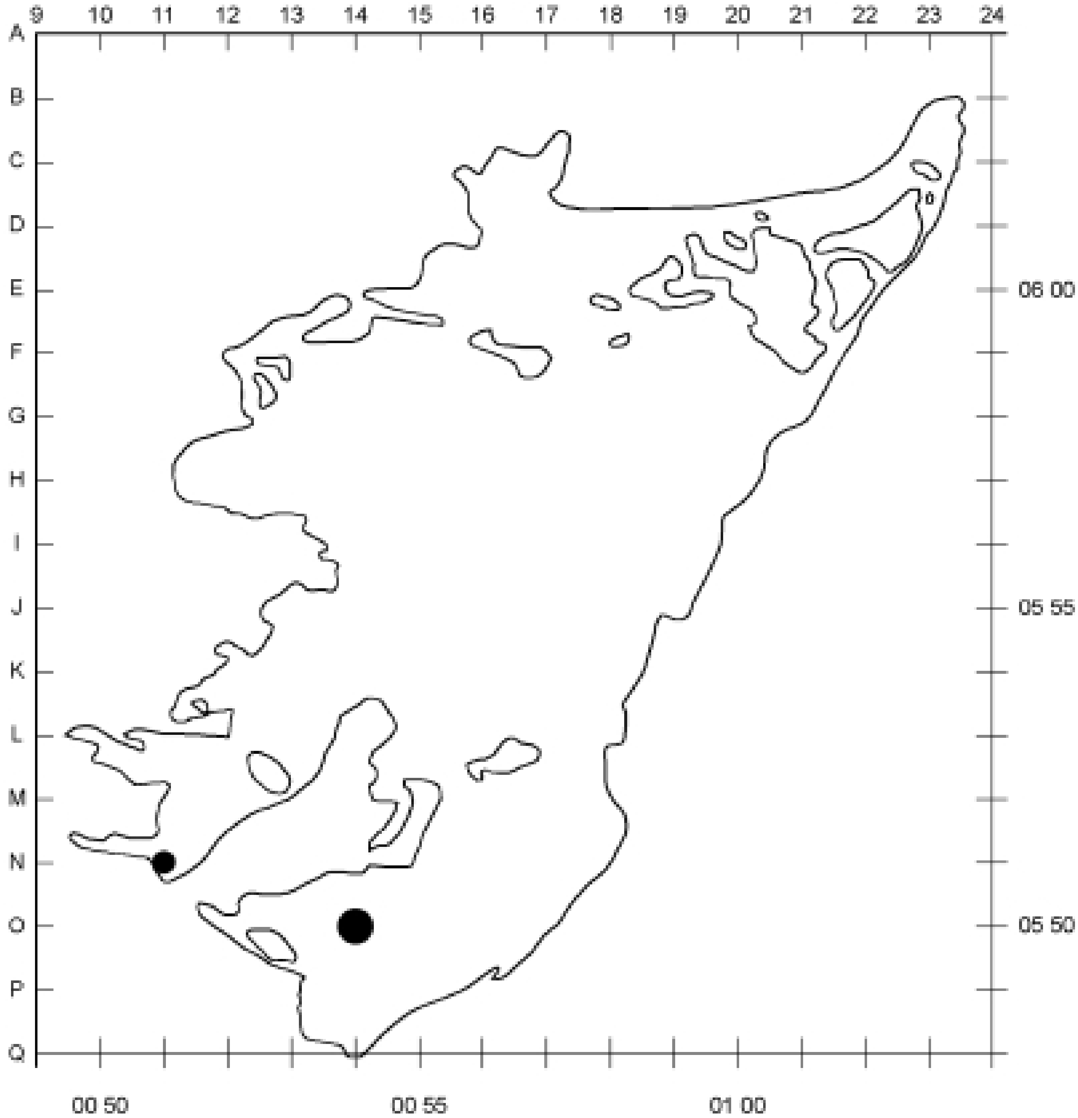


Figure 42 Distribution of *Excirolana* in Keta lagoon

Table 23 Summary of macro-zoobenthos data (numbers per square metre) for Keta and Songor lagoons

Species	Mean	Standard deviation	No. of Sites	Max
Keta				
Boccardiella	547	744	51	4602
Brachidontes	290	371	7	1051
Capitellid	1065	1803	9	5413
Corbula	1387	2049	37	8005
Dipsio	285	279	7	821
Eunice	294	339	27	1505
Glycera	164	100	11	398
Hydrobia	369	517	7	1505
Melanoides	1734	3844	35	18709
Nereis	712	845	52	3903
Neritina	321	340	22	1321
Notomastus	678	1532	17	6485
Oligochaete	8364	23967	9	72270
Tivela	1477	3611	61	22526
Tympanotonos	715	1562	58	8770
Urothoe	804	1077	25	3913
Songor				
Boccardiella	271	354	17	1526
Capitellid	944	1161	7	3082
Corbula	128		1	
Eunice	405	403	3	867
Melanoides	77		1	
Nereis	463	609	18	2112
Notomastus	762	818	16	2270
Tivela	163		1	
Tympanotonos	271	267	10	791
Urothoe	411	714	8	2168

Table 24 Biomass ash free dry weight (mg) of macro-zoobenthos in Keta and Songor lagoons

	Mean	Standard deviation	Max	Min	n
Tivela	1.44	1.39	5.19	0.04	50
Corbula	174.74	326.06	897.56	10.44	7
Melanoides	32.08	54.17	172.36	0.81	18
Tympanotonus	10.02	20.66	110.12	0.37	33
Hydrobia	0.98	0.63	1.58	0.13	7
Neritina	6.09	16.80	107.12	0.27	41
Brachidontes	15.05	31.60	120.38	0.67	28
Oligochaetes	10.68	27.31	87.79	0.24	26
Polychaetes	8.81	22.24	81.75	0.07	20

4.5 Wetland vegetation

4.5.1 Diversity

A list of aquatic and wetland plants collected and identified from Keta and Songor lagoons and the swamps that occur between the lagoons and the Volta River, and the Angor channel connecting Keta to the Volta River, is given in table 25 with a listing for all sampling stations given in appendix 6. Specimens of most plant species were collected and prepared as the basis of a field herbarium for each lagoon. A small number of species were not identified and are not given in table 25. Further, the list is not comprehensive as it is confined to the plants found at the survey sites. However, given the length of the list – 126 species in all with 109 in Keta and surrounding swamps, 57 in Songor and surrounding swamps, and 27 in the Angor channel – it is highly probable that this represents a major component of the macrophytic flora. The greater number of plants in Keta compared with Songor is a likely reflection of the drier and more saline conditions that occur around the latter, especially to the western and northern ends of the lagoon. The Angor channel is characterised by a deep channel and bankside species, with fewer species than dominate the extensive swamps that surround the lagoons.

The most dominant species are the large emergent species *Typha domingensis, Scirpus littoralis* and the rampant grass *Paspalum vaginatum.* These species were most common in the freshwater zones around both lagoons and towards the Volta River. At some sites they occurred together or in close proximity, whereas at others there was a definite dominance by a single species. The relationships between these species and their preferred growth conditions is not known, but it is assumed that water depth and the extent of inundation would be influential. The drier and saline areas around each lagoon are characterised by a *Sesuvium portulacastrum* and *Sporobolus pyriamidialis* association. Whilst these species preferentially grow in the drier and more saline areas they also seem to be influenced by the extent of freshwater flooding, but again there is no evidence on which to base more specific comments.

Many plant species are present in the wetlands that surround the lagoons, especially in the freshwater areas. At a few sites more than one species was prevalent (in a crude sense this was considered as being co-dominant), but at most sites there was one dominant species, especially in the deeper swamps where the large emergent species occurred. The species recorded are typical of the coastal savanna and wetlands, and are similar to species found in the other coastal Ramsar sites.

The dominant species at each sampling station are shown in figure 43. This reflects the nature of the land surrounding the lagoons. The dry salt flats and shallow saline water at the northern end of Keta lagoon are dominated by *Sesuvium portulacastrum* with some *Sporobolus pyramidalis* and *Paspalum vaginatum*. Similarly, the dry and saline flats that surround much of Songor lagoon are dominated by *Sesuvium portulacastrum* and/or *Cyperus articularis* with some *Sporobolus pyramidalis.* The deeper swamps to the west of Keta lagoon contained extensive stands of *Paspalum vaginatum*, both in wet and dry conditions, and the tall *Typha domingensis* that was generally in wet areas or areas that were prone to flooding. These species were often associated with *Scirpus littoralis* and *Cyperus* species.

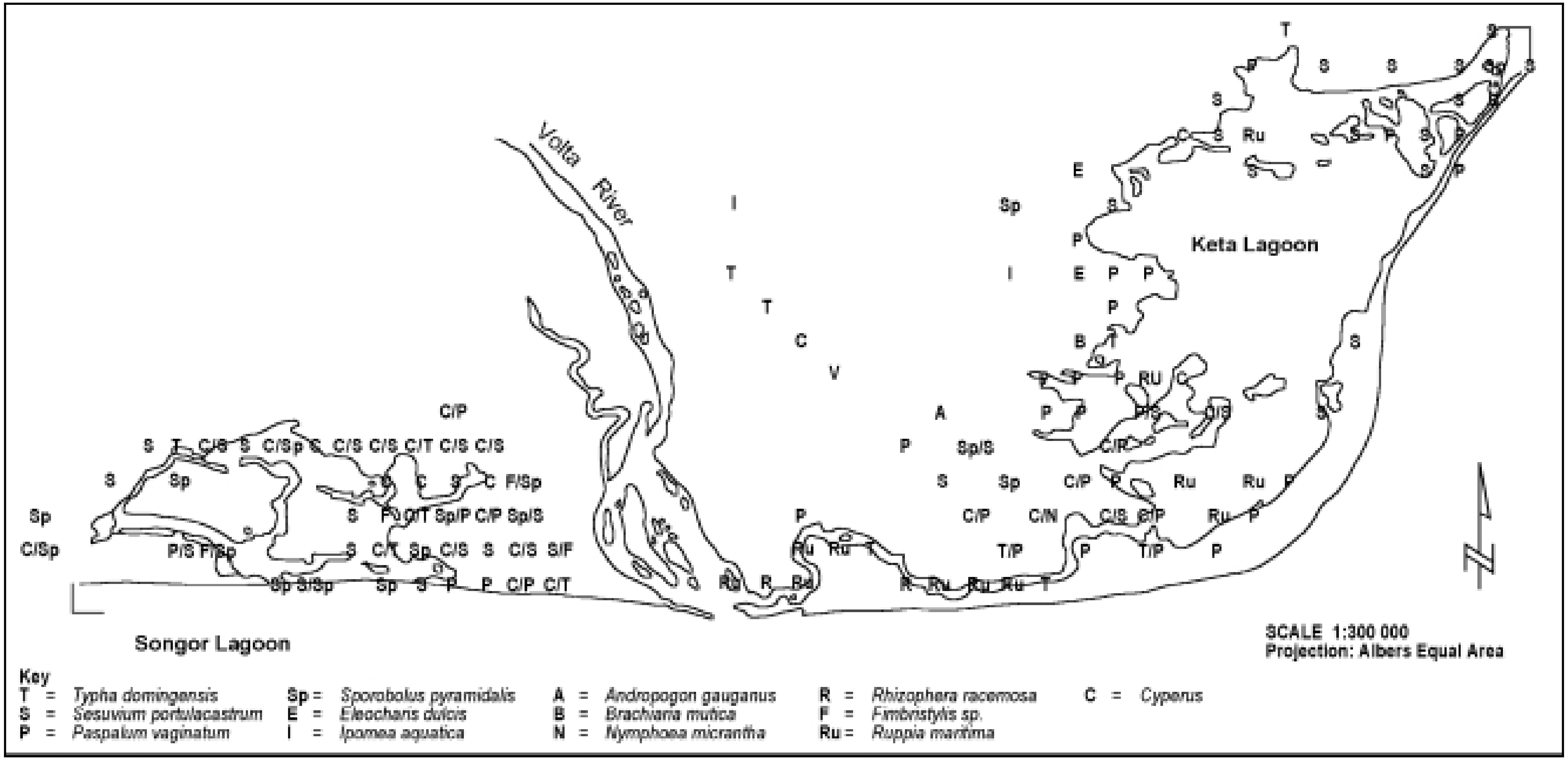


Figure 43 Dominant plant species recorded at the wetland sampling sites at the Songor and Keta lagoons

Table 25 List of macrophyte species collected and identified from Keta and Songor lagoons and surrounding wetlands

Species	Keta lagoon	Songor lagoon	Angor channel
Abutilon mauritianum	X		
Acrochaetium aureum	X		X
Acrostichum aureum	X		
Andropogon contortus	X	X	
Andropogon gayanus		X	
Avicennia nitida	X	X	X
Azadirachta indica	X		
Azolla africana	X	X	
Bacopa crenata	X	X	
Blumea aurita	X		
Borassus aethiopum	X		
Borreria natalensis	X		
Brachiaria mutica	X	X	
Brachiaria pyramidalis	X		
Canavalia rosea		X	X
Ceratophyllum demersum	X		X
Ceratopteris cornuta	X		
Chara sp.	X	X	
Chloris gayana	X	X	
Cocos nucifera	X	X	
Commelina africana	X		
Commelina benghalensis	X		X
Conocarpus erectus	X	X	
Crotalaria retusa	X	X	
Cyclosorus denudataus	X		
Cynodon sp.(not flowering)	X		
Cyperus articulatus	X	X	X
Cyperus denudatus	X	X	
Cyperus distans	X	X	X
Cyperus esculentus	X		
Cyperus rotundus	X		
Diodea serrulata			X
Dodder cuscatha	X		
Echinochloa pyramidalis	X	X	
Eclipta prostrata	X	X	
Elaeis guineensis	X	X	
Eleocharis atropurpurea	X		X
Eleocharis dulcis	X		
Eleocharis mutata	X	X	
Ficus capensis	X		
Fimbristylis dichotoma	X	X	
Fimbristylis ferruginea			X
Fimbristylis obtusifolia	X	X	
Fuirena umbellata	X	X	
Gossypium heterophylla	X		
Grewia villosa	X		
Heteropogon contortus	X		
Hibiscus micrantha	X	X	
Hygrophilla auriculata	X	X	
Imperata cylindrica	X	X	
Indigofera spicata	X		
Ipomoea aquatica	X		X
Ipomoea mauritiana			X
Ipomoea pes-caprae			X

Species	Keta lagoon	Songor lagoon	Angor channel
Ipomoea rubens	X		
Killinga nemoralis	X		
Lactuca taraxacifolia	X	X	
Launea taxifolia	X		
Leersia hexandra	X		
Lemna paucicostata	X	X	
Leptochloa caerulescens	X		
Ludwidgia stolonifera		X	X
Ludwigia erecta	X	X	
Ludwigia leptocarpa	X		
Ludwigia stolonifera	X		
Luffa cylindrica	X		
Marsilea polycarpa			X
Mimosa pigra	X	X	
Mimosa pudica	X		
Mitracarpus scaber	X		
Mitragyna inermis	X		
Nauclea sp.			X
Neptunia oleracea	X	X	
Nymphaea lotus	X	X	X
Nymphaea micrantha	X	X	X
Opuntia sp.		X	
Oryza longistaminanta	X		
Parkinsonia aculeata	X	X	
Paspalum orbiculare		X	
Paspalum polystachyum	X		
Paspalum vaginatum	X	X	X
Passiflora foetida	X		
Passiflora glabra	X		
Pentadon pentandrus	X	X	
Philoxerus vermicularis	X	X	
Phoenix dactylifera	X		
Phragmites karka	X		
Phyllanthus amarus	X		
Physallis micranta	X		
Pistia stratiotes	X	X	
Polygonum lanigerum var. *africanum*	X		X
Polygonum salcifolium	X		
Pycereus lanceolatus	X		
Remirea maritima		X	
Rhizophora racemosa	X		X
Rimerea maritima			X
Ruppia maritima	X	X	
Salvinia nymphellula	X		
Scaveola plumieri		X	
Schizachyrium sanguinium	X	X	
Schwankia americana	X		
Scirpus cubensis	X	X	
Scirpus cubensis with *atriculatus* infloresence	X		
Scirpus littoralis	X	X	
Securinega virosa	X		
Sesbania sesbans	X	X	
Sesbania sp.			X
Sesuvium portulacastrum	X	X	
Setaria anceps	X		
Sida cordifolia	X		
Sphenoclea zeylanica		X	

Species	Keta lagoon	Songor lagoon	Angor channel
Sporobolus maritima		X	
Sporobolus pyramidalis	X	X	X
Sporobolus virginicus	X	X	
Stachytarpheta angustifolia	X		
Teramnus labialis	X		
Typha domingensis	X	X	X
Urena lobata	X		
Utricularia inflexa	X	X	
Vernonia cinerea	X	X	
Vigna ambacensis	X		
Vigna radiata	X		
Vetiveria fulvibarbis	X	X	
Vossia cuspidata	X		X
Wolfia arrhiza	X	X	
Xanthozylon xantholoides	X		

4.5.2 Transects

The vegetation transects at Keta lagoon are shown in figures 44 to 47. These show the diversity of zonation that occurs around the lagoon. Much of the aquatic component of the transects is dominated by the submerged *Ruppia maritima*, generally in monospecific and contiguous beds. Herbs, in particular *Sesuvium portulacastrum* and the grass *Sporobolus virginicus* also occur in the water, but also on exposed and saline land, as occurs in the north-eastern part of the lagoon. These species are commonly found growing in saline or brackish conditions and on exposed salt-flats. The freshwater swamps that dominate large components of the area between the lagoon and the Volta River are dominated by the large emergents *Typha domingensis*, *Cyperus articulatus* and *Scirpus littoralis*, and the rampant grass *Paspalum vaginatum*. These are shown as dominant species in the non-aquatic parts of the transects.

Most of the transects had common species present in the same order with *Ruppia maritima* found in the water or at the waters edge, followed by *Sesuvium*. There is a zone dominated by *Paspalum vaginatum* then an area of *Cyperus articulatus/Scirpus littoralis* or *Typha domingensis*.

The transects provide a ready indication of the pattern of vegetation distribution both around the lagoon and along the hydrological gradient from terrestrial to aquatic. In all instances the monitoring potential of the transect data would be enhanced by actual measures of dominance and weight.

4.5.3 Biomass and phenology

The entire data set from the phenological and biomass sampling is not presented. As this is a large data set only summary information on plant biomass (referring to above-ground dry weight) and height is presented. (The entire data set is stored with the authors.)

A summary of the biomass of the dominant plant species is shown in table 26. These values are relatively high compared with those for tropical aquatic/wetland plants elsewhere and suggest the wetlands have a high primary productivity (see comparative values in Finlayson 1991, Finlayson et al 1983, 1984). A time series of biomass data is required to confirm this indication of primary production. Further, species such as *Typha domingensis* and to a lesser extent *Scirpus littoralis* and *Cyperus articulatus* are likely to have a substantial underground biomass comprised of roots and rhizomes that also undergo seasonal fluctuation as the energy reserves are used by the plant.

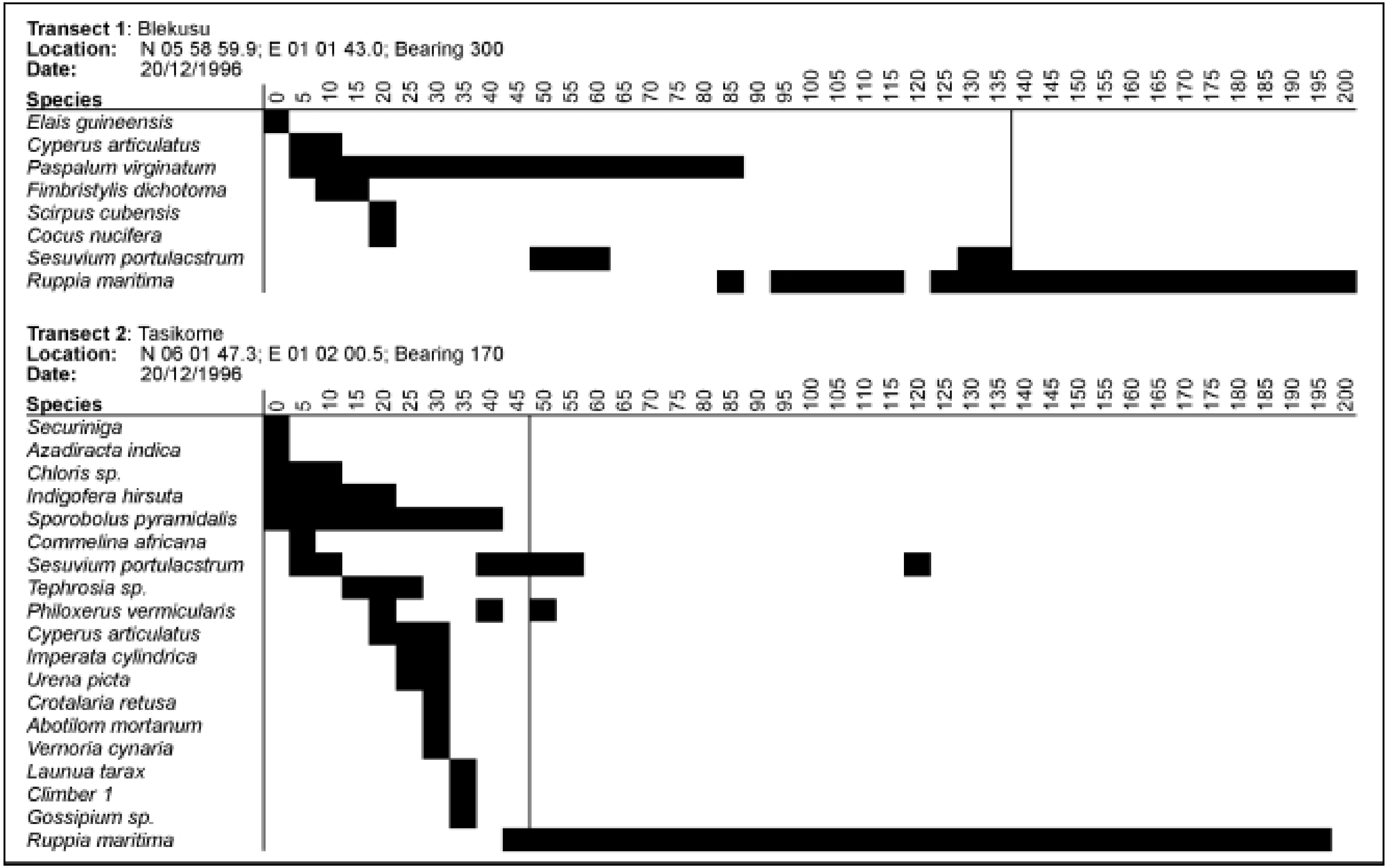


Figure 44 Vegetation transects from Keta lagoon (transects 1 & 2)

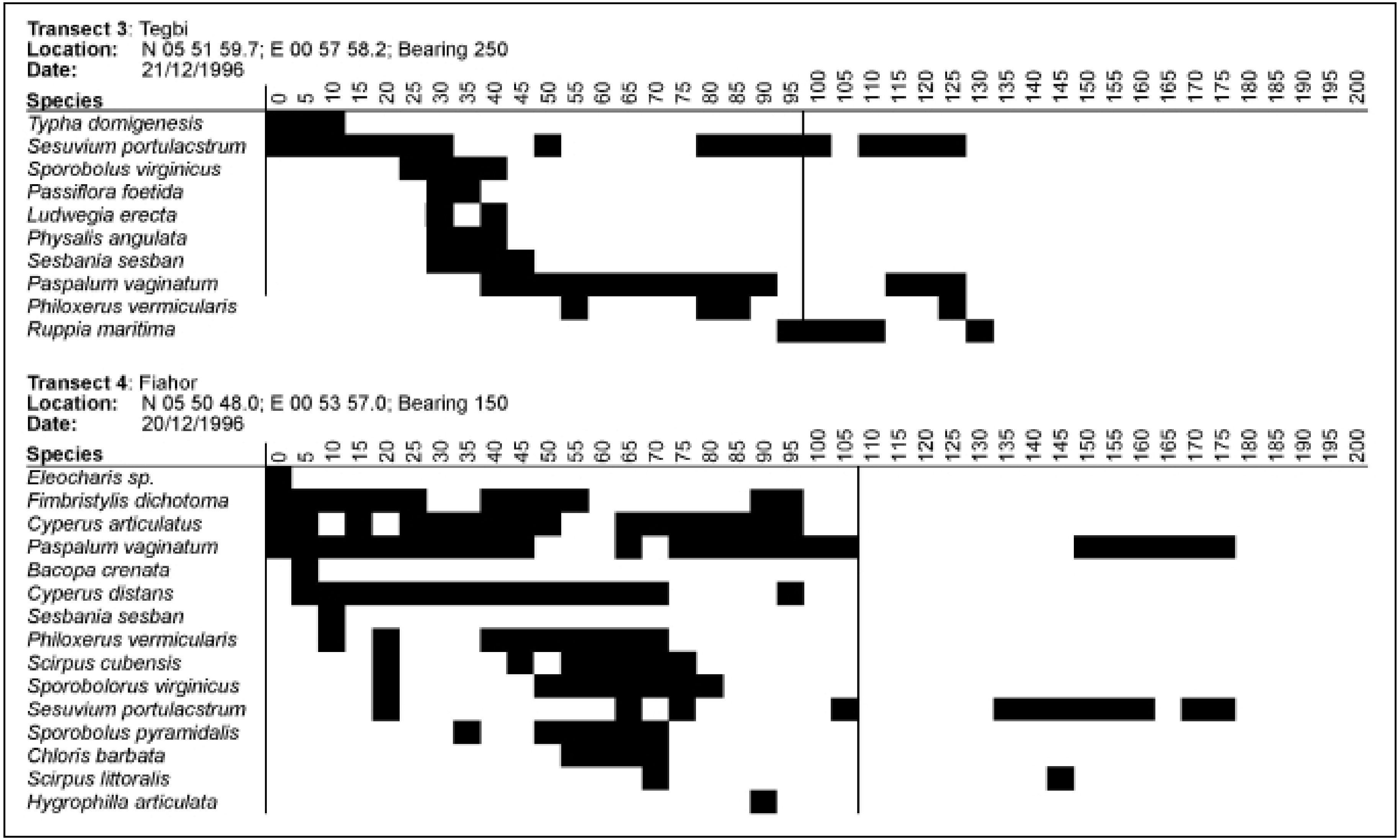


Figure 45 Vegetation transects from Keta lagoon (transects 3 & 4)

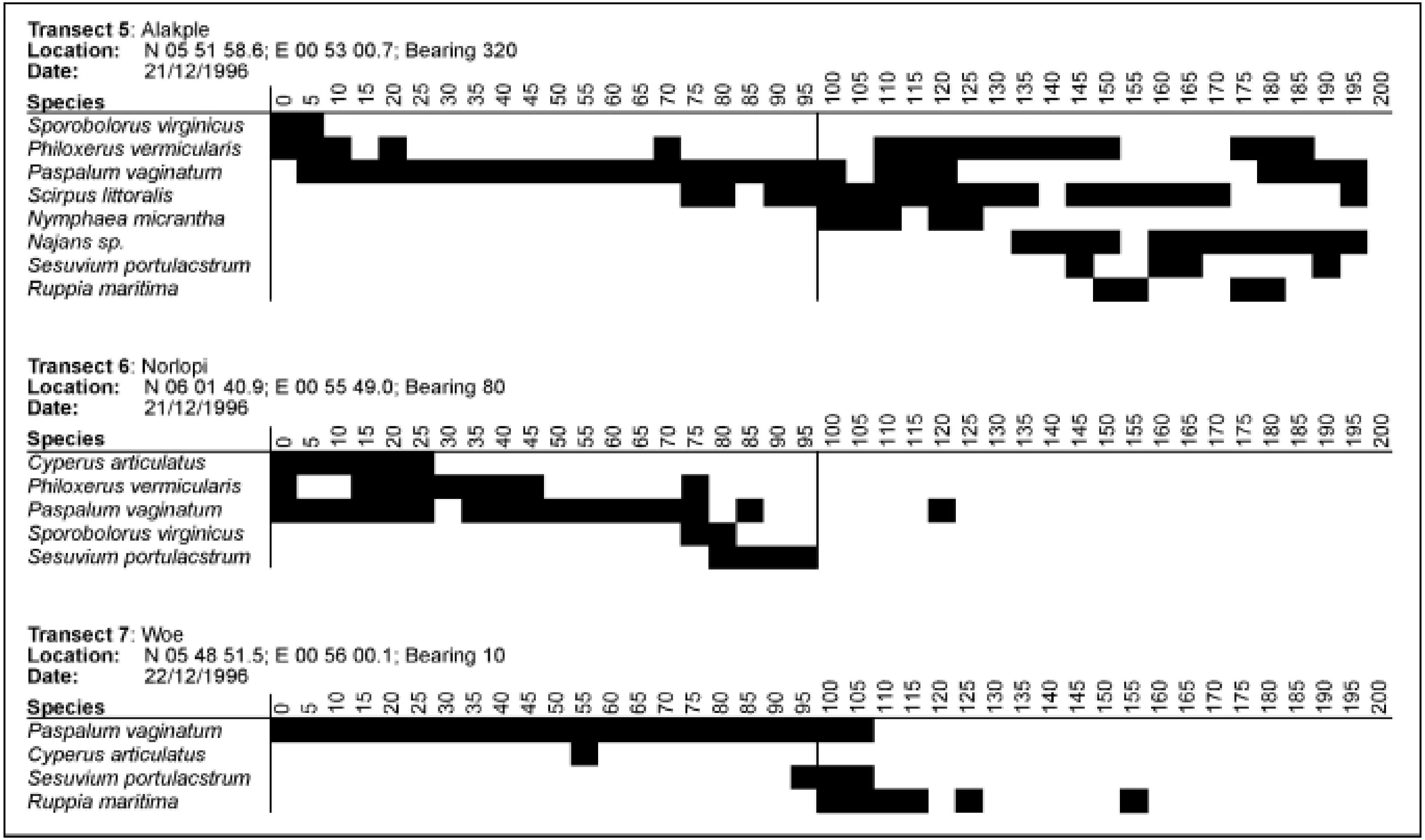


Figure 46 Vegetation transects from Keta lagoon (transects 5–7)

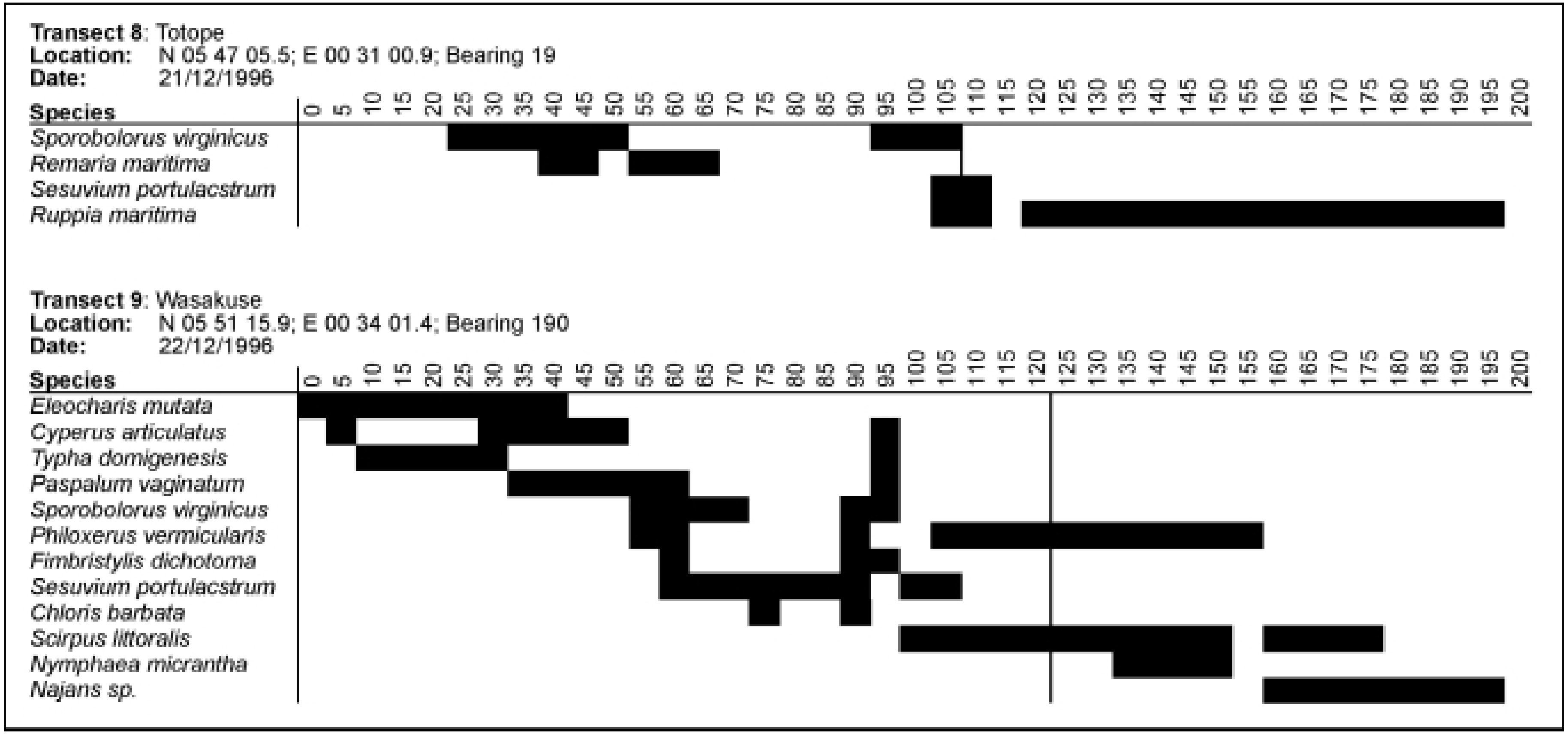


Figure 47 Vegetation transects from Keta lagoon (transects 8 & 9)

Table 26 Biomass (g m^{-2}) of dominant macrophyte species in Keta and Songor lagoons

Species	Mean	Standard deviation	Maximum
Ruppia maritima	545	292	1180
Typha domingensis	1269	790	3528
Eleocharis dulcis	983	828	3264
Cyperus articulatus	1074	577	1992
Sporobolus pyramidalis	432	169	576
Vertivera fulvibarbis	768	392	1016
Paspalum vaginatum	1278	868	5716
Scirpus littoralis	674	358	1508
Sesuvium portulacastrum	684	390	1684
Najas sp.	61	30	92

In many instances the range of values recorded is very large which tended to reflect differences in the water and/or salinity of the different sampling stations. The more robust stands of *Paspalun vaginatum* and *Typha domingensis*, for example, were generally in areas that were deeply flooded. However, some large stands of *Typha domingensis* were dry, not having been flooded by recent rains. The relationship between the plants and the water regime is known in a general sense, but specifics and the range of variation is not well known.

The phenological data provide an indication of the likely height and relative dominance of the wetland plant species. Table 27 contains a summary of the height data for the major emergent species. Similar data were not collected for the submerged plant species in the lagoon. Thus, it is possible to establish that *Typha domingensis* plants reach 3–4 m in height at a number of locations, whereas *Cyperus articulatus* and *Scirpus littoralis* are about 1–1.5 m shorter. However, on average the latter was not greatly taller. The height differences are shown in the greater biomass of the former (table 26). However, the same does not hold for the rampant grass *Paspalum vaginatum* which generally did not exceed 1.5 m in height, but has dry weight biomass values of the same order as *Typha domingensis*. The fresh weight of these plants was not recorded, but it is known that *Typha* species contain a large amount of water and is relatively succulent (Finlayson et al 1983) compared with *Paspalum vaginatum* which was fibrous and non-succulent.

Table 27 Height (cm) of the dominant macrophyte species in Keta and Songor lagoons

Species	Mean	Standard deviation	Maximum
Typha domingensis	264	79	410
Eleocharis dulcis	77	32	180
Cyperus articulatus	115	45	205
Sporobolus virginicus	50	33	95
Paspalum vaginatum	90	44	183
Scirpus littoralis	157	47	240
Sesuvium portulacastrum	30	21	75

At the time of sampling the large emergent *Typha domingensis*, *Cyperus articulatus* and *Scirpus littoralis* species had mature flowers and seeds. This would seem to indicate that flooding and inundation of the swamps had occurred some months before and the current water depths (at some sites greater than 1 m, but generally less than 50 cm) were the result of aseasonal rains and flooding. Plants such as these generally flower at the end of the growing season which is closely correlated with the annual flooding cycles (see Finlayson et al 1983). The growth cycles of the grasses would be expected to similarly respond to the pattern of inundation, but such information is not generally available.

The phenological information collected is of limited further usefulness without subsequent sampling. The current data can be made available as a resource should further phenological analysis continue. Thus, based on the information collected we have a single time point where flowering and plant height have been recorded along with biomass. These data could be extended and combined with biomass and growth cycle data from elsewhere used to determine the effect of cutting on regrowth and plant vigor. However, this would only seem necessary if there was an indication that over-cutting was occurring or was likely to occur, or was occurring at an inappropriate time of the growing cycle and negatively affecting regrowth. No evidence of such events was gathered in these surveys.

The provision of the biomass and phenological data provides a very useful initial monitoring tool for the lagoons. The biomass provides an indication of the productivity of the wetland areas, at least for the dominant species. These values also provide a basis for assessing the extent of reed cutting from the wetland. In both instances, however, further temporal data are required for these measures to be useful indicators.

4.6 Water use and pollution assessment

4.6.1 Domestic water sources

In 1991 an analysis of the extent of water supply in rural areas showed that coverage was low for the southern districts of the Volta Region. As a result Danida is sponsoring a rural water supply and Sanitation Project in the region. However, given the poor groundwater situation in the area, it is not certain how some of the communities will be served. Also, the Danida project is for rural communities with populations of less than 5000. This means that all those towns with populations greater than this will not be served. It is expected that the Sogakope-Keta-Ada-Water Supply project will, when completed complement the Danida project.

Water supply in the Songor Ramsar site is poor. Only a few boreholes have been drilled in the Dangme East District. Some of these have not been patronised because of the high salinity. Danida is planning a rural water supply and sanitation project for the rural districts of the Greater Accra region and some communities in the wetland area would benefit from the project when it is finalised.

History of water supply in the area

From available records, seven boreholes were drilled in the Keta–Anloga area, most of them between 1957 and 1965. Two of these boreholes labelled K50 and K25 were mechanised and used to operate the water supply system in the area. Another two, labelled K21 and K54, were fitted with hand pumps while the rest were abandoned. As the sea progressively eroded the land, especially the area between Keta and Vodza (both towns inclusive), in 1974 part of the supply was cut off as the Keta–Denu road was finally destroyed due to sea erosion. In 1987, the pumps on the boreholes broke down. Further, in 1991, most of the distribution mains were also destroyed during the reconstruction of the main road.

It is proposed by Alpen Consult et al (1992) in a report to Ghana Water and Sewerage Corporation that another borehole could be drilled in the Keta area or water could be imported from Afiadenyigba or Agbosume at the north-east of Keta which have better yielding boreholes to supplement the rehabilitated boreholes (K21 & K50) in order to meet the demand. Water from borehole K50 has excess iron which will need to be removed. Around the area of Afiadenyigba and Agbosume, borehole depths are shallower and the water has lower levels of salinity. However, the cost of pumping over the distance from these towns to Keta is high.

There is no water reticulation system for the communities in the entire Songor Ramsar site. Water for domestic consumption and for commercial and institutional uses in the Songor Ramsar site consist of various sources, including the following: shallow hand-dug wells, shallow boreholes fitted with hand pumps, dugouts in the ground, untreated water from the Volta River and rain harvesting. Most communities depend on a combination of these sources depending on availability, accessibility and the quality of a particular source. Rainwater harvesting is popular in some districts in the Greater Accra Region and has been tried at places such as Big Ada, Sege, Koluedor Anyamam etc. However, the storage facilities are small containers that are not able to store reasonable quantities of water for any long-term use.

Water demand and population

In the stretch of land along the coast of Keta including Agove, Anloga, Aveme, Woe, Tegbi, Vui, Dzelukope, Jiniagi, Keta, Vodza, Zedevu and Kedzi, the estimated 1995 water demand was 5315 $m^3 d^{-1}$ based on an estimated population of 68 169. It is understood that some towns beyond Kedzi on the eastern stretch of the coast and other towns west of the Srogbe and along the coast have not been included.

Water supply sources

Presently, a submersible pump on the only operating mechanised borehole has a daily output of 200 $m^3 d^{-1}$ if operated for 20 hours a day. Due to many problems including damage to the distribution work, this borehole is operated only 2 hours per day. There is a second borehole with a potential yield of 85 $m^3 h^{-1}$. Together with the second borehole (K21) with a potential yield of 11 $m^3 h^{-1}$ they, can supply 1900 $m^3 d^{-1}$ of the estimated peak demand.

The deep limestone aquifer lying between 80–300 m below ground level which underlies the Keta–Anloga basin could meet the future water demand for the whole area. This will necessitate care to prevent the intrusion of saline water from the overlying shallower formations. Controlled pumping will be necessary to maintain the freshwater/saline water boundary at a safe distance from the water levels in wells operating within the aquifer. Shallow hand-dug wells, shallow boreholes fitted with hand pumps, dugouts in the ground, untreated water from the Volta River and rain harvesting are the main sources of water supply in the area. Most of the communities depend on a combination of these sources depending on availability, accessibility and the quality of a particular source.

Two regions water supply project

Ghana Water and Sewerage Corporation (GWSC) has initiated a scheme for the Lower Volta Basin that aims at providing pipe-borne water to some major towns in the Volta Region, and the Dangbe East district of the Greater Accra Region. The project which is being implemented by Biwater and funded by the Ghana Government, DFID and the Export Credit Guarantee Department (UK). It was planned to execute the project in three phases.

Phase 1 of the project which was to commence in 1998, links the towns of Sogakope, Anloga and Keta, and involves 9 town councils and more than 60 villages. A projected population of 183 940 by 2015 is expected to be served with an estimated 11 939 905 litres of water. Phase 1 is expected to last for 2 years. Phase II of the project links Agbozume and Aflao and involves eight town councils with a projected population of 435 690 by 2015 and total water demand of 64 468 335 litres. Phase III of the project links 15 communities from Sogakope to Ada Foah with a projected population of 36 840 by 2015. Estimated total demand for potable water is 2 203 778 litres.

The original plan has recently been modified. Phases I and III, for which funding has been received have been conveniently merged, and is to be executed from July 1996 to September 1998. These two phases are expected to provide 14 million litres of potable water for 78 communities with an estimated population of 220 780 by the year 2015.

4.6.2 Water pollution sources

There is very little industrial development in either of the two sites; as such, most of the pollution within the catchment is from human waste. The use of agro-chemicals is a potential problem, though the amounts in use are currently limited by high cost and availability. A survey carried out for the VRA in the Lower Volta (VBRP 1996) indicated that many chemicals are in use by farmers.

Disposal of human waste

Sludge and liquid waste management are big problems within the wetland sites. The poor disposal systems for human waste are a cause for concern. Although no figures are available, a good percentage of the people have no access to toilet facilities and as such use open defecation that poses a threat to the shallow groundwater resource especially along the coast. Solid waste disposal in the urban areas is an equally big problem. In the upper part of the Keta catchment, 60% of communities surveyed by CDS (1985) defecated freely whereas 39% of the settlements had a traditional pit latrine. Considering the shallow nature of the fresh groundwater resource in the study area, the chances of contamination will be very high.

Facilities for sewerage disposal in the urban areas of the study area include water closets with individual septic tanks, pan/bucket latrines, KVIP latrine, aqua-privy and pit latrines. It is estimated that 60–65% of the population do not have access to household toilet facilities and resort to open defecation on the beaches or along the banks of the lagoons. In the typical rural areas, pit latrines and open defecation are the only disposal facilities. Desludging of the septic tanks in the urban areas is a problem and has to be undertaken using cesspit emptiers which are occasionally loaned from the metropolitan or municipal assemblies such as Accra and Ho. Because of the problems of inadequacy of plant, equipment and lack of conservancy labour among others, management of sanitary facilities in the subregion is poor with a resultant adverse impact on the urban environment. Untreated sludge from septic tanks and night soil are discharged into the sea or the lagoons.

This practice of disposing of septage and nightsoil into lagoons and trenches is unhygienic and poses a potential danger to public health and constitutes a potential source of contamination of the available water sources especially the shallow hand-dug wells exploited in the Keta–Anloga area. It is, however, important to note that the problem of sewage disposal and other basic infrastructure services like refuse disposal, roads, drains, markets and lorry parks is being addressed under the Urban II Project for Keta District. The construction of latrines under the CWMP within some of these communities is therefore very welcome.

Refuse disposal

About 80% of refuse generated within the two study areas is of domestic origin. Industrial waste – mainly sawdust – is generated principally by boat builders and carpenters. The various District Assemblies handle their waste management activities. In the Keta area, this is concentrated in the settlements along the littoral. The District Assembly handles the waste management activities in the Dangbe East study area. In the Songor Ramsar site area, it is Big Ada and Ada Foah with concentrated settlements near the littoral coast that enjoy this facility. There are only limited refuse collection services for markets and lorry parks.

5 Management of Keta and Songor lagoons

The description of the ecological character of the lagoons and the development of monitoring programs are components of a management strategy for the long-term sustainable use of the lagoons. The major management issues and threats that need to be addressed are described below.

5.1 Major management issues and threats

The major management issues and threats at the five Ramsar wetlands in Ghana were identified and prioritised in a subsequent workshop (unpublished information). This was done using a participatory approach, involving representatives from the following:

- Ghana Wildlife Department, Ministry of Lands and Forestry
- Zoology Department, University of Legon
- Volta Basin Research Project, University of Legon
- Water Research Institute, Council for Scientific and Industrial Research
- Ghana Wildlife Society

Additionally, given that the five coastal lagoons are listed as Internationally Important under the Ramsar Wetlands Convention the expertise of the Convention's Scientific and Technical Review Panel on monitoring was accessed. Thus, a workshop that brought together the site managers from the wetlands, wildlife experts, and ecological scientists, all with an interest in monitoring wetlands, was used to identify and elaborate the key issues.

The workshop was used to identify the major issues and threats occurring at each of the coastal wetlands. A list of issues and threats was produced for each wetland. The threats were then grouped into four broad categories (water regime; water pollution; physical modification; exploitation and productivity) in a site/threat matrix and then prioritised.

In undertaking this exercise it was necessary to differentiate between an issue and a threat. The following definitions were used:

> ***A wetland <u>issue</u> is an underlying socio-economic and/or political factor (eg agricultural expansion, urbanisation, population pressure, sectoral structures) that could lead to adverse change in the ecological character of a wetland.***
>
> ***A <u>threat</u> to a wetland is a human induced factor (eg water pollution, siltation, over-exploitation) that could change adversely the ecological character of the wetland.***

Even with these definitions it was not always easy to differentiate between an issue and a threat. In such instances it was necessary to consider an issue as the underlying process that led to the threat(s) that resulted in a physical, chemical and/or biological change in a wetland. Thus, population pressure and urban expansion were issues that led to the threat of urban encroachment on the wetland. Similarly, agricultural expansion was treated as an issue that resulted in land clearance and chemical pollution in the wetland.

A summary of the major management issues and threats at Keta and Songor lagoon follows.

5.1.1 Major issues

The underlying issues affecting Ghana's coastal wetlands are of a generic nature and have an overall influence on the management of both Keta and Songor lagoons. The issues indicate the importance and range of socio-economic imperatives and conflicts in wetland management. These need to be monitored and addressed in concert with the outward expressions of change in the wetlands, that is, the threats.

The major issues affecting Ghana's coastal wetlands can be summarised as follows:

- Population pressure and poverty
- Lack of awareness by the general community and policy makers of wetland values
- Low level of community participation in conservation
- Under-resourced conservation agency
- Shortage of trained personnel for conservation and management of wetlands
- Over-exploitation of fisheries, including the use of inappropriate methods
- Extension of hunting, including intensive activities by groups of hunters from urban areas
- Intensification and expansion of agriculture and increased use of pesticides and herbicides
- Expansion of infrastructure and industry, such as salt winning and saltworks, waterworks, erosion and flood control, quarrying and sand winning, sewage treatment plants
- Development of new industries, such as tourism and recreation
- Urbanisation and lack of land for housing development
- Ownership and access to land and resources, including questions of stewardship, traditional rights and attitudes of new settlers
- Interdepartmental conflicts over jurisdiction
- Weak local management institutions

5.1.2 Major threats

The major threats to the lagoons were identified and grouped under four broad categories: water regime; water pollution; physical modification; and exploitation and loss of production. These are summarised in table 28. The threats at each site were then prioritised on a subjective basis in a decreasing order of importance. These are shown in table 29.

It is clear that some of these threats are beyond the control of the CWMP, eg the erosion of the Keta sea coast, however, where practicable, it is proposed to assess the priority threats through specific monitoring programs as part of the overall management strategy for each lagoon.

Table 28 Major threats to Keta and Songor lagoons (x present; – absent)

Category	Threats	Songor	Keta
Water regime	Flooding	-	x
	Reclamation	X	x
	Water diversion	X	-
	Erosion/Siltation	X	x
	Road extension	X	x
	Irrigation	-	x
Water pollution	Solid waste-refuse	X	x
	Siltation	X	x
	Sewage-faecal	X	x
	Pesticides	X	x
	Fertilisers	X	x
	Salinisation	X	-
Physical modifications	Erosion/erosion control	-	x
	Flooding/flood control	-	x
	Clearance & fire	X	x
	Sedimentation	X	x
	Infrastructure/housing	-	x
	Hunting disturbance	X	x
	Recreational activities	X	-
Exploitation & production	Fishing	X	x
	Fuel wood cutting	X	x
	Marine turtles hunting	x	x
	Birds/mammals hunting	x	x
	Grazing	x	x

Table 29 Perceived priority threats to Keta and Songor lagoons

Wetland	Priority				
	1	2	3	4	5
Keta	Erosion and damage from erosion control measures	Flooding and damage from flood control measures	Reclamation of land	Pollution from sewage	Pollution from fertilisers
Songor	Expansion of urban infrastructure	Hunting marine turtles	Disposal of solid waste-refuse	Over-exploitation of fish	Blockage and diversion of freshwater

6 Monitoring of Keta and Songor lagoons

The two lagoons are very large and it would be impossible to carry out the same sort of sampling intensity that was used in the baseline study for a monitoring program. A stratified random approach has been used to design a simple monitoring strategy for the Keta and Songor lagoons. For the Songor lagoon, sampling should be restricted to six sites: two inland, two on the coast, one to the east and one to the west. Keta with its huge area will require a minimum of 17 sites. Using the existing sampling grid the sites are:

KN 16	KJ17	KO17	KI18	KD19
Tuna	Keta bridge	KE15	Alakple	KL17
KO15	KH19	KP14	KG20	KK17
Atiawa	KM17			

The sites should be sampled every two months for the parameters listed in table 30. The sampling protocols given in section 3 and appendix 1 provide a basis for undertaking this sampling.

Table 30 Parameters for monitoring Keta and Songor lagoons

Hydrological	**Water levels** **Inflow/outflow**
Limnological	pH
	Transparency
	Dissolved Oxygen
	Conductivity/TDS
	BOD
	Temperature
	Nitrate
	Nitrite
	Total Nitrogen
	Orthophosphate
	Total Phosphate
	Lead
	Cadmium
	Arsenic
	Mercury
	COD
Biological	Phytoplankton
	Zooplankton
	Aufwuchs
	Benthos

The methods described in this report (with the field sampling protocols summarised in appendix 1) are suitable for the monitoring of the sites. Care should be taken not to over-sample at any one spot, as this would disturb the environment unduly. Protocols for data collection and archiving should be set up so that a database of information can be accessed easily. For security one copy of the data should be kept separate from the original database in case of unforeseen accidents.

7 Recommendations

Obviously it is impossible to address the research needs for these two large and very complex lagoons in a short study. As such it is recommended that further work be carried out in order to gain an in-depth understanding of the systems and how they function. These studies are suited to higher university degree programs or as long-term research projects. An indicative, but not exhaustive list of potential research projects is given in table 31.

Table 31 Potential research projects recommended for the Keta and Songor lagoons

Project title	Purpose
Re-colonisation by invertebrate fauna	To identify the species entering the lagoons and to establish rates of colonisation of aquatic invertebrate fauna in different parts of the lagoon.
Environmental tolerance of invertebrate fauna	To establish the survivorship limits and mortality rates of invertebrate fauna from the lagoons.
Ecology of Penaeids	To establish the precise timing and requirements for the effective use of the wetlands as a nursery ground for shrimps.
Zooplankton dynamics within the main channels of the wetlands	To establish the role played by zooplankton in energy flow through the system.
The development of invertebrate fauna within acadjas	To assess if there is an increase in fauna in and around acadjas as compared with surrounding areas.
Determination of the factors controlling the spread of various mollusc species, eg *Anadara senilis*, in the wetlands	To link environmental factors to the distribution and abundance of the main species of molluscs with either economic or medical importance.
The decomposition of aquatic plants	To establish rates of decomposition and release of nutrients from aquatic plants in the lagoons.
Resource partitioning between crabs in the lagoons	To establish factors controlling population size of crabs in the area.
Harvesting and usage of aquatic macrophytes by local communities	To assess the extent and rate of plant harvesting in relation to plant growth patterns and recruitment after harvesting.
Ground water salinity and mangroves	To determine the potential spread of mangroves within the lagoons.
Hydrogen sulphide in sediments and its effect on the vegetation in the lagoons	To determine possible limitations to plant growth due to anaerobic conditions and the production of hydrogen sulphide.

All these research activities should be carried out with the aim of increasing the knowledge base available for management. It is recognised that some basic research is required as a base for further management, however, the overall goal is to provide information that can be used to ensure the lagoons are used in a sustainable manner.

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Appendices

Appendix 1 Field sampling protocols

The following protocols were developed for the lagoon sampling program and provide a basis for further efforts.

General information

1 A sampling grid at 1' intervals is placed over each lagoon and each sampling site given a discrete code and coordinates (see 1:50 000 topographical map) and a table of codes and coordinates prepared. Each sampling site can be identified from these data.

2 Data sheets are completed for all samples/sites and descriptive information (site code and coordinates, date and name of recorder) recorded at the top of each sheet. All samples should be labelled with the site code and, if applicable, replicate number and species name.

3 The wetland vegetation will be sampled by one team with two teams attending to the aquatic sampling. The latter will work in unison but attend to different samples. Individual sampling protocols are attached. Sampling locations for each parameter are shown on separate maps and in a site/parameter matrix.

4 Data recording is to be entered onto spread sheets the evening of collection and a disk back-up made.

5 Names and model numbers of all equipment must be noted in the sampling record/diary (see below) along with any information on accuracy or range or limits of operation.

6 A daily record of all sampling and sample data will be compiled. Information in this record will include sites/transects completed, samples collected and processed, samples despatched to Legon for further analysis, and results received from Legon analysts. A mastercopy of the sampling map and matrix will be maintained separately from the daily working copies. Observations and variations in sampling strategy or procedures should be recorded along with the reasons.

Groundwater and domestic water supply sampling protocols

1 Refer to the topographical map and site/sampling matrix for sampling locations and take a record of these into the field.

2 At each sampling site locate the nearest village well, record location details and GPS reading. Note the model name and number of the GPS.

3 Record the depth of water in the well from ground level.

4 Collect a 250 ml water sample in a poly-bottle and take a conductivity sample back at the field base. Do not leave the sample in direct sunlight. Note the name and model number of the conductivity meter.

Wetland vegetation transect protocols

1 Refer to the topographical map and site/sampling matrix for sampling locations and take a record of these into the field.

2 Record GPS at the waterline and note the model name and number of the GPS.

3 Position transect perpendicular to the shoreline and commence sampling from the waterline in both directions. Record the compass bearing taken.

4 Record the species hit by a dropped pin at each one metre (1 m) interval. The sampling interval could be varied in relation to the length of the transect. Stop sampling at commencement of the terrestrial vegetation.

5 At every five metre (5 m) interval place a one square metre (1 m^2) quadrat and record all plant species present as relative abundance on a descending scale for most dominant 5–6 species, % ground cover scaled 1–6, and proportional phenological state scaled 1–6. A key to the proportional scales is given on each data sheet and is repeated below.

Scale	1	2	3	4	5	6
Percentage	1%	2–25%	26–50%	51–75%	76–99%	100%

6 Within each major species association along the transect collect all the above-ground biomass of each species from five (5) replicate 0.25 m^2 randomly placed quadrats. Place this material in labelled paper envelopes, sun dry at field base and return to Legon for oven drying 65ºC and recording of dry weight.

7 Retain the dried plant material for possible nutrient analysis.

8 The areal extent of large stands of vegetation (eg *Typha*) should be determined by separate GPS mapping of the perimeter.

9 Collect and press two specimens of each plant species located in the survey of each lagoon. Record collection and locations information (GPS reading and a general description of the location) for these specimens.

Aquatic vegetation sampling protocols – abundance, phenology and biomass (g m^{-2})

1 Refer to the topographic map and site/sampling matrix for sampling locations and take a record of these into the field.

2 Take GPS reading at the site. Note the model and number of the GPS.

3 Position five (5) one metre square (1 m^2) quadrats at the site – one centrally and the others approximately ten metres (10 m) away along the four cardinal compass bearings.

4 Note the species present as relative abundance on a descending scale for the most dominant 5–6 species, % ground cover scaled 1–6, and proportional phenological state scaled 1–6. A key to the proportional scales is given on each data sheet and is given below.

Scale	1	2	3	4	5	6
Percentage	1%	2–25%	26–50%	51–75%	76–99%	100%

5 Collect all above-ground macrophytic material in each quadrat, place into labelled bags and return to field base for sun drying and despatch to Legon for oven drying at 65ºC and weighing. Separate the species present for weighing.

6 Retain the dried plant material for future nutrient analysis.

Aquatic vegetation – microphytic/algal mats biomass

1 Refer to the topographic map and site/sampling matrix for sampling locations and take a record of these into the field.

2 Take GPS reading at the site. Note the model and number of the GPS.

3 Position five (5) 10 by 10 cm (0.01 m^2) quadrats at the site – one centrally and the others approximately ten metres (10 m) away along the four cardinal compass bearings.

4 Carefully collect the layer of algal material overlaying the substrate of the lagoon and place into labelled plastic bags for sun drying at the field base and oven drying at 65ºC at Legon.

5 Collect a separate sample of the algal mat and place in a tube and cover with methanol for taxonomic identification.

Aquatic vegetation – microphytes/phytoplankton

1 Refer to the topographical map and site/sampling matrix for sampling locations and take a record of these into the field.

2 Take GPS reading at the site. Note the model and number of the GPS.

3 At each site filter one litre (1L) of water, collected from approximately 5–10 cm depth, through a Whatman GFC paper. Place the filtrate and paper in a labelled tube (or insert a paper label with pencil writing into the tube), cover with methanol, place in dark and in ice.

4 Return samples to laboratory (or use HACH kit) for spectrophotometric readings for chlorophyll (a,b, c_1 and c_2) estimations. Record the volume of ethanol in the tube and/or make up to a standard volume.

5 Filter a further one litre (1 L) of water, collected from 5–10 cm depth, through a Whatman GFC paper. Place the filtrate in Lugol's solution.

6 Return samples to laboratory for species identification and density counting using a microscope and haemocytometer.

Water quality – physico-chemistry

1 Refer to the topographical map and site/sampling matrix for sampling locations and take a record of these into the field.

2 Take GPS reading at the site. Note the model and number of the GPS.

3 At each side record water depth, pH, conductivity/salinity, total dissolved solids, dissolved oxygen, temperature at 5–10 cm depth. Record name and model of meter used for each record.

4 Collect water samples for nutrient (ortho-phosphate, total phosphorus, nitrate and Kjeldahl nitrogen), major cations (sodium, potassium, magnesium and calcium) and anions (bicarbonate, sulphate and chloride), and selected trace metals. Place in labelled poly-bottles and in the dark in ice. Return to Legon for analysis after appropriate preservation.

Appendix 2 Water chemistry of Keta and Songor lagoons

Keta Lagoon

Site	Distance from site	Date	Time	Temp (^{0}C)	DO (mgL^{-1})	DO (% sat)	TDS (mgL^{-1})	Cond (mS)	pH	Salinity (ppt)	Depth (cm)	Secchi depth (cm)	Zn (mgL^{-1})	Pb (mgL^{-1})	Cu (mgL^{-1})	SS (mgL^{-1})	Na (mgL^{-1})	K (mgL^{-1})	Ca (mgL^{-1})	Mg (mgL^{-1})	Cl (mgL^{-1})	SO4 (mgL^{-1})	PO4 (mgL^{-1})	CO4 (mgL^{-1})
KC17	<300m	18/11	13.38	35.2	3.4	48	24000	36.9	8.46	23.5	23	14	0.09	<0.03	<0.03	274	6900	268.5	424.8	1956	12710	1560	0.06	178
KD17	<100m	18/11	13.00	32.4	2.3	31	16200	29.1	8.21	17.9	52	30												
KD18	<200m	18/11	12.25	33.1	2.6	35	16100	28.9	8.25	17.9	45	17												
KD19	<300m	16/11	9.50	29.4	3.2	41	E20	52.2	8.2	34.6	35	30	0.04	<0.03	<0.03	282.5	6000	223.5	387.9	854	10540	1080	0.03	156
KD20	<300m	16/11	10.45	33.3	3.8	53	E20	128.8	8.2	E20	22	CTB												
KD21	<300m	16/11	12.45	34.5	2.7	39	E20	164.3	8	E20	15	8	0.04	<0.03	<0.03	214	2125	885	1987.9	2888	41300	2460	0.03	108
KD22	<600m	18/11	10.00	30.7	3.2	42	56700	104.8	6.71	77.6	12	CTB												
KE15	<300m	18/11	16.10	32.4	2.7	37	19700	35.1	8.31	22.2	37	30	0.04	<0.03	<0.03	71	6900	249	396.8	1052	11960	2000	0.03	144
KE16	<100m	18/11	15.30	32	2.4	33	16900	30.2	8.35	18.8	58	18												
KE17	<200m	18/11	14.56	31.9	2.3	32	16900	30.3	8.32	18.9	43	18	0.06	<0.03	<0.03	166	6150	226.5	380.8	902	10520	1280	0.03	148
KE18	<400	23/11	11.05	36.1	0.9	13	15700	28.1	8.11	17.4	5	CTB												
KF13	<300	22/11	11.20	31	1.4	19	E20	36.6	8.02	23	35	22					7750	317.5	533.1		13700	2070	0.07	104
KF14	<100	22/11	12.00	30.7	1.8	24	17400	31.1	8.01	19.4	65	40												
KF15	<300m	18/11	17.00	31	2.5	34	16800	30	8.32	18.7	65	25	0.04	<0.03	<0.03	93	6400	216	347.1	834	10200	1520	0.03	146
KF18	<300	22/11	14.24	32.1	1.7	22	15000	26.8	8.2	16.5	40	20												
KF19	<100	23/11	10.05	29.9	1.2	16	14900	26.6	8.34	16.3	74	CTB												
KF20	<100	23/11	9.23	29.8	1.1	13	14600	26	8.64	15.9	50	CTB												
KG13	<100	22/11	10.45	30.2	1.4	18	17300	31	8.15	19.4	58	22												
KG14	<100	22/11	12.19	31.8	1.7	24	17600	31.6	7.95	19.7	50	22					8688	225	481		11880	1745	0.1	157
KG15	<100	22/11	12.37	31	2	26	16000	28.7	7.45	17.8	63	49												
KG16	<100	22/11	12.58	30.9	1.8	23	15300	27.4	8.15	16.9	80	43												
KG17	<100	19/11	13.35	30.9	1.7	23	14200	25.3	8.6	15.5	60	45	0.04	<0.03	<0.03	79	4425	192	274.1	709	8200	1240	0.03	3080
KG18	<100	19/11	14.39	31.1	2.2	29	13900	24.8	7.28	15.1	80	65	0.04	<0.03	<0.03	125	4225	187.5	254.9	665	815	1260	0.03	146

Site	Distance from site	Date	Time	Temp (^0C)	DO (mgL^{-1})	DO (% sat)	TDS (mgL^{-1})	Cond (mS)	pH	Salinity (ppt)	Depth (cm)	Secchi depth (cm)	Zn (mgL^{-1})	Pb (mgL^{-1})	Cu (mgL^{-1})	SS (mgL^{-1})	Na (mgL^{-1})	K (mgL^{-1})	Ca (mgL^{-1})	Mg (mgL^{-1})	Cl (mgL^{-1})	SO4 (mgL^{-1})	PO4 (mgL^{-1})	CO4 (mgL^{-1})
KG19	<100	22/11	15.00	32.7	1.8	25	14300	25.5	8.21	15.6	45	23												
KG20	<300m	17/11	9.43	28.5	2.8	35	E20	43.3	8.24	28	45	36	0.07	<0.03	<0.03	220	4150	178.5	278.2	639	8110	600	0.08	132
KG21	<200m	17/11	8.49	28.6	2.8	35	E20	44.3	8.24	29	107	18												
KH12	<100	22/11	10.04	29.4	1.7	21	19100	34	8.23	21.4	40	25												
KH13	<100	22/11	9.29	28.9	1.2	16	18700	33.4	8.07	20.8	55	38												
KH14	<100	22/11	9.14	29.1	1.3	16	17600	31.4	8.08	19.6	54	CTB												
KH15	<100	22/11	8.48	28.4	1	13	14600	26		15.9	65	53					7625	227.5	468.9		9320	2030	0.08	157
KH16	<100	21/11	15.23	30.9	2.2	28	14700	26.8	8.2	16.2	90	30												
KH17	<200	19/11	13.05	30.9	2.1	29	13500	24.5	8.3	15.1	95	30	0.05	<0.03	<0.03	101	4300	196.5	254.1	676	8160	1560	0.03	160
KH18	<100	19/11	15.15	31.3	2	26	14000	24.9	6.97	15.2	95	43												
KH19	<100	21/11	16.00	30.6	2	28	14100	25.1	8.04	15.3	60	20					7625	210	400.8		8320	1300	0.06	166
KH20	<200m	17/11	10.30	29	2.1	27	E20	42.5	8.26	27.5	68	31												
KI14	<300	21/11	13.21	32.5	1.3	17	17700	31.6	8.69	19.8	42	CTB												
KI15	<100	21/11	13.47	31.4	1.5	22	15900	28.3	8.09	17.6	62	CTB												
KI16	<100	21/11	14.25	31.1	2.2	29	15100	26.9	7.82	16.6	90	40					7250	222.5	356.7		10280	1550	0.07	150
KI17	<200	19/11	12.33	32	1.8	23	14000	24.9	8.5	15.2	65	46												
KI18	<100	19/11	15.46	31.6	2.2	30	14100	25.3	7.68	15.4	80	33	0.04	<0.03	<0.03	98	4525	205.5	258.1	703	8560	1100	0.03	144
KI19	<100	21/11	16.43	30.1	2.4	31	14300	25.5	7.9	15.6	65	22												
KJ13	<300	21/11	11.42	31.8	0.01	1	1200	2.42	7.02	1.2	60	28												
KJ14	<100	21/11	12.25	31.6	1.1	14	13500	24.1	7.91	14.7	53	44					6688	215	428.9		226000	1265	0.09	138
KJ15	<100	21/11	12.47	30.9	1.3	19	14800	26.3	7.95	16.2	78	58												
KJ16	<100	21/11	14.55	30.8	1.7	23	15000	26.8	7.18	16.4	85	25												
KJ17	<100	19/11	12.06	31.1	1.7	23	14000	25	8.61	15.3	50	CTB	0.04	<0.03	<0.03	61	4550	205.5	280.6	668	8480	1080	0.03	146
KJ18	<200m	17/11	15.39	31.2	2.1	28	13700	24.5	8.16	14.9	63	31												
KJ19	<300m	17/11	14.50	32.5	2.6	35	13400	23.9	8.59	14.5	45	CTB												
KK12	<300	21/11	11.10	31.6	0.6	8	10700	18.98	7.35	11.3	57	CTB												

Site	Distance from site	Date	Time	Temp (^{0}C)	DO (mgL^{-1})	DO (% sat)	TDS (mgL^{-1})	Cond (mS)	pH	Salinity (ppt)	Depth (cm)	Secchi depth (cm)	Zn (mgL^{-1})	Pb (mgL^{-1})	Cu (mgL^{-1})	SS (mgL^{-1})	Na (mgL^{-1})	K (mgL^{-1})	Ca (mgL^{-1})	Mg (mgL^{-1})	Cl (mgL^{-1})	SO4 (mgL^{-1})	PO4 (mgL^{-1})	CO4 (mgL^{-1})
KK13	<100	21/11	10.37	29.9	1.3	17	10600	18.75	7.78	11.1	75	CTB					5312	170	304.6		7140	1365	0.08	97
KK14	<100	21/11	10.17	29.9	1.5	18	10800	19.13	7.56	11.4	75	CTB												
KK15	<100	21/11	9.39	29.2	2.2	27	12900	22.8	7.72	13.8	81	43												
KK16	<100	21/11	9.17	29.2	2.2	27	14600	26.1	7.75	16	100	64												
KK17	<100	19/11	11.38	32	1.9	24	13900	24.7	8.46	15.1	120	78	0.06	<0.03	<0.03	49	3475	207	278.2	681	8050	960	0.03	144
KK18	<300m	17/11	16.30	30.1	2.4	32	13100	23.3	8.27	14.1	65	38												
KL13	<180m	15/11	10.20	31.9	2.9	39	14700	25.5	7.6	15.9	70	CTB												
KL15	<100	20/11	16.10	31	1.7	23	12400	21.9	8.15	13.2	70	41												
KL16	<100	20/11	15.47	31.1	1.7	23	13900	24.7	7.95	15.1	80	54												
KL17	<200	19/11	11.04	31.7	1.6	21	14000	24.9	7.85	15.2	75	68												
KL18	<300m	16/11	16.30	30.5	3.4	45	E20	40.3	8.2	25.9	75	28												
KM12	<300m	15/11	9.15	29.6	3.5	45	6870	12.6	14.25	7	120	CTB	0.06	<0.03	<0.03	16	1222.5	55.8	127.5	231.2	2608	530	0.03	98
KM16	<100	20/11	15.19	31.5	2.1	28	12900	23	8.07	13.9	78	53												
KM17	<200	19/11	10.36	30.60	1.7	21	12700	22.5	9.73	13.6	99	47	0.05	<0.03	<0.03	42	3925	196.5	266.1	618	7360	1060	0.03	132
KN11	<170m	15/11	13.00	32	5	56	5220	9.53	5.6	5.4	90	74	0.06	<0.03	<0.03	6	855	36.6	78.6	133.8	8110	300	0.04	98
KN15	<100	20/11	14.45	31.1	1.7	22	13200	23.6	7.16	14.3	80	69												
KN16	<200	19/11	10.05	30.5	1.4	18	13000	23.1	7.02	14	95	CTB												
KN17	<100	19/11	9.39	29.4	1.2	15	12900	23	8.53	13.9	115	85	0.04	<0.03	<0.03	55	4225	199.5	268.5	646	7840	1020	0.03	116
KO13	<100	20/11	13.30	31.3	1.6	21	14700	26.2	8.08	16.1	80	68												
KO14	<700m	14/11	16.30	28.2	6.3	85	E20	42	5.8	27.1	85	30												
KO15	<100	20/11	16.47	29.8	1.7	22	13100	23.3	7.86	14.1	120	63												
KO16	<100	20/11	13.00	30.2	1.6	21	13000	23.2	7.95	14	125	58					7188	217.5	649.3		8720	1288	0.05	131
KO17	<270m	14/11	10.35	29.3	5.1	70	E20	38.9	8.01	24.9	95	20												
KP13	<400	23/11	15.48	31.6	1.5	19	13000	23.1	7.87	14	57	20												
KP14	<200	20/11	11.30	30.2	1	14	13500	24	7.87	14.6	95	82					7000	222.5	472.9		9260	1340	0.09	141
KP15	<100	20/11	12.01	30.4	1.3	16	13800	24.4	7.71	14.9	90	83												

Site	Distance from site	Date	Time	Temp (^{0}C)	DO (mgL^{-1})	DO (% sat)	TDS (mgL^{-1})	Cond (mS)	pH	Salinity (ppt)	Depth (cm)	Secchi depth (cm)	Zn (mgL^{-1})	Pb (mgL^{-1})	Cu (mgL^{-1})	SS (mgL^{-1})	Na (mgL^{-1})	K (mgL^{-1})	Ca (mgL^{-1})	Mg (mgL^{-1})	Cl (mgL^{-1})	SO4 (mgL^{-1})	PO4 (mgL^{-1})	CO4 (mgL^{-1})
KP16	<300	20/11	12.30	31	1.4	19	13500	24	7.3	14.6	51	47												
KQ10.5	<200	20/11	9.23	29.7	0.5	6	3640	6.81	7.51	3.7	110	CTB												
KQ11	<200	20/11	9.47	29.5	0.6	8	4100	7.61	7.44	4.2	57	CTB												
KQ12	<100	20/11	10.14	30.4	0.2	2	5370	9.81	7.76	5.5	95	CTB												
KQ14	<300	23/11	14.56	31.8	1.4	20	17400	31.2	7.66	19.5	52	CTB												

Songor Lagoon

Site	Distance from site	Date	Time	Temp (^{0}C)	DO (mgL^{-1})	DO (% sat)	TDS (mgL^{-1})	Cond (mS)	pH	Salinity (ppt)	Depth (cm)	Secchi depth (cm)
SB6	<100	25/11	9.50	29.1	1.4	17	E20	64.5	7.04	43.9	30	18
SB7	<100	25/11	10.53	31	1.5	20	E20	64.9	7.02	44.2	40	16
SB13	N 5 51 09 E 0 34 08*	11-Dec	14.50	31.9	11	150	14700	26.4	8.6	16.2	40	CTB
SC3	<100	8-Dec	11.13	29.3	8	102	70800	83.9	7.8	59.7	60	17
SC4	<100	8-Dec	11.56	29.6	17.9	224	64000	85.2	7.2	60.6	65	18
SC5	<100	8-Dec	12.55	30.6	12.3	159	62000	84.9	7.85	60.7	55	19
SC6	<100	8-Dec	13.42	30.8	7.7	102	68000	81.7	7.52	58.1	49	16
SC8	<200	8-Dec	17.14	31	13.5	180	51200	65	6.83	44.3	40	25
SC9	<100	25/11	12.38	31.1	2.1	27	E20	64.2	6.98	43.9	36	16
SC10	<100	25/11	14.26	31	N/A	N/A	E20	71	6.98	49	25	10
SC12.5	N 5 50 00 E 0 33 22.9*	11-Dec	13.51	33.60	7.70	104	E20	69.70	8.29	48.10	5	CTB
SD2	<300	8-Dec	9.46	28.2	7.9	100	4560	8.41	7.64	4.7	57	20
SD3	<100	9-Dec	8.53	28.3	4.3	55	64800	86	5.57	61.2	60	24

* actual coordinates of the sampling location

Site	Distance from site	Date	Time	Temp (^{0}C)	DO (mgL^{-1})	DO (% sat)	TDS (mgL^{-1})	Cond (mS)	pH	Salinity (ppt)	Depth (cm)	Secchi depth (cm)
SD4	<100	9-Dec	9.22	28.4	4.1	53	66800	85.3	5.27	60.4	53	21
SD5	<100	9-Dec	9.47	29.1	4.7	60	56000	85.1	5.33	60.4	60	19
SD6	<100	9-Dec	10.10	28.9	4.6	60	58800	86.3	5.14	61.4	45	20
SD7	<100	9-Dec	11.56	31.8	6.5	90	50000	68.1	5.36	46.8	25	17
SD8	<100	9-Dec	15.56	30.5	5.9	76	50800	67.6	5.52	46.4	50	20
SD9	<200	9-Dec	15.12	31	7.3	100	40400	63.2	5.55	43	40	19
SD10	<100	25/11	15.32	31.4	N/A	N/A	E20	59.8	7.2	40.2	30	16
SD11	N 5 49 14.3 E 0 31 51.7*	11-Dec	13.10	34.00	7.60	106	E20	68.10	8.32	46.90	15	CTB
SE6	N 5 48 14 E 0 26 53*	9-Dec	10.38	29.5	5.4	70	e20	86	5.19	61.2	48	20
SE7	<200	9-Dec	12.51	30.7	6.7	89	47200	66.7	5.11	45.7	40	19
SE8	<100	9-Dec	13.32	31.1	7.2	98	49200	66.6	5.59	45.6	35	18
SE9	<100	9-Dec	14.33	31.5	11.5	154	41200	63.5	5.6	43.1	30	CTB
SE10	<100	11-Dec	12.33	31.90	9.90	132	E20	61.70	7.88	41.70	35	CTB
SF9	N 5 47 14.3 E 0 30 00*	12-Dec	0.39	29.6	9.6	124	E20	70.9	7.73	49	5	CTB
SF10	<100	11-Dec	9.36	28.70	9.60	124	E20	60.10	7.07	40.60	25	CTB
SF11	N 5 47 07.8 E 0 31 58.4*	11-Dec	10.14	30.6	9.8	128	E20	59.1	7.53	39.5	10	CTB
SF12	N 5 47 06.1 E 0 33 05.9*	11-Dec	10.44	32	7.6	107	E20	54.4	7.85	36.3	7	CTB

* actual coordinates of the sampling location

Appendix 3 Chlorophyll concentrations ($\mu g\ L^{-1}$) in water collected from Keta and Songor lagoons

Keta sites	Chloro a	Chloro b	Chloro c	Total
KC17	18	12	8	38
KD17	9	8	10	27
KD18	7	–	–	7
KD19	34	20	10	64
KD20	22	17	19	58
KD21	–	–	–	–
KE15	38	27	80	145
KE16	22	5	–	27
KE17	37	25	7	69
KE18	9	6	11	26
KF13	7	–	2	9
KF14	9	6	–	15
KF15	19	7	12	38
KF18	11	4	4	19
KF19	10	9	5	24
KF20	5	5	3	13
KG13	–	3	5	8
KG14	–	–	–	–
KG15	2	12	4	18
KG16	–	–	–	–
KG17	16	11	–	27
KG18	15	15	1	31
KG19	10	7	–	17
KG20	10	4	–	14
KG21	23	25	5	53
KH12	5	5	3	13
KH13	5	5	3	13
KH14	4	2	3	9
KH15	3	7	–	10
KH16	13	6	–	19
KH17	–	–	–	–
KH18	18	14	–	32
KH19	15	9	–	24
KH20	2	5	25	32
KI14	–	4	–	4
KI16	12	8	–	20
KI19	16	10	–	26
KJ13	–	–	–	–
KJ14	8	–	1	9
KJ15	1	5	–	6
KJ16	25	25	1	51
KJ17	8	10	–	18
KJ18	19	16	4	39
KJ19	6	3	6	15
KK12	2	2	3	7
KK13	–	–	–	–
KK14	–	–	–	–
KK15	–	–	–	–
KK16	6	7	–	13
KK17	3	4	2	9

Keta sites	Chloro a	Chloro b	Chloro c	Total
KK18	9	6	–	15
KL13	9	13	19	41
KL15	17	6	–	23
KL16	11	10	–	21
KL17	–	6	–	6
KL18	–	4	6	10
KM12	3	3	1	7
KM16	7	2	–	9
KM17	3	1	–	4
KN11	2	2	–	4
KN15	1	1	–	2
KN16	3	7	–	10
KO13	3	3	–	6
KO14	–	17	–	17
KO16	–	24	–	24
KO17	–	17	–	17
KP13	39	–	–	39
KP15	1	4	–	5
KP16	2	6	–	8
KQ10	2	2	–	4
KQ11	2	7	–	9
KQ12	11	3	-	14
KQ14	14	8	6	28
KR09	8	41	–	49
KR10	8	–	–	8
Songor sites	**Chloro a**	**Chloro b**	**Chloro c**	**Total**
SC3	9	13	4	26
SC4	6	7	–	13
SC5	31	22	–	53
SC6	29	36	21	86
SC8	16	2	–	18
SD2	11	15	–	26
SD3	3	7	–	10
SD4	9	20	6	35
SD5	1	–	–	1
SD6	5	6	8	19
SD7	10	5	–	15
SD8	21	1	–	22
SD9	11	15	12	38
SD11	–	–	–	–
SE6	–	12	5	17
SE7	2	9	2	13
SE8	11	2	1	14
SE9	7	6	–	13
SE10	2	3	–	5
SC12	12	5	–	17
SB13	15	18	–	33
SF9	26	17	8	51
SF10	6	1	11	18
SF11	3	7	4	14
SF12	9	20	11	40

Appendix 4 Diversity indices for macroinvertebrate fauna in Keta and Songor lagoons

Keta site	Total species	Total indices	Richness	Shannon	Evenness	Simpson
KP15	2	4102	0.12	0.681	0.982	0.512
KH20	2	633	0.155	0.503	0.726	0.677
KI15	2	420	0.166	0.668	0.964	0.525
KJ18	2	322	0.173	0.672	0.969	0.521
KJ19	2	296	0.176	0.573	0.827	0.615
KF13	3	10 791	0.215	0.705	0.642	0.593
KD21	3	3596	0.244	0.843	0.767	0.479
KO17	3	3244	0.247	0.819	0.746	0.489
KH17	3	2634	0.254	0.733	0.667	0.596
KK12	3	2291	0.259	0.401	0.365	0.808
KF14	3	2266	0.259	0.941	0.857	0.441
KG18	3	2097	0.261	0.837	0.762	0.499
KK17	3	603	0.312	0.866	0.788	0.497
KP13	3	542	0.318	0.794	0.723	0.553
KE15	3	532	0.319	0.802	0.73	0.547
KH12	3	459	0.326	1.02	0.929	0.382
KG13	3	373	0.338	0.964	0.878	0.43
KQ14	4	6061	0.344	0.735	0.53	0.644
KK11	3	231	0.367	1.1	1	0.333
KG16	4	2719	0.379	1.03	0.739	0.407
KJ16	4	2042	0.394	1.09	0.783	0.399
KI18	4	1710	0.403	1.22	0.883	0.312
KH13	4	1612	0.406	1.11	0.801	0.384
KI15	5	17 908	0.408	0.335	0.208	0.868
KK13	5	15 230	0.415	0.452	0.281	0.809
KK15	4	1189	0.424	0.945	0.682	0.511
KP14	4	1154	0.425	0.911	0.657	0.535
KL16	4	1047	0.431	1.28	0.924	0.292
KE17	4	904	0.441	1.22	0.881	0.326
KD20	5	8343	0.443	1.19	0.741	0.387
KJ15	5	7612	0.448	1.15	0.712	0.421
KP15	4	735	0.455	1.13	0.813	0.395
KN17	4	699	0.458	1.29	0.928	0.3
KK16	4	664	0.462	1.29	0.933	0.295
KO16	5	5184	0.468	1.11	0.687	0.424
KI16	5	3950	0.483	1.3	0.809	0.345
KL17	5	3873	0.484	0.917	0.57	0.502
KN15	5	3642	0.488	1.3	0.809	0.338
KO13	6	25 854	0.492	0.458	0.255	0.772
KD22	5	2659	0.507	1.27	0.788	0.347
KJ14	6	16 387	0.515	1.36	0.76	0.318
KC17	5	2240	0.519	1.36	0.845	0.305
KI17	6	14 484	0.522	0.898	0.501	0.532
KG14	5	1980	0.527	1.22	0.756	0.389
KM17	6	12 257	0.531	0.999	0.557	0.492
KL13	6	10 953	0.538	1.23	0.686	0.415
KH15	5	1567	0.544	1.36	0.842	0.301
KN11	6	7602	0.56	0.556	0.31	0.772
KK18	6	6449	0.57	1.46	0.816	0.277

Keta site	Total species	Total indices	Richness	Shannon	Evenness	Simpson
KG19	5	1097	0.571	1.45	0.902	0.277
KF18	5	1077	0.573	1.52	0.945	0.231
KM12	6	5388	0.582	1.37	0.765	0.287
KH18	5	936	0.585	1.35	0.839	0.305
KD19	6	3449	0.614	0.966	0.539	0.568
KF15	5	604	0.625	1.48	0.921	0.258
KE18	6	2327	0.645	1.48	0.828	0.279
KI19	7	9393	0.656	1.6	0.82	0.254
KM16	7	8836	0.66	1.16	0.596	0.469
KF19	7	7796	0.67	1.48	0.763	0.287
KG15	7	7648	0.671	1.64	0.843	0.229
KF20	6	1699	0.672	1.51	0.843	0.268
KD18	6	1664	0.674	1.67	0.932	0.207
KH19	8	20 347	0.706	1.45	0.699	0.276
KG17	7	3476	0.736	1.06	0.546	0.531
KJ17	7	3267	0.742	1.61	0.829	0.251
KH14	7	2594	0.763	1.3	0.668	0.387
KL15	7	2446	0.769	1.51	0.777	0.291
KK14	9	27 165	0.784	1.05	0.478	0.507
KO14	9	23 714	0.794	1.68	0.764	0.241
KL18	7	1904	0.795	1.67	0.86	0.223
KP16	8	5302	0.816	1.64	0.787	0.246
KN16	8	2792	0.882	1.76	0.848	0.218
KI14	9	2868	1	1.96	0.89	0.165
KE16	10	7537	1.01	1.59	0.692	0.314
KD17	10	5057	1.06	1.73	0.75	0.263
Songor site	**Total species**	**Total indices**	**Richness**	**Shannon**	**Evenness**	**Simpson**
SE7	2	2189	0.13	0.152	0.22	0.932
SE6	2	1026	0.144	0.693	0.999	0.501
SD9	2	831	0.149	0.495	0.714	0.685
SC12	2	622	0.155	0.649	0.936	0.544
SD3	2	347	0.171	0.658	0.95	0.534
SD4	2	240	0.182	0.627	0.905	0.564
SC6	2	205	0.188	0.662	0.955	0.531
SD2	2	205	0.188	0.662	0.955	0.531
SC4	2	154	0.199	0.693	1	0.5
SE8	3	3974	0.241	0.658	0.599	0.633
SD7	3	3797	0.243	0.898	0.817	0.442
SD11	3	2454	0.256	0.478	0.435	0.753
SD6	3	2088	0.262	0.314	0.286	0.861
SC9	3	1454	0.275	1.08	0.987	0.342
SB13	3	541	0.318	1	0.912	0.389
SF10	3	449	0.327	1.02	0.928	0.383
SC10	3	373	0.338	0.964	0.878	0.43
SB6	4	3479	0.368	1.06	0.768	0.399
SD8	4	2587	0.382	0.498	0.359	0.776
SF9	4	1684	0.404	1.13	0.814	0.365
SC8	5	2354	0.515	0.634	0.394	0.724
SE10	5	2229	0.519	1.52	0.945	0.239

Songor site	Total species	Total indices	Richness	Shannon	Evenness	Simpson
SE9	5	807	0.598	1.46	0.908	0.264
SB7	6	1425	0.689	1.33	0.74	0.367
SF11	7	4266	0.718	1.46	0.749	0.319

Appendix 5 Macro-zoobenthos collected from Keta and Songor lagoons

		Numbers per core				Numbers per metre square		
Site	Genera	Lower	Mean	Upper		Lower	Mean	Upper
KC17	Melanoides	0	0.15	0.69		0	77	352
KC17	Nereis	0	0.15	0.69		0	77	352
KC17	Notomastus	0	0.64	2.86		0	327	1459
KC17	Tympanotonos	0	0.15	0.69		0	77	352
KC17	Urothoe	0	0.74	4.35		0	378	2219
KD14	Corbula	0	0.15	0.69		0	77	352
KD14	Melanoides	0	0.15	9.32		0	77	4755
KD14	Oligochaete	0	0.86	0.69		0	439	352
KD14	Tivela	0	0.15	0.69		0	77	352
KD14	Tympanotonos	0	0.52	3.81		0	265	1944
KD17	Boccardiella	0	0.25	1.29		0	128	658
KD17	Capitellid	0	0.15	0.69		0	77	352
KD17	Dipsio	0	1.61	6.82		0	821	3480
KD17	Eunice	0	1.35	6.19		0	689	3158
KD17	Glycera	0	0.32	1.85		0	163	944
KD17	Hydrobia	0	0.25	1.29		0	128	658
KD17	Nereis	0	0.3	1.38		0	153	704
KD17	Notomastus	0	1.49	30.16		0	760	15 388
KD17	Tivela	0	0.43	1.7		0	219	867
KD17	Tympanotonos	0	0.84	8.97		0	429	4577
KD17	Urothoe	0.68	4.53	17.18		347	2311	8765
KD18	Boccardiella	0	0.89	3.13		0	454	1597
KD18	Capitellid	0	0.25	1.29		0	128	658
KD18	Corbula	0	0.55	4.26		0	281	2173
KD18	Eunice	0	0.25	1.29		0	128	658
KD18	Nereis	0	0.89	4.64		0	454	2367
KD18	Urothoe	0	0.43	1.7		0	219	867
KD19	Boccardiella	0	0.4	1.98		0	204	1010
KD19	Eunice	0	0.48	3.35		0	245	1709
KD19	Nereis	0	0.38	2.37		0	194	1209
KD19	Notomastus	0	0.15	0.69		0	77	352
KD19	Tivela	1.13	5.03	16.07		577	2566	8199
KD19	Urothoe	0	0.32	1.85		0	163	944
KD20	Boccardiella	0	0.89	3.13		0	454	1597
KD20	Hydrobia	0.27	2.95	11.24		138	1505	5735
KD20	Melanoides	0	0.15	0.69		0	77	352
KD20	Notomastus	0	0.15	0.69		0	77	352
KD20	Tivela	0	0.15	0.69		0	77	352
KD20	Tympanotonos	0	0.64	1.99		0	327	1015
KD20	Urothoe	0	0.15	0.69		0	77	352
KD21	Boccardiella	0.41	4.24	18.54		209	2163	9459
KD21	Nereis	0	2.38	11.82		0	1214	6031
KD21	Urothoe	0	0.43	2.87		0	219	1464
KD22	Boccardiella	0	0.15	0.69		0	77	352
KD22	Dipsio	0	0.15	0.69		0	77	352
KD22	Eunice	0	0.32	1.11		0	163	566
KD22	Nereis	0.55	2.65	7.58		281	1352	3867
KD22	Oligochaete	0	0.64	5.53		0	327	2821

		Numbers per core				Numbers per metre square		
Site	Genera	Lower	Mean	Upper		Lower	Mean	Upper
KD22	Tivela	0	0.25	1.29		0	128	658
KD22	Urothoe	0	1.35	5.41		0	689	2760
KE15	Boccardiella	0	0.7	3.48		0	357	1776
KE15	Eunice	0	0.74	4.35		0	378	2219
KE15	Glycera	0	0.15	0.69		0	77	352
KE15	Melanoides	0	0.15	0.69		0	77	352
KE15	Nereis	0	1.16	6.36		0	592	3245
KE15	Oligochaete	0	0.32	1.85		0	163	944
KE15	Tivela	0	0.15	0.69		0	77	352
KE15	Urothoe	0.87	3.65	10.57		444	1862	5393
KE16	Boccardiella	0	0.84	3.38		0	429	1724
KE16	Eunice	0	0.89	5.04		0	454	2571
KE16	Melanoides	0	0.15	0.69		0	77	352
KE16	Nereis	0	2.46	15.38		0	1255	7847
KE16	Notomastus	0	1.09	6.45		0	556	3291
KE16	Oligochaete	0	0.43	2.87		0	219	1464
KE16	Tivela	0	0.25	1.29		0	128	658
KE16	Tympanotonos	0	0.15	0.69		0	77	352
KE16	Urothoe	4.8	7.67	11.96		2449	3913	6102
KE17	Corbula	0	0.25	1.29		0	128	658
KE17	Notomastus	0	0.67	5.94		0	342	3031
KE17	Tivela	0	0.15	0.69		0	77	352
KE17	Urothoe	0	0.7	6.34		0	357	3235
KE18	Boccardiella	0	0.58	2.39		0	296	1219
KE18	Eunice	0	0.52	2.27		0	265	1158
KE18	Nereis	0	1.07	3.69		0	546	1883
KE18	Tivela	0.19	1.99	6.51		97	1015	3321
KE18	Tympanotonos	0	0.25	1.29		0	128	658
KE18	Urothoe	0	0.15	0.69		0	77	352
KF13	Boccardiella	0	1.35	5.5		0	689	2806
KF13	Dipsio	0	0.95	5.21		0	485	2658
KF13	Nereis	1.26	4.39	11.59		643	2240	5913
KF13	Tivela	0	1.12	7.2		0	571	3673
KF13	Tympanotonos	0	15.64	2.68		0	7980	1367
KF14	Boccardiella	0	0.15	0.69		0	77	352
KF14	Dipsio	0	0.15	0.69		0	77	352
KF14	Nereis	0	0.64	3.35		0	327	1709
KF14	Tivela	0.16	2.63	10.35		82	1342	5281
KF14	Urothoe	0	1.17	3.82		0	597	1949
KF15	Boccardiella	0	0.48	3.35		0	245	1709
KF15	Eunice	0	0.15	0.69		0	77	352
KF15	Nereis	0	0	0		0	0	0
KF15	Notomastus	0	0.25	1.29		0	128	658
KF15	Tympanotonos	0	0.15	0.69		0	77	352
KF15	Urothoe	0	0.15	0.69		0	77	352
KF18	Boccardiella	0	0.58	2.82		0	296	1439
KF18	Capitellid	0	0.32	1.85		0	163	944
KF18	Nereis	0	0.58	2.39		0	296	1219
KF18	Tivela	0	0.15	0.69		0	77	352
KF18	Tympanotonos	0	0.48	3.35		0	245	1709

		Numbers per core				Numbers per metre square		
KF19	Dipsio	0	0.52	3.81		0	265	1944
KF19	Glycera	0	0.25	1.29		0	128	658
KF19	Melanoides	0	0.15	0.69		0	77	352
KF19	Nereis	0.92	3.16	7.96		469	1612	4061
KF19	Tivela	0	3.74	6.41		0	1908	3270
KF19	Tympanotonos	2.16	2.78	11.07		1102	1418	5648
KF19	Urothoe	0	0.48	3.35		0	245	1709
KF20	Boccardiella	0	0.32	1.11		0	163	566
KF20	Corbula	0	0.32	1.11		0	163	566
KF20	Melanoides	0	0.25	1.29		0	128	658
KF20	Nereis	0	0.97	3.83		0	495	1954
KF20	Neritina	0	0.15	0.69		0	77	352
KF20	Tympanotonos	0	1.32	5.4		0	673	2755
KG13	Corbula	0	0.15	0.69		0	77	352
KG13	Tivela	0	0.15	0.69		0	77	352
KG13	Tympanotonos	0	0.43	1.7		0	219	867
KG14	Boccardiella	0	0.32	1.85		0	163	944
KG14	Corbula	0	0.58	2.28		0	296	1163
KG14	Eunice	0	0.15	0.69		0	77	352
KG14	Tivela	1.11	2.25	3.98		566	1148	2031
KG14	Tympanotonos	0	0.58	3.56		0	296	1816
KG15	Boccardiella	0	1.27	8.01		0	648	4087
KG15	Capitellid	0	0.78	2.54		0	398	1296
KG15	Corbula	0.3	4.97	26.3		153	2536	13 418
KG15	Melanoides	0	3.75	29.1		0	1913	14 847
KG15	Nereis	0	0.58	2.82		0	296	1439
KG15	Tivela	0	0.48	3.35		0	245	1709
KG15	Tympanotonos	0	3.16	20.28		0	1612	10 347
KG16	Nereis	0	0.3	1.38		0	153	704
KG16	Tivela	0.38	2.39	7.33		194	1219	3740
KG16	Tympanotonos	0	0.25	1.29		0	128	658
KG16	Urothoe	0	2.39	0.69		0	1219	352
KG17	Corbula	3.44	0.38	2.37		1755	194	1209
KG17	Melanoides	0	0.7	6.34		0	357	3235
KG17	Nereis	0	0.3	1.38		0	153	704
KG17	Neritina	0	0.15	0.69		0	77	352
KG17	Notomastus	0	0.25	1.29		0	128	658
KG17	Tivela	0	4.88	6.78		0	2490	3459
KG17	Tympanotonos	0	0.15	0.69		0	77	352
KG18	Corbula	0	1.14	4.27		0	582	2179
KG18	Melanoides	0	0.32	1.11		0	163	566
KG18	Tympanotonos	0	2.65	14.85		0	1352	7577
KG19	Boccardiella	0	0.93	3.08		0	474	1571
KG19	Corbula	1.88	1.99	9.69		959	1015	4944
KG19	Nereis	0	0.86	4.57		0	439	2332
KG19	Neritina	0	0.25	1.29		0	128	658
KG19	Tivela	0	5.19	12.31		0	2648	6281
KG19	Tympanotonos	1.31	3.42	7.17		668	1745	3658
KH12	Boccardiella	0	0.32	1.85		0	163	944
KH12	Melanoides	0	0.43	1.7		0	219	867
KH12	Tympanotonos	0	0.15	0.69		0	77	352
KH13	Boccardiella	0	0.9	4.13		0	459	2107

		Numbers per core				Numbers per metre square		
KH13	Melanoides	0	0.15	0.69		0	77	352
KH13	Tivela	0	1.68	14.82		0	857	7561
KH13	Tympanotonos	0	0.43	1.7		0	219	867
KH14	Boccardiella	4.02	2.42	10		2051	1235	5102
KH14	Corbula	0	9.37	20.88		0	4781	10 653
KH14	Nereis	0.28	2.67	9.16		143	1362	4673
KH14	Tivela	0	1.64	6.04		0	837	3082
KH14	Tympanotonos	0	0.25	1.29		0	128	658
KH15	Boccardiella	0	0.95	5.21		0	485	2658
KH15	Capitellid	0	0.25	1.29		0	128	658
KH15	Eunice	0	0.15	0.69		0	77	352
KH15	Nereis	0	0.43	2.87		0	219	1464
KH15	Tivela	0	1.29	8.41		0	658	4291
KH16	Boccardiella	0.13	0.15	0.69		66	77	352
KH16	Tivela	0	1.35	3.59		0	689	1832
KH16	Tympanotonos	0.21	1.42	4.44		107	724	2265
KH17	Corbula	1.4	0.64	2.86		714	327	1459
KH17	Sarotherondon	0	0.15	0.69		0	77	352
KH17	Tivela	0	3.88	8.92		0	1980	4551
KH17	Tympanotonos	0	0.64	3.35		0	327	1709
KH18	Boccardiella	0	0.15	0.69		0	77	352
KH18	Eunice	0	0.15	0.69		0	77	352
KH18	Melanoides	0.04	0.25	1.29		20	128	658
KH18	Nereis	0	0.4	1.98		0	204	1010
KH18	Neritina	0	0.58	2.82		0	296	1439
KH18	Tivela	0.73	1.99	7.62		372	1015	3888
KH18	Tympanotonos	0	1.17	1.72		0	597	878
KH19	Boccardiella	0	0.93	3.23		0	474	1648
KH19	Capitellid	8.01	10.61	13.95		4087	5413	7117
KH19	Corbula	0.09	1	2.68		46	510	1367
KH19	Eunice	0	0.25	1.29		0	128	658
KH19	Nereis	0	0.67	296		0	342	151 020
KH19	Notomastus	8.4	12.71	19		4286	6485	9694
KH19	Tivela	0	12.71	19		0	6485	9694
KH19	Tympanotonos	0	1	2.68		0	510	1367
KH20	Corbula	0	0.99	12.37		0	505	6311
KH20	Tivela	0	0.25	1.29		0	128	658
KI14	Boccardiella	0	1.15	4.68		0	587	2388
KI14	Capitellid	0	0.82	4.07		0	418	2077
KI14	Corbula	0	0.43	1.7		0	219	867
KI14	Glycera	0	0.43	1.7		0	219	867
KI14	Nereis	0	1.46	6		0	745	3061
KI14	Neritina	0	0.15	0.69		0	77	352
KI14	Notomastus	0	0.78	3.99		0	398	2036
KI14	Tivela	0	0.15	0.69		0	77	352
KI14	Tympanotonos	0	0.25	1.29		0	128	658
KI15	Triv Tup	14.24	0.74	73.42		7265	378	37 459
KI15	Boccardiella	0	0.15	0.69		0	77	352
KI15	Corbula	0	0.25	2.58		0	128	1316
KI15	Melanoides	0	1.15	1.29		0	587	658
KI15	Nereis	0	0.32	1.11		0	163	566
KI15	Tivela	0	32.68	3.86		0	16 673	1969

		Numbers per core				Numbers per metre square		
KI15	Tympanotonos	0	0.7	5.24		0	357	2673
KI16	Boccardiella	0	0.47	6.35		0	240	3240
KI16	Corbula	0	4.09	0.69		0	2087	352
KI16	Nereis	0	1.05	3.86		0	536	1969
KI16	Tivela	0	1.49	15.13		0	760	7719
KI16	Tympanotonus	0	0.64	2.86		0	327	1459
KI17	Boccardiella	0	2.14	10.24		0	1092	5224
KI17	Corbula	0.64	5.54	25.03		327	2827	12 770
KI17	Eunice	0	2	18.86		0	1020	9622
KI17	Nereis	0	0.57	2.4		0	291	1224
KI17	Notomastus	0	0.15	0.69		0	77	352
KI17	Tivela	0	0.15	0.69		0	77	352
KI18	Corbula	0	1.17	10.98		0	597	5602
KI18	Neritina	0	0.86	5.74		0	439	2929
KI18	Tivela	0	1.17	4.92		0	597	2510
KI18	Tympanotonos	0	0.15	0.69		0	77	352
KI19	Boccardiella	0	1.32	4.97		0	673	2536
KI19	Corbula	0.08	2.84	12.67		41	1449	6464
KI19	Eunice	0	1.4	7.14		0	714	3643
KI19	Melanoides	2.16	3.79	6.26		1102	1934	3194
KI19	Nereis	0.66	7.65	40.3		337	3903	20 561
KI19	Notomastus	0	0.25	1.29		0	128	658
KI19	Tympanotonos	0	1.16	5.63		0	592	2872
KJ14	Boccardiella	0.58	2.65	6.94		296	1352	3541
KJ14	Corbula	7.11	15.69	33.34		3628	8005	17 010
KJ14	Eunice	0	0.15	0.69		0	77	352
KJ14	Melanoides	3.77	6.71	11.48		1923	3423	5857
KJ14	Nereis	2.46	5.11	9.78		1255	2607	4990
KJ14	Tivela	0.21	1.81	5.25		107	923	2679
KJ15	Boccardiella	0.88	9.02	52.47		449	4602	26 770
KJ15	Corbula	0	0.7	6.34		0	357	3235
KJ15	Nereis	0	1.07	4.86		0	546	2480
KJ15	Tivela	0	3.13	6.84		0	1597	3490
KJ15	Tympanotonos	0	1	3.73		0	510	1903
KJ16	Boccardiella	0	2.24	10.96		0	1143	5592
KJ16	Eunice	0	0.64	3.35		0	327	1709
KJ16	Nereis	0	0.15	0.69		0	77	352
KJ16	Tympanotonos	0	0.97	3.71		0	495	1893
KJ17	Corbula	0	0.78	2.54		0	398	1296
KJ17	Dipsio	0	0.38	2.37		0	194	1209
KJ17	Glycera	0	0.15	0.69		0	77	352
KJ17	Hydrobia	0	0.25	1.29		0	128	658
KJ17	Nereis	0	1.35	6.08		0	689	3102
KJ17	Neritina	0	0.64	2.96		0	327	1510
KJ17	Notomastus	0	2.65	15.83		0	1352	8077
KJ17	Tivela	0	0.58	2.39		0	296	1219
KJ18	Boccardiella	0	0.38	2.37		0	194	1209
KJ18	Tympanotonos	0	0.25	1.29		0	128	658
KJ19	Eunice	0	0.43	2.87		0	219	1464
KJ19	Tivela	0	0.15	0.69		0	77	352
KK11	Boccardiella	0	0.15	0.69		0	77	352
KK11	Corbula	0	0.15	0.69		0	77	352

		Numbers per core				Numbers per metre square		
KK11	Eunice	0	0.15	0.69		0	77	352
KK11	Notomastus	0	0.64	5.53		0	327	2821
KK11	Tivela	0	0.15	0.69		0	77	352
KK12	Boccardiella	0	4.02	32.5		0	2051	16 582
KK12	Melanoides	0	0.32	1.11		0	163	566
KK12	Tympanotonos	0	0.15	0.69		0	77	352
KK13	Boccardiella	0	1.26	8.6		0	643	4388
KK13	Corbula	0	1.06	4.43		0	541	2260
KK13	Eunice	0	0.58	4.69		0	296	2393
KK13	Melanoides	1.07	26.8	371.46		546	13 673	189 520
KK13	Nereis	0	0	0		0	0	0
KK13	Notomastus	0	0.15	0.69		0	77	352
KK14	Boccardiella	0	0.58	2.82		0	296	1439
KK14	Corbula	5.21	8.49	13.51		2658	4332	6893
KK14	Eunice	1.06	2.95	6.56		541	1505	3347
KK14	Hydrobia	0	0.32	1.11		0	163	566
KK14	Melanoides	10.74	36.67	119.87		5480	18 709	61 158
KK14	Nereis	0	0.15	0.69		0	77	352
KK14	Neritina	0	0.74	2.58		0	378	1316
KK14	Tivela	1.22	3.19	6.91		622	1628	3526
KK14	Tympanotonos	0	0.15	0.69		0	77	352
KK15	Boccardiella	0.18	1.61	4.73		92	821	2413
KK15	Eunice	0	0.25	1.29		0	128	658
KK15	Tivela	0	0.32	1.11		0	163	566
KK15	Tympanotonos	0	0.15	0.69		0	77	352
KK16	Boccardiella	0	0.38	2.37		0	194	1209
KK16	G3	0	0.15	0.69		0	77	352
KK16	Nereis	0	0.25	1.29		0	128	658
KK16	Tivela	0	0.52	2.27		0	265	1158
KK16	Tympanotonos	0	0.15	0.69		0	77	352
KK17	Eunice	0	0.78	2.54		0	398	1296
KK17	Neritina	0	0.15	0.69		0	77	352
KK17	Tivela	0	0.25	1.29		0	128	658
KK17	Tympanotonos	0	0.15	0.69		0	77	352
KK18	Corbula	0	0.96	11.72		0	490	5980
KK18	G4	0	0.15	0.69		0	77	352
KK18	Melanoides	0	0.32	1.85		0	163	944
KK18	Nereis	0	0.25	1.29		0	128	658
KK18	Neritina	0	0.32	1.85		0	163	944
KK18	Tympanotonos	0	0.3	1.38		0	153	704
KL13	Glycera	0	0.78	2.54		0	398	1296
KL13	Nereis	0.95	2.47	5.17		485	1260	2638
KL13	Oligochaete	79.57	141.65	251.57		40 597	72 270	128 352
KL13	Tivela	0	1.95	7.86		0	995	4010
KL13	Urothoe	0.41	2.55	7.92		209	1301	4041
KL15	Corbula	0	1.51	6.18		0	770	3153
KL15	Eunice	0	0.15	0.69		0	77	352
KL15	Melanoides	0	0.55	2.28		0	281	1163
KL15	Nereis	0	2.26	14.56		0	1153	7429
KL15	Tivela	0	0.89	4.64		0	454	2367
KL15	Tympanotonos	0	0.15	0.69		0	77	352
KL15	Urothoe	0	0.64	1.99		0	327	1015

		Numbers per core				Numbers per metre square		
KL16	Capitellid	0	0.64	1.99		0	327	1015
KL16	Melanoides	0	0.64	3.35		0	327	1709
KL16	Tivela	0	0.62	5.12		0	316	2612
KL16	Tympanotonos	0	0.15	0.69		0	77	352
KL16	Urothoe	0	0.15	0.69		0	77	352
KL17	Brachidontes	0	0.15	0.69		0	77	352
KL17	Nereis	1.67	4.98	12.52		852	2541	6388
KL17	Neritina	0.35	1.99	5.62		179	1015	2867
KL17	Tivela	0	0.32	1.11		0	163	566
KL17	Tympanotonos	0	0.15	0.69		0	77	352
KL18	Boccardiella	0	0.32	1.85		0	163	944
KL18	Melanoides	0	1.29	5.43		0	658	2770
KL18	Nereis	0	0.83	3.57		0	423	1821
KL18	Neritina	0	0.15	0.69		0	77	352
KL18	Tivela	0	0.74	4.35		0	378	2219
KL18	Tympanotonos	0	0.15	0.69		0	77	352
KL18	Urothoe	0	0.25	1.29		0	128	658
KM12	Glycera	0	0.32	1.11		0	163	566
KM12	Melanoides	0.18	0.74	1.56		92	378	796
KM12	Nereis	1.86	6.15	19.36		949	3138	9878
KM12	Oligochaete	0	0.89	3.13		0	454	1597
KM12	Tivela	0	0.52	2.27		0	265	1158
KM12	Tympanotonos	2.1	4.96	10.43		1071	2531	5321
KM12	Urothoe	0.15	1.7	5.33		77	867	2719
KM16	Corbula	0	0.62	5.12		0	316	2612
KM16	G3	0	0.25	1.29		0	128	658
KM16	Glycera	0	0.32	1.11		0	163	566
KM16	Melanoides	0	1.46	6.15		0	745	3138
KM16	Nereis	0.77	2.26	5.22		393	1153	2663
KM16	Neritina	0	0.32	1.11		0	163	566
KM16	Tivela	0.56	11.5	85.35		286	5867	43 546
KM16	Tympanotonos	0	0.84	3.38		0	429	1724
KM17	Boccardiella	0	0.15	0.69		0	77	352
KM17	Brachidontes	0	0.32	1.11		0	163	566
KM17	Capitellid	3.1	4.96	7.65		1582	2531	3903
KM17	Eunice	0	0.15	0.69		0	77	352
KM17	Nereis	0	1	3.73		0	510	1903
KM17	Neritina	0	0.32	1.11		0	163	566
KM17	Tympanotonos	0	1.6	5.95		0	816	3036
KN11	Boccardiella	0	0.15	0.69		0	77	352
KN11	Excirolana	0	0.32	1.11		0	163	566
KN11	Hydrobia	0	0.25	1.29		0	128	658
KN11	Melanoides	1.42	5.65	17.23		724	2883	8791
KN11	Odonata I	0	0.4	1.98		0	204	1010
KN11	Oligochaete	0	0.15	0.69		0	77	352
KN11	Tivela	26.09	44.15	74.24		13 311	22 526	37 878
KN11	Urothoe	0	0.32	1.11		0	163	566
KN15	Boccardiella	0	0.57	3.14		0	291	1602
KN15	Corbula	0	3.67	37.05		0	1872	18 903
KN15	Nereis	0	1.29	6.4		0	658	3265
KN15	Neritina	0	0.32	1.11		0	163	566
KN15	Tivela	0	1.29	7.14		0	658	3643

		Numbers per core				Numbers per metre square		
KN16	Boccardiella	0	1.05	6.29		0	536	3209
KN16	Brachidontes	0	2.06	12.81		0	1051	6536
KN16	Corbula	0	0.64	3.35		0	327	1709
KN16	Eunice	0	0.25	1.29		0	128	658
KN16	Nereis	0	0.3	1.38		0	153	704
KN16	Neritina	0	0.32	1.85		0	163	944
KN16	Tivela	0	0.7	3.86		0	357	1969
KN16	Tympanotonos	0	0.15	0.69		0	77	352
KN17	Boccardiella	0	0.32	1.85		0	163	944
KN17	Nereis	0	0.58	2.39		0	296	1219
KN17	Tivela	0	0.15	0.69		0	77	352
KN17	Tympanotonos	0	0.32	1.85		0	163	944
KO13	Brachidontes	0	0.15	0.69		0	77	352
KO13	Corbula	5.45	13.06	29.66		2781	6663	15 133
KO13	G3	0.61	2.29	5.73		311	1168	2923
KO13	Melanoides	0	0.32	1.85		0	163	944
KO13	Nereis	0	0.75	2.81		0	383	1434
KO13	Neritina	0	0.32	1.11		0	163	566
KO13	Tivela	0	0	0		0	0	0
KO13	Tympanotonos	0	0.3	1.38		0	153	704
KO14	Boccardiella	0	2.02	9.61		0	1031	4903
KO14	Brachidontes	0	1	3.73		0	510	1903
KO14	Callinectes	0	0.32	1.11		0	163	566
KO14	Corbula	7.84	12.68	20.15		4000	6469	10 281
KO14	Excirolana	0	2.85	17.45		0	1454	8903
KO14	Glycera	0	0.15	0.69		0	77	352
KO14	Neritina	0.1	2.59	10.77		51	1321	5495
KO14	STP	0	0.72	3.43		0	367	1750
KO14	Tilapia	0	0.15	0.69		0	77	352
KO14	Tivela	1.11	2.25	3.98		566	1148	2031
KO14	Tympanotonos	5.63	17.19	45.97		2872	8770	23 454
KO14	Urothoe	0	1.99	9.69		0	1015	4944
KO16	Melanoides	0.14	6.13	31.5		71	3128	16 071
KO16	Nereis	0	0	0		0	0	0
KO16	Neritina	0	0.52	1.43		0	265	730
KO16	Tivela	1.05	2.06	3.59		536	1051	1832
KO16	Tympanotonos	0.12	1.3	3.72		61	663	1898
KO17	Neritina	0	0.32	1.11		0	163	566
KO17	Oligochaete	0.15	2.17	7.73		77	1107	3944
KO17	PT	0	1.51	9.02		0	770	4602
KO17	Tivela	1.3	3.87	9.31		663	1974	4750
KP13	Boccardiella	0	0.15	0.69		0	77	352
KP13	Melanoides	0	0.76	7.5		0	388	3827
KP13	Tympanotonos	0	0.15	0.69		0	77	352
KP13	Urothoe	0	0.15	0.69		0	77	352
KP14	Corbula	0	0.25	1.29		0	128	658
KP14	Melanoides	0	1.61	13.42		0	821	6847
KP14	Nereis	0	0.25	1.29		0	128	658
KP14	Tympanotonos	0	0.15	0.69		0	77	352
KP15	Brachidontes	0	0.15	0.69		0	77	352
KP15	Glycera	0	0.15	0.69		0	77	352
KP15	Melanoides	0.36	3.39	13.2		184	1730	6735

		Numbers per core				Numbers per metre square		
KP15	Nereis	0	0.32	1.11		0	163	566
KP15	Neritina	0	0.82	3.14		0	418	1602
KP15	Tivela	0.79	1.35	2.1		403	689	1071
KP15	Tympanotonos	1.56	4.65	11.46		796	2372	5847
KP16	Boccardiella	0	1.07	4.55		0	546	2321
KP16	Corbula	0	0.32	1.11		0	163	566
KP16	Eunice	0	0.15	0.69		0	77	352
KP16	Melanoides	0	4.18	30.22		0	2133	15 418
KP16	Nereis	0.12	1.94	7.07		61	990	3607
KP16	Tivela	0	0.72	3.43		0	367	1750
KP16	Tympanotonos	0.19	1.86	5.89		97	949	3005
KQ14	Corbula	0	0.82	3.14		0	418	1602
KQ14	Hydrobia	0	0.89	5.04		0	454	2571
KQ14	Melanoides	0.9	9.43	56.34		459	4811	28 745
KQ14	Tympanotonos	0	0.74	2.58		0	378	1316
KR10	Glycera	0	0.52	2.27		0	265	1158
KR10	Oligochaete	0	0.43	1.7		0	219	867
KR10	Urothoe	1.1	7.19	30.98		561	3668	15 806
Q3	Eunice	0	0.15	0.69		0	77	352
Q3	Tympanotonos	0	0.15	0.69		0	77	352
R1	Boccardiella	0	0.32	1.11		0	163	566
R1	Hermit crab	0	0.15	0.69		0	77	352
R1	Nereis	0.8	2.24	2.27		408	1143	1158
R1	Notomastus	0	0.15	0.69		0	77	352
R7	Nereis	0	0.9	4.67		0	459	2383
R7	Notomastus	0	0.43	2.87		0	219	1464
R7	Tivela	0	0.15	0.69		0	77	352
R9	Boccardiella	0	0.15	0.69		0	77	352
R9	Dipsio	0	0.15	0.69		0	77	352
R9	Nereis	0	0.89	3.13		0	454	1597
R9	Urothoe	0	0.15	0.69		0	77	352
SB13	Boccardiella	0	0.43	1.7		0	219	867
SB13	Urothoe	0	0.15	0.69		0	77	352
SB6	Boccardiella	0	1.2	6.61		0	612	3372
SB6	Eunice	0	1.7	7.96		0	867	4061
SB6	Nereis	0	0.15	0.69		0	77	352
SB6	Notomastus	0.33	3.77	16.03		168	1923	8179
SB7	Boccardiella	0	0.15	0.69		0	77	352
SB7	Capitellid	0	0.15	0.69		0	77	352
SB7	Eunice	0	0.25	1.29		0	128	658
SB7	Notomastus	0	1.57	8.08		0	801	4122
SB7	Tympanotonos	0	0.15	0.69		0	77	352
SB7	Urothoe	0	0.52	1.43		0	265	730
SC10	Boccardiella	0	0.43	1.7		0	219	867
SC10	Notomastus	0	0.15	0.69		0	77	352
SC12	Boccardiella	0	0.75	3.55		0	383	1811
SC12	Eunice	0	0.43	1.7		0	219	867
SC12	Nereis	0	0.79	3.65		0	403	1862
SC3	Notomastus	0	0.15	0.69		0	77	352
SC4	Nereis	0	0.15	0.69		0	77	352
SC4	Notomastus	0	0.15	0.69		0	77	352
SC6	Boccardiella	0	0.15	0.69		0	77	352

		Numbers per core				Numbers per metre square		
SC6	Nereis	0	0.25	1.29		0	128	658
SC8	Boccardiella	0	0.25	1.29		0	128	658
SC8	Nereis	2.22	3.91	6.93		1133	1995	3536
SC8	Notomastus	0	0.15	0.69		0	77	352
SC8	Tympanotonos	0	0.15	0.69		0	77	352
SC8	Urothoe	0	0.15	0.69		0	77	352
SC9	Boccardiella	0	0.73	3.15		0	372	1607
SC9	Nereis	0.13	1.17	3.15		66	597	1607
SC9	Notomastus	0	1.05	4.28		0	536	2184
SD10	Boccardiella	0	0.25	1.29		0	128	658
SD10	Capitellid	0	0.15	0.69		0	77	352
SD11	Nereis	1.7	4.14	8.78		867	2112	4480
SD11	Urothoe	0	0.15	0.69		0	77	352
SD2	Corbula	0	0.25	1.29		0	128	658
SD2	Melanoides	0	0.15	0.69		0	77	352
SD3	Nereis	0	0.43	1.7		0	219	867
SD3	Tympanotonos	0	0.25	1.29		0	128	658
SD4	Boccardiella	0	0.32	1.11		0	163	566
SD4	Notomastus	0	0.15	0.69		0	77	352
SD6	Nereis	0	0.15	0.69		0	77	352
SD6	Notomastus	0.25	3.79	17.31		128	1934	8832
SD6	Tympanotonos	0	0.15	0.69		0	77	352
SD7	Boccardiella	1.12	2.99	6.51		571	1526	3321
SD7	Capitellid	1.65	3.9	8.06		842	1990	4112
SD7	Nereis	0	0.55	2.28		0	281	1163
SD8	Boccardiella	0	0.15	0.69		0	77	352
SD8	Nereis	0	0.15	0.69		0	77	352
SD8	Notomastus	0.42	4.45	19.84		214	2270	10 122
SD8	Tympanotonos	0	0.32	1.11		0	163	566
SD9	Notomastus	0	0.32	1.11		0	163	566
SD9	Tympanotonos	0	1.31	6.91		0	668	3526
SE10	Boccardiella	0	0.32	1.11		0	163	566
SE10	Nereis	0	0.72	3.43		0	367	1750
SE10	Notomastus	0.18	1.61	4.73		92	821	2413
SE10	Tympanotonos	0	0.86	5.74		0	439	2929
SE10	Urothoe	0	0.48	3.35		0	245	1709
SE6	Nereis	0	1.04	5.33		0	531	2719
SE6	Notomastus	0	0.97	3.71		0	495	1893
SE7	Boccardiella	0	0.15	0.69		0	77	352
SE7	Notomastus	1.28	4.14	10.59		653	2112	5403
SE8	Capitellid	1.88	6.04	16.19		959	3082	8260
SE8	Nereis	0.13	1.32	3.84		66	673	1959
SE8	Tympanotouns	0	0.43	1.7		0	219	867
SE9	Boccardiella	0	0.15	0.69		0	77	352
SE9	Capitellid	0	0.64	1.99		0	327	1015
SE9	Nereis	0	0.32	1.11		0	163	566
SE9	Urothoe	0	0.32	1.85		0	163	944
SF10	Boccardiella	0	0.15	1.7		0	77	867
SF10	Capitellid	0	0.43	34.01		0	219	17 352
SF10	Nereis	0	0.3	1.38		0	153	704
SF11	Boccardiella	0.65	0.47	1.8		332	240	918
SF11	Capitellid	0	1.64	3.23		0	837	1648

		Numbers per core				Numbers per metre square		
SF11	Nereis	0	0.64	1.99		0	327	1015
SF11	Tivela	0	0.32	1.11		0	163	566
SF11	Tympanotonus	0	0.15	0.69		0	77	352
SF11	Urothoe	0	4.25	34.01		0	2168	17 352
SF12	Notomastus	0	0.32	1.11		0	163	566
SF9	Nereis	0	0.15	0.69		0	77	352
SF9	Notomastus	0	1.17	4.28		0	597	2184
SF9	Tympanotonus	0	1.55	2.36		0	791	1204
SF9	Urothoe	0	0.43	1.7		0	219	867

Appendix 6 Dominant plant species recorded at the wetland sites surrounding Keta and Songor lagoons and in the Angor channel connecting Keta to the Volta River

Keta lagoon

Site	Date	Coordinates*		Dominant species (Top 5)	Comments
		N	E		
KB17	16/11	06 03.4	00 56.9	*Typha domingensis* *Paspalum vaginatum* *Cyperus articulatus* *Cyperus distans*	Inundated
KB23	16/11	06 02.9	01 03.0	*Sesuvium portulacastrum* *Avicennia nitida* *Sporobolus pyramidalis*	Dry land
KC16	16/11	06 02.0	00 55.8	*Paspalum vaginatum* *Avicennia nitida* *Cyperus articulatus* *Nymphaea micrantha* *Sesuvium portulacastrum*	Dry land
KC18	16/11	06 01.8	00 58.0	*Sesuvium portulacastrum* *Paspalum vaginatum* *Philoxerus vermicularis* *Cyperus articulatus* *Typha domingensis*	Dry land
KC20	16/11	06 01.4	01 00.0	*Sesuvium portulacastrum* *Sporobolus pyramidalis* *Chloris gayana* *Cocos nucifera* *Commelina* sp	Dry drainage depression
KC22	16/11	06 01.7	01 02.1	*Sesuvium portulacastrum* *Sporobolus pyramidalis* *Chloris gayana* *Crotalaria retusa* *Philoxerus vermicularis*	Dry land
KC23	27/11	06 02.0	01 03.0	*Sporobolus pyramidalis* *Paspalum vaginatum* *Cyperus articulatus* *Azadirachta indica* *Borassus aethiopum*	Island with pronounced elevation hence less hydrophillic vegetation; would only experience very brief inundation.
KC24	16/11	06 02	01 04.0	*Sesuvium portulacastrum* *Andropogon gayanus* *Avicennia nitida* *Borassus aethiopum* *Cocos nucifera*	Dry land
KD15	16/11	06 00.9	00 55.0	*Sesuvium portulacastrum* *Cyperus articulatus* *Cyperus distans* *Fimbristylis small* *Paspalum vaginatum*	Dry land
KD22	27/11	06 01.0	01 02.1	*Paspalum vaginatum* *Cyperus articulatus* *Sesuvium portulacastrum* *Philoxerus vermicularis* *Sporobolus pyramidalis*	Expanse of dry flat country 100 m from edge of lagoon. *Paspalum* with *Sporobolus* dominates

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
KD23	16/11	06 01.0	01 03.0	*Sesuvium portulacastrum* *Cyperus rotundus* *Sporobolus pyramidalis* *Cyperus articulatus*	Dry land
KE14	17/11	05 59.8	00 53.9	*Cyperus articulatus* *Philoxerus vermicularis* *Paspalum vaginatum* *Nymphaea micrantha*	Dry land
KE15	27/11	06 00.2	00 54.9	*Sesuvium portulacastrum* *Philoxerus vermicularis* *Sporobolus pyramidalis* *Fimbristylis dichotoma* *Cyperus articulatus*	Site in lagoon; sampling took place on edge of lagoon 400 m to west.
KE19	27/11	06 00.0	00 59.0	*Sesuvium portulacastrum* *Cyperus distans* *Scirpus cubensis* *Philoxerus vermicularis* *Sporobolus pyramidalis*	Mud flats on edge of island; higher ground is dominated by *Sporobolus pyramidalis*
KE20	19/11	06 00.0	01 00.0	*Paspalum vaginatum* *Lonyia taxifolia* *Vernonia* sp *Sesuvium portulacastrum* *Ruppia maritima* (in lagoon)	Dry sandy edge of lagoon within 10 m of water.
KE21	19/11	06 00.0	01 01.00	*Sesuvium portulacastrum* *Philoxerus vermicularis* *Sporobolus pyramidalis* *Cyperus distans* *Fimbristylis* sp	Extensive dry pan
KE22	27/11	06 00.0	01 02.0	*Paspalum vaginatum* *Cyperus distans* *Cyperus articulatus* *Sesuvium portulacastrum* *Philoxerus vermicularis*	Dry plain on island subject to inundation. Cassava and coconut plantation on higher elevation to the west.
KF11	17/11	05 59.1	00 51.7	*Eleocharis dulcis* *Paspalum vaginatum* *Cyperus distans*	Inundated (depth 9 cm)
KF16	27/11	05 59.1	00 56.0	*Sesuvium portulacastrum* *Avicennia* sp *Concocarpus* sp *Crotalaria retusa* *Imperata cylindrica*	Mud flats on Island; higher ground dominated by *Sporobolus pyramidalis* and *Paspalum vaginatum*
KF21	19/11	05 59.0	01 00.0	*Sesuvium portulacastrum* *Cyperus* sp *Ruppia maritima (senesced)* *Philoxerus vermicularis*	Extensive area of dry flats
KF22	16/11	05 59.1	01 01.7	*Paspalum vaginatum* *Sesuvium portulacastrum* *Philoxerus vermicularis* *Avicennia nitida* *Ruppia maritima (senesced)*	Moist ground (depth 1 cm)

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
KG01	9/12	05 58.1	00 41.0	*Ipomea aquatica* *Salvinia nymphellula* *Ludwigia erecta* *Nymphaea lotus* *Pistia stratiotes*	
KG09	6/12	05 58.0	00 49.0	*Sporobolus* sp *Sphenoeclea* sp *Ipomea aquatica* *Ludwigia leptocarpa* *Scirpus cubensis?*	Note surrounding area disturbed by sugar cane growing.
KG12	21/11	05 57.9	00 52.0	*Sesuvium portulacastrum* *Avicennia nitida* *Paspalum vaginatum*	Dry land
KH08	6/12	05 57.1	00 47.0	No dominant species – see comments *Andropogon gayanus* *Cyperus articulatus* *Cyperus distans* *Fimbristylis dichotoma* *Imperata cylindrica*	Whole area for 500 m in any direction is being cultivated under sugar cane. Remnant wetland vegetation in channels and beside paths.
KH11	17/11	05 57.2	00 51.0	*Paspalum vaginatum* *Cyperus articulatus* *Cyperus distans*	Dry land
KI01	9/12	05 56.1	00 41.0	*Typha domingensis* *Paspalum vaginatum* *Ludwigia leptocarpa*	Inundated site (depth 65 cm). Slightly (150 m) north of site. Sampling took place 50 m into the stand.
KI09	6/12	05 56.0	00 49.0	*Ipomea aquatica* *Ceratophyllum demersum* *Eclipta prostrata* *Ludwigia erecta* *Ludwigia leptocarpa*	Area disturbed by human activity; sugar cane growing.
KI11	6/12	05 56.0	00 50.9	*Eleocharis dulcis* *Cyperus articulatus* *Ipomea aquatica* *Ludwigia stolonifera* *Nymphaea lotus*	Boat trip from Atiavi through a very diverse range of wetland flora; it seems that everything is here. However, there is a virtual monoculture of *Eleocharis dulcis* at the site.
KI12	21/11	05 56.6	00 52.1	*Paspalum vaginatum* *Sporobolus pyramidalis* *Philoxerus vermicularis* *Sesuvium portulacastrum* *Cyperus articulatus*	Dry land
KI13	21/11	05 56.4	00 52.9	*Paspalum vaginatum* *Cynodon* sp (not flowering) *Sesuvium portulacastrum*	Dry land
KJ02	9/12	05 55.1	00 42.2	*Typha domingensis* *Paspalum vaginatum* *Ipomea aquatica*	Site is 200 m further west in an extensive *Typha* stand. Sampling took place 50 m into the stand. Very moist soil (av depth only 1 cm).
KJ12	21/11	05 54.5	00 52.6	*Paspalum vaginatum* *Sesuvium portulacastrum* *Ceratophyllum demersum* *Cyperus distans* *Nymphaea lotus*	Water and dry land site

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
KK03	9/12	05 54.0	00 42.0	*Cyperus articulatus* *Paspalum vaginatum* *Brachiaria pyramidalis* *Cyperus distans* *Typha domingensis*	Extensive *Typha* bed 100 m to the NE of site.
KK11	18/11	05 54 1	00 51.0	*Brachiaria mutica* *Cyperus articulatus* *Andropogon gayanus* *Azolla africana* *Borassus aethiopum*	Dry stream bank and stream
KK12	21/11	05 53.9	00 51.0	*Typha domingensis* *Paspalum vaginatum* *Nymphaea lotus* *Sesuvium portulacastrum*	Inundated (av depth 56 cm)
KK19	19/11	05 54.0	00 59.0	*Sesuvium portulacastrum* *Ruppia maritima* *Typha domingensis* *Paspalum vaginatum*	Flats with moist soil
KL04	9/12	05 53.1	00 44.0	*Veteveria vulvibarbis* *Paspalum vaginatum* *Andropogon gayanus* *Azarachtea indica* *Bacopa crenata*	Drainage line through savanna area 100 m from site. Area recently burnt.
KL10	18/11	05 53.0	00 50.1	*Paspalum vaginatum* *Nymphaea micrantha* *Sesuvium portulacastrum* *Philoxerus vermicularis* *Typha domingensis*	Dry land
KL11	21/11	05 53.0	00 51.0	*Paspalum vaginatum* *Sesuvium portulacastrum*	Dry land
KL12	18/11	05 53.0	00 52.0	*Paspalum vaginatum* *Cyperus articulatus* *Sesuvium portulacastrum* *Typha domingensis*	Inundated (av depth 4 cm)
KL14	15/11	05 53.0	00 54.0	*Cyperus articulatus* *Sesuvium portulacastrum* *Philoxerus vermicularis* *Nymphaea micrantha* *Paspalum vaginatum*	No water on site
KM07	28/11	05 52.0	00 47.0	*Andropogon gayanus* *Sporobolus* sp *Borassus aethiopum* *Cyperus distans* *Sporobolus pyramidalis*	Higher elevation drier country; > 1 km of *Andropogon gayanus*
KM10	18/11	5 51.0	0 49.9	*Paspalum vaginatum* *Cyperus articulatus* *Sesuvium portulacastrum* *Typha domingensis*	Dry land
KM11	20/11	05 53.1	00 50.9	*Paspalum vaginatum* *Philoxerus vermicularisn* *Typha domingensis* *Najas* sp	Inundated (depth 24–33 cm)

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
KM13	15/11	05 52.0	0053.0	*Paspalum vaginatum/ Sesuvium portulacastrum/ Cyperus water association* (av depth 19 cm) *Cyperus water/Paspalum vaginatum/ Sesuvium portulacastrum association* (av depth 30 cm) Others: *Algal scum* *Nymphaea lotus* *Nymphaea micrantha* *Typha domingensis*	Inundated
KM15	20/11	05 52.1	00 55.0	*Cyperus water/Sesuvium portulacastrum association* (Av depth 20 cm) *Sesuvium portulacastrum monoculture* (Av depth 20 cm) Others: *Avicennia nitida* *Nymphaea micrantha* *Paspalum vaginatum* *Sesuvium white*	Inundated
KM18	19/11	05 52.0	00 58.0	*Sesuvium portulacastrum/ Cyperus water association* *Cyperus water/Sesuvium portulacastrum association* Others: *Cyperus distans* *Cyperus 2* *Paspalum vaginatum* *Ruppia maritima (senesced)* *Sesuvium white* *Typha domingensis*	Moist ground
KN06	28/11	05 51.0	00 46.0	*Paspalum vaginatum monoculture* Others: *Avicennia* sp *Sesuvium portulacastrum* *Typha domingensis*	Site near drainage line containing *Avicennia* and *Typha*
KN08	28/11	05 51.0	00 47.9	*Sporobolus pyramidalis/Sesuvium white/Cyperus articulatus association* Others: *Cyperus distans* *Paspalum vaginatum* *Shrub A*	Dry plain subject to inundation
KN10				Others:	
KN12	15/11	05 51.2	00 51.9	*Paspalum vaginatum/Cyperus 2/ Nymphaea micrantha association* (Av depth 5 cm) Others: *Andropogon gayanus* *Cyperus articulatus* *Cyperus distans*	Inundated
KN14				Others:	Not sampled, too dry

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
KO07	28/11	05 50.0	00 47.0	*Sesuvium portulacastrum* monoculture *Paspalum vaginatum/Cyperus articulatus* association Others: *Cyperus articulatis* *Sesuvium white* *Sporobolus pyramidalis*	Flat dry floodplain. Adjacent drainage line contains *Avicennia* and *Typha*.
KO09	28/11	05 50.0	00 49.0	*Sporobolus pyramidalis* *Imperata cylindrica/ Paspalum vaginatum/ Fimbristylis dichotoma* association Others: *Borassus aethiopum* *Cyperus articulatus* *Cyperus distans* Dodder yellow *Sesuvium* white *Scoparia ?* Wine palm	Very gently sloping plain
KO11	15/11	05 50.1	00 51.0	*Nymphaea micrantha/Cyperus water/Paspalum vaginatum* association (av depth 28 cm) *Paspalum vaginatum/Nymphaea micrantha* association (av depth 24 cm) *Cyperus water/Nymphaea* association (av depth 20 cm) Others: *Sesuvium portulacastrum* *Sesuvium* white *Sporobolus pyramidalis*	Inundated
KO12	20/11	05 50.0	00 52.0	*Paspalum vaginatum* monoculture (av depth 8 cm) Others: *Avicennia nitida* *Cassia* round *Cyperus articulatus* *Nymphaea micrantha* *Sesuvium portulacastrum* *Scirpus cubensis*	Inundated
KO17	20/11	05 49.9	00.57.1	*Paspalum vaginatum* monoculture (Av depth 11 cm) Others: *Cyperus 1* *Cyperus articulatus* *Typha domingensis*	Edge of lagoon in water
KP08	28/11	05 49.0	00 48.0	*Paspalum vaginatum Cyperus articulatus* association Others: *Cyperus 1* *Cyperus 2* *Sporobolus pyramidalis* *Typha domingensis* *Sesuvium white*	Floodplain of grasses and sedges with edge of extensive stand of *Typha* 300 m to west.

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
KP10	15/11	05 50.0	00 49.8	*Cyperus 2/Nymphaea micrantha/* association (av depth 21 cm) *Eleocharis/ Cyperus* 1 association (av depth 35 cm) *Cyperus water/Cyperus* 2 association *(av depth 1 cm)* Others: *Azolla africana* *Cyperus distans* *Paspalum vaginatum* *Sporobolus pyramidalis* *Utricularia* sp	Inundated
KP12	20/11	05 49.3	00 52.2	*Cyperus water/Sesuvium portulacastrum* association (av depth 1 cm) *Paspalum vaginatum monoculture* (No water but moist soil) Others: *Avicennia nitida* *Nymphaea micrantha*	Partially inundated site on edge of lagoon 900 m short of designated site which is blocked by an extensive stand of *Cyperus* water. 50 m strip of *Paspalum* on edge of lagoon.
KP13	20/11	05 49.0	00.52.0	*Paspalum vaginatum/Cyperus water association* (Av depth 27 cm) *Cyperus water/ Nymphaea micrantha* association (Av depth 30.4) Others: *Avicennia nitida*	Inundated
KP16	20/11	05 49.0	00 56.1	*Paspalum vaginatum* monoculture Others: *Cyperus articulatus* *Cyperus distans* *Eclipta prostratas* *Ludwigia erecta* *Passiflora foetida* Succulent 1 *Typha domingensis*	Dry land on edge of lagoon.
KQ03	5/12	05 48.0	00 42.9	*Paspalum vaginatum* monoculture *Typha domingensis/ Paspalum vaginatum* association Others: *Acrochaetium areum* Sedge 1 *Rhizophora racemosa*	Near Keta/Volta Channel
KQ05	5/12	05 48.0	00 45.0	*Typha* monoculture Others: No others	Bank of Keta/Volta Channel

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
KQ11	15/11	05 47.3	00 51.0	*Paspalum vaginatum* monoculture (Depth zero) *Cyperus water/ Nymphaea micrantha* association (av depth 15 cm) Others: *Algal scum* *Aviccenia nitida* *Ceratophyllum demersum* *Lemna paucicostata* *Ruppia maritima* (in pans of water) *Sesuvium* white *Typha domingensis*	Dry land with pans of water
KQ13	14/11	05 48.0	00 53.0	*Typha domingensis/Paspalum vaginatum* association (av depth 42 cm) *Paspalum vaginatum* monoculture (av depth 25 cm) *Cyperus water, Nymphaea micrantha/ Paspalum vaginatum* association (av depth 33 cm) Others: *Algal scum* *Avicennia nitida* *Azolla africana* *Chara* sp *Pistia stratiotes* *Ruppia maritima* Sesuvium portulocastrum *Sesuvium white*	Inundated
KQ15	9/12	05 48.2	00 55.0	*Paspalum vaginatum monoculture* Others: *Bloomia (Hairy Herb)* *Cyperus articulatus* *Cyperus distans* *Eclipta prostrata* *Fimbristylis tall (KQ15)* *Passiflora glabra* *Pentadon pentandrus* *Physalis micrantha* *Scirpus cubensis* *Sesbania sesbans* *Sesuvium potulacastrum* *Sesuvium white*	Site near Anloga Camp. Actual site in market gardens so walked beyond them toward the lagoon.
KQ9	14/11	05 48.0	00 48.8	*Typha domingensis Paspalum vaginatum association* Others: *Creeper 3* *Cyperus articulatus* *Gossypium* sp. *Indigofera 1* *Mimosa pudica*	Water depth zero but ground moist

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
KR02	5/12	05 47.2	00 42.0	*Rhizophora racemosa* monoculture Others: No others	Near Keta/Volta Channel
KR06	5/12	05 47.0	00 46.0	*Rhizophora racemosa* monoculture Others: *Acrochaetium areum*	Bank of Keta/Volta Channel
KR08	5/12	05 46.8	00 48.0	*Typha domingenis* monoculture *Rhizophora racemosa* monoculture Others: *Ceratophyllum demersum* *Nymphaea lotus* *Paspalum vaginatum*	
KR10	28/11	05 470	00 50.0	*Typha domingensis* Fern association *Paspalum vaginatum* monoculture Others: *Avicennia* sp *Cyperus articulatus* *Dodder cuscatha* *Fimbristylis small* *Imperata cylindrica* *Sesuvium portulacastrum* *Sesuvium* white *Sporobolus maritima* *Sporobolus pyramidalis*	Side of channel leading to Volta R from Keta Lagoon. Channel lined with Typha interspersed with Fern ?. Outside the *Typha* is an extensive floodplain of grasses and *Sesuvium portulacastrum*.

* Coordinates were initially read from 1:50 000 Ghana topographical maps (sheets 0600D4, 0500B2, E0601C3 & E0501A1 based on air photography December 1974) and in the field taken with a hand-held GPS (*Garmin GPS 45*) with an accuracy of about 100 m.

Songor lagoon

Site	Date	Coordinates*		Dominant species (Top 5)	Comments
		N	E		
SA07				Dominant: Others:	Terrestrial site – not sampled
SA13	26/11	00 51.7	00 34.0	Dominant: *Cyperus 2 Paspalum vaginatum* association Others: *Cyperus articulatus* *Sesuvium* white	Moist soil
SB04	22/11	5 51.0	00 25.0	Dominant: *Sesuvium portulacastrum/ Sesuvium white* association Others: *Sporobolus pyramidalis*	Very dry

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
SB05	22/11	5 51.0	00 26.1	Dominant: *Typha domingensis/ Neptunia oleracea/ Paspalum vaginatum* association (Av depth 37 cm) Others: *Azolla africana* *Cyperus articulatus* *Lemna* sp *Mimosa pigra* *Nymphaea micrantha* *Parkinsonia aculeata* *Scirpus cubensis* *Utricularia inermis* *Wolfia* sp	Inundated
SB06	22/11	05 51.3	00 27.1	Dominant: *Sesuvium portulacastrum/ Cyperus distans* association Others: *Chloris gayana* *Parkinsonia aculeata*	Very dry
SB07	22/11	05 51.1	00 28.0	Dominant: *Sesuvium portulocastrum* monoculture Others: *Sporobolus pyramidalis*	Very dry and heavily grazed by cattle
SB08	22/11	05 51.0	00 29.1	Dominant: *Cyperus 2/ Sporobolus pyramidalis/ Sesuvium* white association Others: *Cyperus articulatus* Dry herb *Paspalum vaginatum* *Typha domingensis*	Very dry
SB09	22/11	5 51.0	00 30.0	Dominant: *Cyperus 2/ Cyperus water* association Others: *Cyperus articulatus* *Nymphaea micrantha* *Paspalum vaginatum* *Typha domingensis*	Very dry
SB10	22/11	5 50.9	00 31.0	Dominant: *Cyperus 5/ Grass 1/ Sesuvium* white association Others: *Cyperus articulatus* *Cyperus 2* *Fimbristylis small* *Ludwigia erecta* *Sesuvium portulacastrum* *Sporobolus pyramidalis*	Very dry

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
SB11	25/11	05 50.9	00 32.0	Dominant: *Cyperus water/ Sesuvium portulacastrum* association Others: *Chara* (senesced) - ordinary *Cyperus articulatus* *Cyperus 2* *Nymphaea micrantha* *Paspalum vaginatum* *Sesuvium* white *Typha domingensis*	Moist soil
SB12	25/11	05 50.9	00 30.0	Dominant: *Typha domingensis/ Cyperus articulatis/ Nymphaea micrantha/ Paspalum vaginatum* association. *Paspalum vaginatum/ Cyperus articulatis* association. *Cyperus articulatis/ Nymphaea micrantha/ Paspalum vaginatum* association. Others: Dry herb	Inundated. Within 50 m of a new road.
SB13	26/11	05 50.0	00 34.0	Dominant: *Cyperus water/ Sesuvium white* association Others: *Cyperus 2* *Nymphaea micrantha* *Paspalum vaginatus* *Sesuvium portulacastrum*	Edge of Truku lagoon. Wet
SB14	26/11	05 51.0	00 35.0	Dominant: *Cyperus water/ Sesuvium white/ Paspalum vaginatum/ Nymphaea micrantha* association. Others: *Avic*ennia sp *Cassia* round *Cyperus articularis* *Cyperus distans* *Cyperus 2* *Fimbristylis dichotoma* *Sesuvium portulacastrum* *Sporobolus maritima* *Typha domingensis*	Inundated
SC03	22/11	5 58.1	00 24.1	Dominant: *Sesuvium portulacastrum* monoculture Others: *Cornocarpus* sp *Opuntia* sp *Sesuvium white* *Sporobolus pyramidalis*	Very dry

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
SC05	26/11	05 50.1	00 26.0	Dominant: *Sporobolus maritima/ Sesuvium portulacastrum* association Others: *Cornocarpus* sp	Dry sand
SC11	25/11	05 50.1	00 32.2	Dominant: *Cyperus water/ Nymphaea micrantha/ Cyperus 2* association Others: *Paspalum vaginatum* *Typha domingensis*	200 m short of site inundated site - deep
SC12	25/11	05 50.0	00 33.0	Dominant: *Cyperus articulatus* monoculture Others: *Cyperus distans* *Cyperus 2* *Paspalum vaginatum* *Sesuvium portulacastrum* *Sesuvium* white	Dry land. Grazed. Little biomass
SC13	26/11	05 49.9	00 33.9	Dominant: *Sesuvium portulacastrum/ Sesuvium white* association Others: *Cyperus articulatus* *Paspalum vaginatum*	Dry cracked pan near lagoon
SC14	26/11	05 50.1	00 34.9	Dominant: *Cyperus 2* monoculture Others: *Cyperus water* *Nymphaea micrantha*	Extensive swamp
SC15	26/11	05 50.0	00 36.0	Dominant: *Fimbristylis tall/ Sporobolus pyramidalis/ Grass 1/ Cyperus distans* association Others: *Cyperus 1*	Grazed plain
SD01	23/11	5 49.0	00 22.0	Dominant: *Sporobolus pyramidalis/ Cyperus articulatus* association Others: Grass 1 Grass 2 *Sesuvium white*	Very dry and area had been burnt. Some regrowth after fire.
SD09	26/11	05 49.1	00 30.1	Dominant: *Sesuvium portulacastrum monoculture*	Dry sand
SD10	26/11	05 49.0	00 31.0	Dominant: *Sesuvium portulacastrum/ Sporobolus maritima association* Others: *Cassia* round *Sesuvium* white	Dry sand

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
SD11	25/11	05 49.0	00 32.0	Dominant: *Fimbristylis dichotoma/ Sporobolus pyramidalis/ Cyperus 1* association. Others: *Cyperus articulatus* Grass 1 (see SD01) *Sesuvium* white	Dry site
SD12	25/11	05 49.1	00 32.9	Dominant: *Typha domingensis/ Cyperus articulatus/ Nymphaea micrantha* association Others: *Cyperus 1* *Cyperus 2* *Eleocharis* *Ludwigia erecta* *Nymphaea micrantha* *Paspalum vaginatum* Succulent 1 Shrub	Isolated stands of *Typha* in depressions. Moist ground.
SD13	26/11	05 48.9	00 34.0	Dominant: *Sporobolus pyramidalis/ Paspalum vaginatum/ Sesuvium* white association Others: *Cyperus articulatus* *Cyperus distans* *Ludwigia erecta* Shrub A	Subject to inundation. Flat – open
SD14	26/11	05 48.6	00 34.9	Dominant: *Cyperus 2/ Paspalum vaginatum* association Others: *Algal scum* *Avicennia juvenile*	Some distance from site - access difficulties
SD15	26/11	05 49.0	00 35.9	Dominant: *Sporobolus pyriamidalis/ Sesuvium* white association Others: *Cyperus articulatus* *Paspalum vaginatum*	Dry floodplain
SE01	23/11	5 48.0	00 22.1	Dominant: *Grass 1/ Cyperus articulatus/ Sporobolus pyramidalis* association Others: *Cassia round* *Ludwigia erecta*	Very dry

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
SE02	23/11	5 48.3	00 23.1	Dominant: *Sporobolus pyramidalis/ Sesuvium white/ Cyperus articulatus* association *Cyperus articulatus/ Paspalum vaginatum/ Sporobolus pyramidalis* association Others: *Cassia* round *Cyperus 1* *Paspalum vaginatum* *Sesuvium portulacastrum*	Very dry; a long way from lagoon
SE05	23/11	5 48.0	00 26.1	Dominant: *Paspalum vaginatum/ Sesuvium portulacastrum/ Cyperus distans* association. Others: *Andropogon gayanus* *Avicennia nitida* *Brachiaria mutica* *Cyperus articulatus* *Sesuvium white* *Sporobolus pyramidalis* *Vernonia* sp Woody herb (KE20)	On edge of lagoon 150 m from designated point. Very dry.
SE06	23/11	5 48.0	00 27.0	Dominant: *Fimbristylis tall/ Sporobolus pyramidalis* association *Others:* *Andropogon contortus* Grass 2 (SD01) Herb woody sida-like *Sesuvium portulacastrum* *Sesuvium* white	Very dry.
SE10	25/11	05 48.1	00 31.1	Dominant: *Sesuvium portulacustrum/ Sporobolus maritima* association Others: *Avicennia nitida (juveniles)* *Chloris gayana* *Cyperus articulatus* *Paspalum vaginatum* *Sesuvium* white Shrub A	Edge of lagoon short of the site.
SE11	25/11	05 47.9	00 32.0	Dominant: *Typha domingensis/ Cyperus articulatus/ Paspalum vaginatum* association. *Paspalum vaginatum/ Cyperus articulatis* association. Others: *Cyperus 1* *Cyperus 2* *Cyperus distans*	Small depression in a grassy plain containing a stand of *Typha* surrounded by *Paspalum vaginatum*. Moist soil

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
SE12	25/11	05 48.0	00 33.0	Dominant: *Sporobolus pyramidalis* monoculture Others: *Cyperus articulatus* *Cyperus 1* Dry herb *Paspalum vaginatum* *Sesuvium* white *Typha domingensis*	Dry grassy plain of *Sporobolus* and *Paspalum*
SE13	26/11	05 48.0	00 33.9	Dominant: *Cyperus water/ Sesuvium white/ Paspalum vaginatum* association Others: *Avicennia sp* *Cyperus 2* *Nymphaea micrantha* *Sesuvium portulacastrum*	200 m short of site. Deep water
SE14	26/11	05 48.0	00 34.9	Dominant: *Sesuvium white/ Fimbristylis tall* association Others: *Sporobolus pyramidalis* Wine palms	Dry plain subject to inundation
SE15	26/11	05 48.0	00 36.0	Dominant: *Cyperus articulatus/ Paspalum vaginatum* association. Others: Shrub A	Dry plain subject to inundation
SE16	24/11	05 48.0	00 37.0	Dominant: *Fimbristylis dichotoma/ Sporobolus pyramidalis* association Others: *Paspalum vaginatum* *Sesuvium* white	Dry land
SF08	24/11	05 47.3	00 29.0	Dominant: *Sporobolus pyramidalis* monoculture Others: *Avicennia nitida* *Euphorbia* sp *Corancarpus* sp	Dry land

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
SF09	24/11	05 47.1	00 29.9	Dominant: *Sesuvium portulacastrum/ Sporobolus pyramidalis* association (av depth 2 cm) *Sporobolus pyramidalis/ Sesuvium portulacastrum* association (av depth 2 cm) Others: *Avicennia nitida* *Canavalia rosea* *Cocos nucifera* *Fimbristylis short* *Paspalum vaginatum* *Remerea maritima* *Sesuvium* white *Sporobolus maritima*	Inundated
SF10	24/11	05 47.16	00 31.0	Dominant: No dominant plants Others: Scattered *Sesuvium portulacastru*m *Sporobolus pyrimidalis*	Dry land
SF11	24/11	05 47.0	00 31.9	Dominant: *Sporobolus pyramidalis* monoculture Others: *Fimbristylis tall* *Fimbristylis short* *Remerea maritima* *Sesuvium portulacastrum* *Sesuvium* white	Dry land
SF12	24/11	05 47.0	00 33.0	Dominant: *Sesuvium portulacastrum/ Sesuvium white/ Sporobolus pyramidalis* association Others: *Avicennia nitida* *Cassia* round *Climber* *Crotalaria retusa* *Cyperus articulatus* *Cyperus distans* *Fimbristylis tall* *Imperata cylindrica* *Paspalum vaginatum* *Short woody herb* *Vernonia* sp	Dry land

Site	Date	Coordinates		Dominant species (Top 5)	Comments
		N	E		
SF13	24/11	05 47.1	00 34.1	Dominant: *Paspalum vaginatis* monoculture Others: *Azolla africana* *Brachiaria mutica* *Cyperus 2* *Cyperus articulatus* *Cyperus distans* *Eclipta prostrata* *Ludwigia erecta* *Nymphaea micrantha* *Pistia stratiotes* *Eleocharis* sp *Typha domingensis*	Moist soil Market gardens pushing out in lagoon
SF14	24/11	05 47.1	00 35.1	Dominant: *Paspalum vaginatis* momoculture Others: *Cyperus distans* *Eclipta prostrata* *Nymphaea lotus* *Paspalum* 2 infloresences (see SF13) *Pistia stratiotes* *Sphenoclea zeylanica* *Typha domingensis*	Moist soil Market gardens pushing out in lagoon
SF15	24/11	05 47.2	00 36.1	Dominant: *Paspalum vaginatum/ Cyperus articulatus/*Succulent 1 association Others: *Cyperus distans* *Ludwigia erecta* *Typha domingensis*	Dry land Market gardens pushing out in lagoon
SF16	24/11	05 47.2	00 37.0	Dominant: *Typha domingensis/ Cyperus articulatus* association (av. depth 24 cm) Others: *Azolla africana* *Pistia stratiotes*	Inundated Market gardens pushing out in lagoon

* Coordinates were initially read from 1:50 000 Ghana topographical maps (sheets 0600D4, 0500B2, E0601C3 & E0501A1 based on air photography December 1974) and in the field taken with a hand-held GPS (*Garmin GPS 45*) with an accuracy of about 100 m.

Angor channel

Site	Date	Coordinates N	Coordinates E	Species list	Comments
C1	6/12	05 46.7	00 41.0	Dominant: *Paspalum vaginatum/Ipomea pes-caprae/Creeper 1* association Others: *Brachiaria ?* *Canavalia rosea* *Combretum?* *Commelina* (common, blue flowers) *Cyperus articulatus* *Cyperus distans?* *Fimbristylis tall* Grass 1 Herb 1 *Momordica?* *Nauclea ?* *Remerea maritima* Sedge 1 (round stem, composite head) *Sesbania* *Sphenoclea* sp *Sporobolus pyramidalis* *Vossia*	Near mouth of river. Beach like edge to Channel
C2	6/12	05 46.8	00 42.0	Dominant: *Acrochetium areum/ Sesbania?* association Others: *Cyperus distans* *Fimbristylis tall* (see R1) Grass 1 *Laguncularia* sp *Nauclea* *Paspalum vaginatum* *Rhizophora racemosa* *Typha domingensis* *Vossia*	
C3	6/12	05 46.9	00 43.0	Dominant: *Typha domingensis* Others: *Acrochetium areum* *Ipomea aquatica* *Ludwigia stolonifera* *Rhizophora racemosa* *Sphenoclea* *Vossia*	

Site	Date	Coordinates		Species list	Comments
		N	**E**		
C4	6/12	05 47.7	00 43.0	Dominant: *Vossia sp monoculture* Others: *Acrochetium areum* *Brachiaria* sp *Paspalum vaginatum* *Rhizophora racemosa* *Sesbania ?* *Typha domingensis*	
C5	6/12	05 48.6	00 43.0	Dominant: *Rhizophora racemosa monoculture* Others: *Acrochaetium areum* *Typha domingensis* *Vossia*	
C6	6/12	05 48.2	00 44.0	Dominant: *Typha domingensis* monoculture Others: *Rhizophora racemosa* *Vossia*	
C7	6/12	05 48.0	00 45.0	Dominant: *Typha domingensis* monoculture Others: No others	
C8	6/12	05 47.0	00 46.0	Dominant: *Rhizophora racemosa* monoculture Others: *Acrochetium areum*	
C9	6/12	05 46.6	00 47.0	Dominant: *Rhizophora racemosa* regrowth Others: *Acrochaetium areum* *Paspalum vaginatum* Sedge 1 *Typha domingensis*	Regrowth of juvenile *Rhizophora* following harvest
C10	6/12	05 46.8	00 48.0	Dominant: *Typha domingenis monoculture* *Rhizophora racemosa monoculture* Others: *Ceratophyllum demersum* *Nymphaea lotus* *Paspalum vaginatum*	On channel edge; impenatrable Typha stand. 300 m south of site.
C11	6/12	05 46.8	00 49.0	Dominant: *Typha domingensis* monoculture Others: *Ceratophyllum demersum* Fern (marsilea like) *Nymphaea lotus* *Rhizophora racemosa*	

Site	Date	Coordinates N	Coordinates E	Species list	Comments
C12	6/12	05 47.0	00 50.0	Dominant: *Typha domingensis* monoculture Others: *Ceratophyllum demersum* *Rhizophora racemosa*	

* Coordinates are given as degrees and minutes with the latter having an integer and decimal component (eg 05 48.4 N = 05° 48.4’ N)