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The CASSARINA PROJECT (ERBIC18CT960029)

An EU programme on environmental change in North African Wetlands

Final Report

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Change, stress, sustainability and aquatic ecosystem resilience in North African wetland lakes during the 20th century: The CASSARINA Project

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ABSTRACT

The CASSARINA Project was designed to initiate a co-ordinated joint study of environmental change in North African wetland lakes, nine primary sites were selected for detailed study comprising three sites in each of Morocco, Tunisia and Egypt. Multidisciplinary studies were undertaken by scientists from each of these countries working in co-operation with European colleagues in the UK and Norway.

A combination of modern survey and palaeolimnological techniques was employed to help set ecological baselines for the late 20th century and to reconstruct past environmental changes at each site during the 20th century. Communality in scientific methodology and consensus protocols for sample and data collection/exchange were established at the beginning of the project.

Co-ordinated sampling of water quality, phytoplankton, zooplankton and fish and the monitoring of fixed littoral vegetation transects were begun for each of the nine lakes in 1997 and continued until 1998/99. Collection of sediment cores for palaeoecological analysis was carried out in 1997/98.

Using sediment core chronologies based mainly on radio-isotopes (^{210}Pb and ^{137}Cs) and analysis of the sedimentary remains of aquatic biota (diatoms, zooplankton, higher plants and benthic animals), major changes in the species abundances were demonstrated for the 20th century period. These changes were interpreted in terms relevant to biodiversity issues and to water quality change.

Lake contamination as assessed by analysis of heavy metals and pesticide residues in sediment cores was relatively low compared with some European sites. However, significant lead contamination was noted at two sites and the sedimentary concentrations of DDE in Morocco and Tunisia showed a close correspondence with known usage rates for each country since the 1950s.

For all nine lakes, baseline data were set for water chemistry, one lake was acid with low salinity and all the other sites had high alkalinity and to varying degrees brackish with NaCl usually dominant. Total phosphorus measurements indicated that the lakes were usually eutrophic and phytoplankton was mainly dominated by species of diatoms, green or blue-green algae. Where fish were present, growth rates were high with marginally highest rates in the Egyptian Delta lakes.

Vegetation survey establish littoral vegetation sequences but only at the Delta lakes were emergent macrophytes still widespread. Here, their presence is very important for isolating water pollution. In 1998, one Moroccan wetland lake was drained completely and the new land cultivated. The single acid lake still supports an acidophilous biota that is unique in Tunisia but site quality is rapidly diminishing due to increasing local cultivation activity and inflow water abstraction in recent decades.

Hydrological changes resulting from land-use intensification during the 20th century are the main cause of biodiversity disturbance at all nine CASSARINA sites. These changes remain the greatest imminent threat to the ecological integrity of remaining North African wetland lakes. Reduction in freshwater supply is the main, sometimes catastrophic, issue for many sites but, for several sites (Merja Zerga and all three Delta lakes) *enhanced* freshwater supply by increased agricultural irrigation and drainage has been a significant driver of ecological change during the 20th century.

Intensified time-space multidisciplinary environmental monitoring of aquatic ecosystems *at the species level* is identified as a key factor for effective wetland lake management and for validating future environmental change scenarios in North Africa. Co-ordinated monitoring and modelling should be integrated with satellite surveillance for the larger lakes. These aquatic ecosystems are a disappearing resource yet, ultimately, only through a knowledge of their past and present states can their true societal value be fully estimated. CASSARINA has provided a foundation stone for wetland lake research in North Africa that has important implications for biodiversity *per se* and for national obligations to biodiversity responsibilities.

INTRODUCTION

Biological diversity is part of every country's natural heritage and should therefore be protected and conserved wherever possible. This principal is enshrined in the 1992 Rio Convention on Biological Diversity and yet the 21st century begins with wetland lake ecosystems being threatened globally by pollution, land-use pressures, and climate change. Irrespective of climate-change scenarios, the major imminent threat to wetland lakes in many habitable regions stems directly from population growth and associated land and water usage, urbanization and industrialization (Dugan 1993, Finlayson & Moser 1992). These problems are epitomized in North Africa where typically high population growth combined with accelerating demand for food and water conspire with a dry climate to exacerbate degradation of continental aquatic ecosystems. Water stress is rapidly increasing (Hollis 1992, Biswas 1993, Matoussi 1996) and nowhere is the loss rate of wetlands and lowland lakes more alarming than in the North African coastal zone. Many wetland lakes listed in recent inventories of the region (Kerambrun 1986, Ramdani 1988, Hughes *et al.* 1997) no longer exist or are severely degraded.

Some remaining wetland lakes nonetheless do support high value ecosystems that not only contribute to essential regional biodiversity but also often provide important resources for local human populations (e.g. Shaheen & Yousef 1980, Hollis 1986 & 1992, Kerambrun 1986, Benessaiah & Belhai 1999). These environmental values are sometimes recognized in national legislation but planners need reliable and biodiversity relevant information about the current status of sites as well as recent environmental change time trends. Such information is needed to assess ecosystem quality and sustainability so that, when combined with development needs, effective conservation can be implemented. Site specific, space-time data for aquatic diversity is however not generally available in North Africa where biological monitoring of aquatic ecosystems is typically absent or is uncoordinated and where records about past changes are generally inadequate (e.g. Flower *et al.* 1990, Turner *et al.* 1995). Reconciling biodiversity objectives with human exploitation of natural aquatic ecosystems is a global problem that reaches acute proportions in North Africa and many other developing countries. The issue of achieving sustainable resource usage was recognised by the European Commission which in 1996, as part of a package of investigative and potentially mitigating measures, sponsored the CASSARINA Project (Change, stress and sustainability: aquatic ecosystem resilience in North Africa).

OBJECTIVES

The CASSARINA Project represents an innovative approach to tackling environmental changes issues confronting North African wetland lakes. The project has initiated co-ordinated studies of selected sites so that assessments about current and past biodiversity and about rates of environmental change can be made for in nine wetland lakes selected from three North African countries (Morocco, Tunisia and Egypt). CASSARINA has four principal objectives:

* to assess the impact of land-use practices and other changes on shallow lake ecosystems in intensively farmed regions of North Africa during the 20th century;

* to establish ecological base-lines and pre-disturbance communities so that ecosystem changes during the 20th century can be reconstructed for each lake investigated;

* to implement and integrate regional monitoring of aquatic organisms and water quality with centrally imposed analytical quality control;

* to establish internationally co-ordinated protocols for future monitoring and to set environmental objectives for future conservation management of selected lake ecosystems.

We believe that regionally derived and co-ordinated multidisciplinary studies about the status, quality and past changes of wetland and lake ecosystems need to be robust and validated before soliciting the attention of national and international bodies concerned with environmental management. CASSARINA was instigated with the aim to achieve these requirements. The field work and much of the analysis of the data from the first three years this work programme has now been carried out and this report introduces the project and gives an overview of the methods of investigation, the initial results and their implications.

Background: Prior to the CASSARINA Project, there already existed a wealth of information about wetland lakes and aquatic diversity in North Africa. However, although valuable, much of this work was on the taxonomy and distribution of aquatic animals and plants (e.g. Boulenger 1907, Gauthier 1937, Feldmann 1946, Gayral 1954, Blanc 1954 and the standard botanical floras for North Africa) but contained little environmental context. More recently, Morgan & Boy (1982), Ramdani (1988) and Chergui *et al.* (1999) presented a broader view of freshwater biology in Northwest Africa and a series of papers about pollution, water quality and the biota of Egyptian lakes has appeared mainly from the 1970s (e.g. Saad 1973, Shaheen & Yousef 1980, El-Sherif 1993, Drainage Research Institute 1997, Gharhib 1999). Fishery issues have attracted considerable research in Tunisia (Kraiem *et al.* 1987) but much of the conservation value of North African wetland lakes has focused on their value as bird habitats in Egypt (Goodman & Meininger 1989), in Morocco (e.g. Dakki *et al.* 1991) and in Tunisia (Hughes *et al.* 1997). In the MedWet Programme, conservation and economic aspects of wetlands around the Mediterranean region have been assessed in an international manner (Farinha *et al.* 1996, Benessaiah & Belhaj 1999). Few of these studies have however tried to use or access rates of recent environmental change in wetlands lake evaluation.

Sedimentary records of recent environmental change have been investigated in a number of North African lakes and lagoons (Stevenson & Battarbee 1991, Flower *et al.* 1984 & 1990, Siegal *et al.* 1994). Usually however, palaeo-studies were focused on Holocene time scales and used pollen analysis of cores from wetlands to indicate terrestrial vegetation changes during this period in Morocco (e.g. Reille 1979), in Tunisia (Ben Tiba 1980) and Egypt (Mehringer *et al* 1979, Leroy 1992). Diatom remains were also used to reconstruct wetland lake systems and climate change in regions of North Africa that are now arid (e.g. Baudrimont 1974, Gasse *et al.* 1987). In the Egyptian Nile Delta, lakes both faunal remains and petrographic analyses of sediment cores were used to trace Holocene changes (Howe & Stanley 1991, Arbouille & Stanley 1991, Stanley & Warne 1993).

CASSARINA builds upon on these earlier studies but attempts to integrate aquatic diversity with both contemporary and past site characteristics so that the current status of each site can be placed in a recent historical context that is appropriate to conservation issues.

ACTIVITIES

The focus of CASSARINA is human impacts on the biodiversity and water quality of wetland lakes in North Africa during the 20th century. Monitoring of these wetland ecosystems was generally absent and little was known about the resilience of their aquatic communities to recent environmental changes. Collection of survey data for setting modern limnological baselines was therefore an essential part of CASSARINA but these data alone are insufficient to detect trends in ecosystem stress responses to human activities sustained over decades. Without long-term monitoring, the only reliable source of information about past ecosystem biodiversity lies preserved in lake sediments. Sediment analysis using palaeolimnology techniques can reveal evidence not only about species no longer present in contemporary lake communities but also about time scales of ecosystem change at the species level (Berglund 1986). Palaeolimnology is particularly appropriate for revealing species change trends for algae, zooplankton, benthic invertebrates, and aquatic plants. Furthermore, the factors driving these changes (nutrient enrichment, salinization, metal and pesticide contamination, and soil erosion for example) can also be identified. Results of such work are commonly used to answer questions about wetland lake pollution in many European and North American regions (e.g. Battarbee 1991, Smol 1992). Consequently, applying palaeolimnology techniques to North African wetland lakes offers a useful and inexpensive aid for monitoring recent environmental change. Combining limnological and palaeolimnological techniques offers a particularly powerful way of tackling environmental change and aquatic diversity issues (Smol 1992). CASSARINA sites were selected to facilitate this joint approaches.

Site selection: CASSARINA wetland lakes were selected following site visits with interested parties from each host country. In all, 12 potential sites were identified and all lie in coastal zones on an approximate geographical transect from west to east. This latitudinal gradient is reflected in declining annual rainfall, from > 500 mm on the Atlantic coast of Morocco to ca. 100 mm for the eastern Nile Delta region. Being less than 6 m in maximum depth, all are classified as wetland lakes (see Davis 1994).

Following initial sediment coring (see below), nine of the twelve lakes were considered amenable for sampling of both current *and* past environments and these were designated as the primary CASSARINA sites. They are Merjas Sidi Bou Rhaba, Zerga, and Bokka (Morocco), Megene Chitane, Garaet El Ichkeul, and Lac de Korba (Tunisia) and Lakes Edku, Burullus and Manzala (Egypt). These primary sites are described in detail by Ramdani *et al.* (2001a) and several have considerable value for conservation and/or fisheries. Three sites, Merja Sidi Bou Rhaba and Merja Zerga (Morocco) and Lake Burullus (Egypt) are recognised by the RAMSAR Convention as being of international importance for water birds. One site, Garaet Ichkeul, is a World Heritage Site, recognised partly for its importance for birds (Hollis 1986). They are all in coastal regions where intensive agriculture is actively practised and yet the impact of this environmental stresses is largely unknown, except that habitat quality is generally declining and migrant bird populations are threatened.

CASSARINA consists of several sub-projects and the main analytical work can be divided into environmental monitoring and palaeoecology:

Environmental monitoring: Sampling over a seasonal cycle (1998) was carried out at each site according to protocols established jointly at the first CASSARINA workshop (Flower & Patrick 1997). The site attributes monitored at each site were:

i. Water quality (conductivity, pH, alkalinity and common ion concentrations)
ii. Phytoplankton and zooplankton species occurrences and abundances
iii. Fish species diversity and fish growth rates
iv. Marginal vegetation by establishing fixed littoral transects

Sampling protocols and techniques used are described in the CASSARINA methods manual (Flower & Patrick 1997) and in following consecutive papers, Ramdani *et al.* (2001a & b), Fathy *et al.* (2001), Kraiem *et al.* (2001).

Palaeolimnology: Two adjacent replicate 7.4 cm diameter piston cores were collected from each site (Table 1) and each pair of cores was collected within an area of < 1 m^2. One core (the master core) was selected for radiometric dating and correlated with the other core using lithostratigraphy. Except for the Delta lakes, all cores were from central lake locations. Coring the Delta lakes was more problematic, since large exposed lake surface areas combined with shallow water caused sediment focusing and re-deposition problems. Hence, the 1997 cores from central Edku were undatable (very low activities) but more amenable cores were collected in 1998. Only in Burullus were the locations of the two cores different, one from the open central area (BULR1) and one from a sheltered bay (BULR2). It is noteworthy that, with the exception of Sidi Bou Rhaba and Bokka all cores were <1 m long, the generally cohesive and compacted sediments were not amenable to deeper coring without using power assisted equipment.

Specific techniques used on sediment cores collected from the nine sites were:

i. Radioisotope assay and lithostratigraphic measurements: to provide sediment chronologies and sediment accumulation rates for the recent period (ca. last 100 yr.). These measurements can identify past erosion and disturbance episodes.
ii. Macro- and microfossil analysis: diatoms (siliceous micro-algae that indicate water quality and are often preserved in sediment), pollen (to indicate the vegetation change in and around the lake), macrofossils (to evidence water quality and changes in benthic habitat and aquatic vegetation) and zooplankton remains (past diversity).
iii. Sedimentary heavy metals and persistent organic residues: stratigraphic changes were measured to indicate pollution impacts.

Table 1 **CASSARINA sediment cores: sampling dates, locations and lengths of the master cores. Note that some 7 m of sediment were recovered from Sidi Bou Rhaba but only the upper ca. 2.5 m are reported on here.**

SITE	DATE	LOCATION	LENGTH
Sidi Bou Rhaba Morocco	April 1997	34.24065°N,06.67257°W	260 cm
Merja Zerga-Morocco	April 1997	34.83574°N,06.28536°W	40
Merja Bokka-Morocco	April 1997	34.37255°N,06.29019°W	114
Megene Chitane-Tunisia	April 1997	37.15276°N,09.09781°E	74
Garaet El Ichkeul-Tunisia	April 1997	37.16754°N,09.62393°E	98
Lac de Korba-Tunisia	April 1997	36.61764°N,10.89130°E	42
Lake Edku-Egypt	Mar. 1998	31.25064°N,30.20681°E	56
Lake Burullus (1) Egypt	Nov. 1997	31.42063°N,30.63400°E	40
Lake Burullus (2) Egypt	Nov. 1997	31.43164°N,30.63755°E	70
Lake Manzala-Egypt	Nov. 1997	31.29561°N,31.88191°E	53

Structure and partner roles: Because CASSARINA is an international environmental evaluation programme, the co-ordination of specific investigations, designation of tasks appropriate to the skill-base available, and information and material exchange were all central to its success. Following mutual agreements, tasks were assigned to various CASSARINA participant groups that comprised the Institut Scientifique in Rabat (IS-RABAT), Faculty of Sciences, University of Tunis (FS-TUNIS), Botany Department, University of El Minia (BOT-El MINIA). The collaboration was augmented by the two well established European research groups, University College London (ECRC-UCL) and the Botanical Institute Bergen (BI-UIB) who in addition were responsible for some analytical quality control. Pesticide analysis of sediments and sediment chronologies were sub-contracted to the Universities of Liverpool and Lancaster.

ECRC-UCL: The project co-ordinators were Drs. Flower & Patrick (co-ordinators, workshops, sediment fieldwork, diatom analysis, analytical quality control, sample exchange and with technical assistance by Mr. S. Dobinson and E. Shilland). IS-RABAT: Dr M. Ramdani and Dr N. Elkhiati were the CASSARINA co-ordinating scientists for Morocco and were responsible for zooplankton (in water and sediments) analysis, and aquatic plants and monitoring in Morocco (with assistance graduate students, Mrs. L. Somoue, M. Chaoui and M. Dahou, & Mrs. F. Sarf). FC-TUNIS: Associate Prof. M. Kraïem (jointly at INSTM Salammbô) was the co-ordinator for Tunisia and was responsible for fish studies in the CASSARINA lakes and monitoring in Tunisia, together with Dr. C. Ben Hamza, a hydrogeochemist (jointly at Bizerte University), Aslam Djellouli (Faculty of Sciences, Tunis) responsible for CASSARINA vegetation transect studies. L. Baccar was an independent consultant and Prof. Mohammed Boussaïd (INSAT) gave specialist advice. Mr. Slah BAHRI, President General Director of the Société Lagunes de Tunisie of the Tinja fisheries at Ichkeul, provided fishery data and materials and access to the lake. Mr. F. Ben Dakhlia (Director of the National Institute of Meteorology) provided climate data. BOT-El MINIA: CASSARINA work in Egypt was co-ordinated by Drs. A. Fathy and H. Abdelzaher and they were responsible for CASSARINA water chemistry and phytoplankton analysis. Other Egyptian staff involved as consultants were Prof. F. Abdelhaleim, Prof. M. Ali, Dr E. Ali, Prof. M. El-Naghy, and Prof. M. El Katatny. Technicians were Y. Safwat and E. Tawefk. BI-BERGEN: Dr H. H. Birks was the co-ordinator for the laboratory work in Norway and was also the analyst for macrofossils in CASSARINA sediment cores. Dr S. Peglar was the pollen analyst. Prof. H. J. B. Birks gave advice on statistical procedures for analysing CASSARINA data. Technical work on heavy metals and organic measurements was undertaken by Anne Bjune and Jorunn Svanevik.

RESULTS

Results of the specific research themes within CASSARINA are reported below but full results data are contained in the CASSARINA FINAL RESULTS REPORTS (Annex 1) which were presented at the final workshops in February 2000.

Modern survey, lake characterization and documentary records

Site Characteristics: The nine primary CASSARINA lakes (Figs 1-6, Annex 2) vary considerably in morphometries, biodiversity and in water chemistry. All the lakes are <2 m deep and vary greatly in area (< 0.2 km^2 for Tunisian Megene Chitane to > 1000 km^2 for Lake Manzala in Egypt). Partial mixing with seawater occurs at several sites, Merja Zerga (Atlantic Morocco) and Ichkeul and Korba (Tunisia) and all three Delta lakes. However, only the former is affected perceptibly by the (Atlantic) tidal cycle. Intensive agriculture typically predominates around each site, except for Moroccan Sidi Bou Rhaba (a national nature reserve) and Chitane, where some semi-natural woodland persists. Ground water and irrigation water sources combined with the marine connections make delimitation of catchments difficult but in means that water quality is slightly to strongly brackish (Korba and Ichkeul are hypersaline in summer months) and alkaline. Megene Chitane is an exception, having a small well defined catchment that is fed by acid spring water. The poignancy of threats to North Africa wetlands is illustrated by Merja Bokka which possessed 0.5 km^2 of open water in 1997 but by late 1998 the entire basin was under cultivation.

Fixed base-line vegetation transects: To enable marginal vegetation baselines to be set for the late 20th century, transect survey lines were established at each site and fixed by GPS co-ordinates. At least one vegetation transect survey at each of the nine sites was conducted during the first year of CASSARINA (1997). Transects were surveyed seasonally in 1998 and the transect length varied from 14 m for the smallest site (M. Chitane) to 960 m for the largest site (Manzala Lake). An example of the vegetation record across each transect is given in Annex 3 (Table 1).

When compared with earlier data, the reed beds (important for many bird species) were formerly extensive at Zerga, Bokka and Ichkeul but are now severely diminished by grazing and cutting at Zerga, by salinization at Ichkeul, or are lost entirely by drainage for agriculture (Bokka). By far the most extensive emergent macrophyte vegetation (*Phragmites, Typha, Juncus*) persists in the Delta lakes. Interestingly, and despite active land reclamation and harvesting, emergent macrophyte beds have tended to increase in these Delta lakes, especially Manzala. Water quality change is a factor and the proliferation of reeds is probably the result of water freshening. At those sites linked to the sea and where freshwater inflow has been curtailed, *Salicornia* dominates the wetland margins and is this is typical of Korba, Ichkeul and Zerga. *Ruppia* is a common submerged macrophyte in the western sites but *Potamogeton* and *Ceratophyllum* predominate in the less saline Delta lakes. Although the smallest CASSARINA site, the softwater habitat provided by Chitane is unique in the study region and the lake still supports a soft-water community of *Isoetes velata*, a rare plant in Tunisia.

Documentary records: Documentary records for the 20th century period assembled for each lake vary from fragmentary to fairly detailed. Organization of large farming enterprises under French direction was typical of the early to mid part of this period in the Gharb region of Morocco and also around Ichkeul and Korba (see Annex 3 - Table 2). From the early 20th century and particularly since the 1950s, large scale water hydrological modifications for irrigation purposes, drinking water supply and winter flood control measures have been undertaken especially around Zerga, Ichkeul and Bokka. The Egyptian sites are somewhat different, local rain water supply is not important and their freshwater source is sustained by regulation of Nile water flow. Modern large scale regulation of Nile water began in the 19th century and culminated in the Aswan High Dam, built in the mid-1960s. One result of this regulation was the provision of enhanced freshwater availability for agriculture in the Delta region. Now, the long-term effects of agricultural intensification during the 20th century is to reduced freshwater availability (Hollis 1986) by lowering ground water levels and reducing ground water recharge by land drainage. In the short-term, these hydrological manipulations have tended to increase the supply of freshwater to CASSARINA lakes. Older publications clearly show that salinity of the Delta lakes have declined this century (Banoub 1979, Shaheen & Yousef 1980) and there is sedimentological evidence (see below) that Bokka, Zerga and Ichkeul all experienced transient freshening phases during the 20th century. These lakes then are, or have been, the recipients of enhanced freshwater supply and some of the ecological effects of this change are discussed below. Clearly, for all those sites with sea connections (the Delta lakes, Zerga, Ichkeul, Korba), water supply *per se* is not so much a problem as is water quality (salinity) and site disturbance.

Water quality and phytoplankton: All the lakes are brackish to some extent (conductivity >1,000 μS cm), with Ichkeul and particularly Korba being occasionally hypersaline in summer months. An exception is dilute Megane Chitane, the only site where water pH is <7 (an example of water chemistry data is given in Annex 3 - Table 2). Suspended solids were generally highest in Ichkeul and in Bokka and results from wind induced re-suspension of soft margins and surface sediment that doubtless strongly suppressed productivity. Average total phosphate concentrations were high or very high at all the sites indicating eutrophy, only Chitane and Manzala having values <100 $\mu g\ l^{-1}$. Baseline species data as well as seasonality and spatial differences for phytoplankton communities of each site were sampled during 1998 (see example Annex 3 - Fig. 7). Generally, the crops and species diversity are highest in the spring period and the most eutrophic sites, according to blue-green algal abundances, are Sidi Bou Rhaba and Lake Manzala. These sites are at opposite ends of the CASSARINA west-east North African transect and both have high crops of *Microcystis* crops. In terms of species richness, the Delta lakes have more than twice the number of phytoplankton species than the western CASSARINA sites. Diatom microalgae growing epiphytically in the CASSARINA lakes were also for species rich at the Delta sites (see Appendix 4).

Zooplankton: The zooplankton collected from the CASSARINA sites are diverse and often present in high abundances of cladocera, ostracod and copepod species are well represented (see example Annex 3, Table 3). A species of particular note and importance, *Eucyclops ceratulus,* was the most widespread copepod species being only absent from seasonally hypersaline Korba and the partly desiccated Bokka. Cladocerans were rather less tolerant of water quality variation but *Chydorus sphericus* was present in six of the nine sites. They were most diverse in the acid site M. Chitane (6 species present). Here the copepod *Diaptomus cyaeous* occurred and is a 'cold' water species only once previously recorded in Tunisia. Ostracods were even less well distributed across the sites but *Cyprideis torosa* occurred in five sites. Again Chitane is unusual in only supporting one species of ostracod, *Cypria opthalmica* with poorly calcified shells. No east-west trend in species diversity was found.

Fish: All three delta lakes support important fisheries based on *Tilapia* (*sensu lato*) and this contrasts sharply with the western Mediterranean sites in Morocco and Tunisia where mullet or cyrpinids predominate. In Ichkeul and Zerga mullet provide the largest catches and are of commercial interest. At the other four sites, fish populations were either small (Sidi Bou Rhaba and Lac de Korba) or absent (Chitane, Bokka in 1998). Fish growth rates growth rates and condition were compared (Kraiem *et al.* 2001) using weight/ length data (example Annex 3, Fig. 8). Mullet growth rates were estimated for a comparative study of fish production in three sites with significant fisheries, Zerga, Ichkeul and Edku. Fish growth rates were greatest in Edku when compared with similar species in Ichkeul and Zerga. Seasonal growth patterns were different but overall production was slightly higher in Ichkeul. The ichthyofauna diversity was highest in the delta lakes and Ichkeul; it is relatively low in the western lakes, with five species or less. The least diverse sites were Sidi Bou Rhaba and M. Bokka (only two species present before reclamation in 1998). Annual fish production, as captured biomass, is very variable with ca 250 tons yr^{-1} in Ichkeul to 1000 tons yr^{-1} or more in the Delta lakes. The ichthyofauna in all these lakes is in good physical condition and exploited fish are essentially: Ichkeul: Mullet (*Mugil cephalus* and *Liza ramada*), Eel (*Anguilla anguilla*), Sea bass (*Dicentrarchus labrax*); Edku, Burullus and Menzala: Tilapia (*Oreochromis niloticus* mainly, *Tilapia zillii* and *O. aureus*), Mullet (*Mugil cephalus, Liza ramada*), Vundu (*Heterobranchus longifilis*), Nile perch (*Lates niloticus*), Grass Carp (*Ctenopharyngodon idella*); Merja Zerga: Mullet (*Mugil cephalus, Liza ramada* and *L. saliens*), Eel (*Anguilla anguilla*), Sea bass (*Dicentrarchus labrax* and *D. punctatus*) and Carp (*Cyprinus carpio*).

Palaeolimnology: CASSARINA sediment core analyses provide a unique data set for assessing environmental change at all nine sites during the 20th century. Providing adequate sediment chronologies is however a pre-requisite for reconstructing environmental histories.

Sediment chronologies and accumulation rates: Lakes in dry climates with disturbed catchments often yield sediment profiles that are difficult to interpret, mainly because of high and/or episodic nature of sediment supply and deposition. Furthermore, deposition of radionuclides used in dating profiles can vary regionally. We used principally ^{137}Cs and ^{210}Pb isotope profiles to construct core chronologies (example Annex 3, Fig. 9). From these data it is immediately apparent that ^{210}PB inventories are unusually low in the Delta lakes and made dating difficult however by combining with dates from exotic pollen introductions and with other stratigraphic markers, a basic sediment chronology was established in most cases. Because of low radionuclide supply or high sediment accumulation rates, establishing 19 century ^{210}Pb chronologies was only possible for Sidi Bou Rhaba and so elsewhere, dates beyond ca. the past 50 years were by extrapolation. Only one core (BULR1), from the central area of Lake Burullus, was entirely undatable but a second core

(BULR2) collected from a sheltered bay had detectable but low radionuclide activities. At M. Zerga only the top ca. 35 cm of post 1950s soft sediment, above compacted marine clays, was datable. Because of high and variable local erosion, sediment accumulation often exceeded 1.5 cm yr^{-1} in Chitane in the 1940s. In Sidi Bou Rhaba such high rates are due mainly to autochthonous carbonate deposition. Where rates are usually <1 cm yr^{-1} in (the Delta lakes, Korba, Ichkeul and M. Zerga) and despite being surrounded by disturbed landscapes, sea connections probably allow some particulates to be transported out of the deposition area.

Diatom stratigraphies: Diatom microalgae contribute to both the plankton and benthos of most lakes. Particular species are excellent indicators of water quality, in particular, of salinity. In the CASSARINA cores, the value of diatom stratigraphies is variable, in the Tunisia lakes Korba and Ichkeul sedimentary diatoms are very poorly preserved. In the former, sediment below several centimetre depth was entirely devoid of diatom remains. Similarly diatoms were absent from the lower sections of the Delta lakes and the Bokka cores but upper sections do possess diatoms and these indicate recent changes in salinity. Preservation was best in acid Chitane and here acidophilous species predominate but species indicative of enrichment increase since the 1960s. There is also a good diatom record in Sidi Bou Rhaba and species abundance changes indicate gradually increasingly saline water during the 20th century (see example Annex 3, Fig. 9). The increase in planktonic diatoms recorded in Burullus (BULR1) and in Chitane indicate recent eutrophication problems.

Zooplankton stratigraphies: Zooplankton remains are preserved throughout all the CASSARINA sediment cores (cf. Annex 3, Fig. 11). Relatively stable diversity is displayed by Sidi Bou Rhaba and M. Zerga, but the sediment record is much longer for the former. In Bokka a major species change occurred at the beginning of the 20th century and again ca. 1960 as more species indicative of very low lake levels appeared. In Tunisian Chitane several new species of cladocera appeared in the 1940s, e.g. *Alonella exsica* but the fauna was otherwise fairly stable as was that in strongly saline Lac de Korba. Formanifera were abundant in those cores from sites with marine connections. In Ichkeul the zooplankton communities were quite stable until ca. 1960 when freshwater cladocera increased and some foramiferans declined indicating a decline in salt water influences. Marked salinity variations were indicated by the faunal assemblages in the Delta lake cores, with freshwater Cladocera increasing since the 1940s in Edku. Similarly in Manzala water freshening occurred since about the beginning of the 20th century. In Burullus open water core a change from fairly fresh to more marine conditions in indicated but dating is unclear.

Pollen and macrofossil stratigraphies: In general, the pollen diagrams for each core typically shows disturbed local terrestrial vegetation. Introduction dates of exotic plants provides a valuable chronological marker in several sediment cores. Hence, planting of *Eucalyptus* and/or *Casuarina* near many of the CASSARINA sites enable sediment deposited after ca 1900 to be identified. A good example of such markers occurs in the Lake Manzala core. Ruderal plants have high pollen values in the site near agriculture but at the less disturbed sites SBR and Chitane woodland vegetation has increased during the 20th century. In the Delta lakes, aquatic macrophytes have generally increased associated with 20th century declines in salinity (see Annex 3, Fig. 12). In Burullus however, the littoral coring site was dominated by *Phragmites* in the early period, then was it subjected to a higher salinity phase before returning to fresher conditions in the mid-20th century and growth of *Typha* reed beds. This indicates that *Typha* is less tolerant of salt.

Animal macrofossils, particularly molluscs, also provide good indicators of major changes in water salinity. These have occurred at most of the sites during the 20th century and an example of the Lake Edku macrofossil diagram is given (Annex 3, Fig. 13). The Delta lakes have experienced strong and sustained changes in salinity during the 20th century no doubt linked with hydrological changes resulting from Nile water irrigation programmes. The aquatic communities have undergone dynamic changes but only in Burullus are pre-20th century conditions inferred to be markedly freshwater.

Pesticide contamination in CASSARINA sediments: Pesticide residues were detected in all nine lakes (see Annex 3, Table 4 and Peters *et al.* 2001). The two pesticides commonly found in the upper sections of the CASSARINA sediment cores are hexachlorocyclohexane (HCH) and dichloro-diphenelethane (DDE, a product of DDT). Relatively high levels were found in SBR and Bokka recent sediments. Chitane was unusual in that peak in pesticide residue values occurred in sediment dated to around 1980. There was some indication that residues has also recently decreased marginally in the Edku and Burullus cores and in Bokka. The onset of pesticide contamination was earlier in Tunisia than in Morocco and interestingly the sediments indicate that pesticide usage is diminishing in Tunisia but not in Morocco. The most complete pesticide record in Egypt was found in Manzala but levels of contamination were not particularly high compared with some non-African sites. The sources of pesticides in Chitane raises interesting issues, since the catchment is mainly semi-natural vegetation with only one small field of crops. Here the mixture of residues present could indicate contamination via an atmospheric pathway from Europe.

Numerical analysis: Treating the palaeoecological data statistically has provided an impressive way of estimating not only the relative amounts of biological change between sites but also the trends within sites. The combined botanical and zoological sedimentary records are being subjected to multivariate analysis to detect trends in biological change (using diatoms, pollen, macrofossils and in zooplankton remains in cores). This work is currently on going at the University of Bergen.

Results overview: Summaries of 20th century sediment records of environmental change events occurring at the Moroccan, Tunisian and Egyptian sites are given in Annex 3, Tables 1, 2 and 3). Overall, these changes can be mainly attributed to the physicochemical effects of soil erosion, hydrological disturbance (associated with water abstraction and crop irrigation) and land reclamation on the lake biota.

Biodiversity: In the CASSARINA sites where species groups (phytoplankton, zooplankton and diatoms) have been qualitatively measured, species richness (number of taxa per standard sample) is used to indicate diversity. There is a clear trend for the Delta lakes to be more diverse for algae but there is no clear trend for zooplankton. Physicochemical conditions do not appear to be very different at the Egyptian sites (Fathy *et al.* 2001) but they are generally less saline. On the other hand, the Delta lakes are by far the largest in area but, because of the constraints on aquatic diversity by between lake differences in water quality, species-area curves are not generally applicable to the lake biota. It also must be noted that sampling areas in those larger CASSARINA sites with marine connections and freshwater streams, were selected far away from these inflow/outflow channels. Hence, diversity of invertebrates, plankton and algae can be expected to vary considerably along these environmental gradients and so overall site diversity is underestimated by CASSARINA sampling.

Of all the CASSARINA lakes, only the smallest (Chitane) is acidic and although biological diversity is not high, some particular aquatic species present are very rare both nationally and for North Africa. With the exception of several acid pools and streams (Ben Khalifa 1994), this site is the only acid wetland lake known in the CASSARINA North African countries. Its modern diatom flora is unique for a Tunisian lake, being composed of *Eunotia* species and other acidophilous taxa such as *Frustulia rhombides v, saxonica*. It is also the only the second recorded site for the cladoceran cold water preferring *Diaptomus cyaneus* and the benthic aquatic pteridophyte, *Isoetes velata*. These species are often common in many softwater European lakes but the site is of national significance for aquatic biodiversity in Tunisia. Unfortunately, it is being currently degraded by local land-use activities.

All the other eight CASSARINA sites have alkaline brackish water and, in addition to water quality, biogeographic related factors play an important role in influencing aquatic biodiversity. This is demonstrated particularly well by the Delta lakes which form a distinct group characterized by endemic fish species and by high diversity of benthic invertebrates and unusual species of aquatic higher plants. These are all of freshwater origin whereas those derived from marine habitats, for example mullet and the bivalve molluscs, commonly occur in Mediterranean lagoons. Species of *Tilapia*, *Oreochromis* and the Nile Perch (*Lates nilocticus*) are endemic within the Nile system. Recent introductions of exotic aquatic plants, notably the water hyacinth (*Eichhorina cressipes*) and the water fern (*Azolla filiculoides*), have proliferated in all three Delta lakes. Since Pharonic times, *Cyperus papyrus* has become virtually extinct in the Delta region (Tackholme & Drar 1950) as has the endemic freshwater fern *Azolla nilocticus* (Birks *et al.* 2001). The Delta lakes also have several unusual features regarding their diatom floras, planktonic *Cyclotella caspia* (=*C. choctawhacheeana)* in the surface sediment of Burullus Lake was previously known only as a fossil species in North Africa (Carvalho *et al.* 1995). The neritic diatoms *Biddulphia laevis* and *Hylodiscus scoticus* are known from British coastal water (Hendey 1964) but occur in low numbers only in Edku recent sediments. Endemic or unusual taxa are not exclusive to the Delta lakes and one endemic variety of copepod is known only from several sites in Morocco, including

Sidi Bou Rhaba (Ramdani 1988). However, with the partial exception of acid Chitane, the aquatic taxa occurring in the Moroccan and Tunisian sites can be considered to be widely distributed in remaining North African wetland habitats.

Change and stress: All forms of rapid environmental change can be considered as stressors for aquatic ecosystems yet inherent resilience (see below) means that in many cases a site can recover or be transformed into a equally diverse but different ecosystem. Although biological and chemical monitoring of the nine CASSARINA lakes enables setting of ecological baselines for the late 20th century, evidence of past stresses and ecosystem disturbance phases must be sought in older publications or in the sediment record. Palaeoecological studies have shown that aquatic ecosystems are never stable if considered over a long enough time period (Birks 1996). Communities can however adapt and maintain diversity if the rate of change is not excessive or is of short duration. In the past century or so, mechanisation of agriculture has grown dramatically in North Africa and this increased capacity for impacting lake-catchments has resulted in abrupt changes to many of the CASSARINA lake systems.

In many CASSARINA sites, hydrology is shown to be a key factor in maintaining ecosystem viability. Irrespective of a lake's biological attributes and even of moderate pollution, the obvious primary need is adequate water supply. Twentieth century variations in the supply of freshwater has been the single most important factor affecting all the CASSARINA sites. Changes in hydrology can be complex but in Morocco and Tunisia, Ichkeul, Bokka and M. Zerga experienced enhanced freshwater earlier in the 20th century and the former two had reduced water supply in the post 1980 period. In Ichkeul, late 19th century manipulation of the connection to the Mediterranean lead to a small increase in salinity that promoted growth of *Potamogeton* and other aquatic plants (Stevenson & Battarbee 1991). From the 1940s *Phragmites* expanded and freshwater cladocera appeared in the sediment record evidencing fresher conditions (probably by prolonging the winter low salinity phase by enhanced freshwater from irrigation/drainage schemes). In the 1980s, higher salinities began to prevail as freshwater inflow streams were barraged and salinization occurred to such an extent in the early 1990s that emergent macrophyte beds catastrophically declined, invertebrate communities changed, and large over-wintering bird populations, especially geese, diminished. Despite a past erosion event and some recent enrichment by fertilisers leaching, the main stress on Megene Chitane is reduced water supply, following diversion of an inflow stream for irrigation of one small cereal crop. The lake was dry for several months in 1996 and sediment core lithostratigraphy indicated that this was the first time complete drying had occurred during the lake's recent history. At the other Tunisian site, Korba, the sediment record indicates relative stability but high salinity persisted throughout the 20th century.

At the Moroccan sites, hydrological change in and around Merja Bokka has brought extreme stress through drainage and cessation of runoff water supply, leading to extinction of all aquatic life and reclamation of the entire basin by late 1998. Yet an enhanced freshwater phase persisted here during the first part of the 20th until the 1950s and was doubtless also caused by early manipulation of drainage channels in this agricultural lowland region. Zerga was formerly a saline lagoon (Ramdani *et al.* 2001) and a *Salicornia* marsh and hard compacted marine shell-rich sediment in the south part of the lagoon persisted before the Nador Canal began delivering fresh drainage water and silt to the site in ca. 1956. More flourishing growth of emergent aquatic macrophytes in this southern region is probably prevented by livestock grazing. On the other hand the Oued Drader in the northeast of the basin has been much reduced in recent decades by water abstraction. Of all the CASSARINA sites, Sidi Bou Rhaba is the only lake where the sediment record does not indicate major abrupt past changes but sedimentary diatom and ostracod records indicate a gradual increase in salinity. Direct human pressure on this protected site is relatively small but the high sediment accumulation rate means that permanent open water could cease to exist here by the middle of the 21st century.

Despite the general problem of water shortage in North Africa, environmental change records from the CASSARINA sites on the Nile Delta give different histories of water availability and quality but all show a trend towards declining salinity during the 20th century. Here increased irrigation for agricultural purposes has clearly promoted sustained freshwater inputs that have affected the molluscan fauna (Bernasconi & Stanely 1993), especially after the Aswan dam (Banoub 1979). Some of the ecological effects of this change are clearly seen in the biostratigraphies of Egyptian lake sediment cores (Flower *et al.* 2001, Ramdani *et al* 2001b, Birks *et al.* 2001a.). Biotas more typical of saline conditions or of reed bed communities, occurred at or before the beginning of the 20th century but in recent decades more species typical of open freshwater conditions are found. This is particularly marked in the zooplankton record for Manzala (Ramdani *et al.* 2001). The core biostratigraphies clearly show that a trend towards fresh conditions appeared well before the Aswan dam was built and have persisted throughout the 20th century. Interestingly, Stanley & Warne (1993) predicted that the Delta lakes will eventually become increasingly marine due to subsidence of the whole Delta region and sea level rise. The small increase in halophilous diatoms in several core tops may be an indication that the 1993 prediction is beginning to take effect.

Pollution also stresses aquatic systems and trace metals and pesticide levels are cause for concern at several sites. There is however no evidence that their effects are at present greater than those being caused by reclamation and water abstraction. Where extreme pollution has occurred such as in the Delta Lake Maryut (e.g. Saad *et al.* 1985), fisheries are lost and biological recovery is not possible without extreme measures such as dredging contaminated sediment and redeveloping the ecosystem. Nevertheless the CASSARINA Delta lakes do receive high pollution loadings, particularly in eastern Manzala, yet the pollutants are localized and prevented from dispersion by reed beds. This pollution control role is recognised elsewhere were reed beds are managed for waster water control (e.g. Duning *et al.* 1996). Industrial pollution is apparently not a major problem in the lake regions investigated in CASSARINA, Korba and Burullus have elevated sedimentary lead, probably from waste water but values are not high compared with some European sites (e.g. Rippey *et al.* 1982). Notwithstanding elevated freshwater supply to some of the CASSARINA lakes in the early - mid-20th century period, management to protect lakes from contamination and from loss of freshwater supply is the only sensible course for sustaining North Africa's remaining wetland lakes resources. Conservation of reed beds offers one way to mitigate, or at least localize, pollution effects in the Delta lakes and promoting emergent macrophytes elsewhere would help maintain local biodiversity.

Resilience: Aquatic ecosystem resilience can be considered in several ways but a system can be considered resilient if biological changes in response to perceived disturbance are small. Measuring disturbance pressure in field situations is difficult (Tokeshi 1999) but the concept of ecological 'sensitivity' of lake communities to water quality changes is well known for acid lakes (Battarbee 1991) and species changes are known to be more sensitive that functional attributes (Schindler 1987). Species environmental tolerances must ultimately control aquatic ecosystem resilience. Consequently, those CASSARINA sites that remain important for aquatic diversity, despite pollution, salinity change, lake area loss and intensive fishing must comprise largely of resilient species. Even so, many species changes have occurred during the 20th century but the Delta lakes can be considered to be particularly resilient since they remain diverse in the face of major disturbance. Their extensive reed beds, essential for many species of water birds, and viable fisheries persist in these productive systems and must at least be partly responsible for maintaining local diversity. Nevertheless, fishery yields and open water areas have been recently reduced in the Delta lakes and chemical contamination is a problem but the centres of high diversity that remain in the less damaged parts of these lakes are vital refugia for biodiversity and provide for potential recruitment elsewhere if detrimental processes are mitigated.

The palaeo-records indicate that species abundances fluctuate on a range of time-scales (cf. Birks 1996) and recovery from some large disturbance events can be rapid. The Chitane and Burullus (marginal) cores indicate major environmental changes in the recent past yet some biological recovery has occurred. Where disturbance has been more sustained, such as in hydrology at Bokka, Ichkeul and Zerga, reed beds are now virtually lost. In Ichkeul the interpretation of the macrofossil record of this process is problematic because post 1980s salinization has proceeded mainly by the critical reduction of the winter phase of low salinity water. However, even at the latter two sites there is potential for recovery, the littoral seed bank persists and new but unsustained new growth of *Phragmites* occurs seasonally. In Merja Bokka however the resilience mechanisms (species tolerances) were overwhelmed as standing water receded to zero. In any future (but unlikely) event that this site is restored, re-developing the area by re-establishing hydrology and importing the key aquatic organisms is required. If this were to occur, the CASSARINA palaeo-data provide the only source of information on the aquatic species that formerly inhabited the lake but selection of particular past analogue conditions depends partly on subjective criteria (cf. Birks 1996).

CONCLUSIONS

Benefits: CASSARINA is the first jointly planned international environmental assessment programme to be carried out on North African wetland lakes. Before this project was begun, co-ordinated mutidisciplinary ecological research on these sites was absent. Continuous instrumental records of water quality collected over more than several years existed only for one site (Tunisian Ichkeul, Hollis 1986, Anon. 1996). The contemporary environmental status of the other sites was either unknown or known very incompletely. CASSARINA has clearly achieved its four main aims and has provided an innovative approach to measuring regional 20th century environmental change using palaeoecology and modern survey. Achieving these aims and so providing information about the pace and extent of past change is of fundamental importance in formulating conservation plans and promoting of biodiversity values to society. The biodiversity value of many of North Africa's wetland lakes and lagoons are directly linked with conflicting human needs. At the larger sites, fisheries are a major food resource, bird populations are important parts of site biodiversity and have potential for eco-tourism. Yet, they are threatened habitats being convenient sinks for waste water and, especially in Egypt, the areas they occupy are potential sources of new land for agriculture and housing.

CASSARINA has begun to monitor changes at the aquatic ecosystem level and will bring the initial results to the attention of influential NGO's and GO's. CASSARINA will add to the debate on conservation in North Africa and will therefore benefit progress on this complex issue. These results stem from progress made on meeting the primary CASSARINA objectives (see introduction) and these are summarized as:

I. Twentieth century land-use practises are shown unequivocally to have caused major environmental changes at all the CASSARINA sites and these activities pose the greatest threats to sustainability. Although land irrigation and drainage schemes initially promoted freshwater supply to several wetland lakes the effect is sustained only for sites in the Delta and Merja Zerga (southern part).

II. Direct water abstraction from freshwater lake inflows (Chitane, Bokka, and Ichkeul) and sustained ground water exploitation (Bokka and Sidi Bou Rhaba) has reduced lake open water areas and promoted lake water salinity.

III. Emergent aquatic macrophytes were formerly important components at several CASSARINA sites and have declined in recent decades due to rising salinity (Ichkeul), harvesting and grazing (Zerga), loss of standing water (Bokka). On the other hand sustained increases in freshwater supply from irrigation schemes has promoted emergent macrophytes at the Delta sites, despite an absolute loss in lake areas by land reclamation.

IV. Location specific baseline data on the diversity of aquatic species and on water quality are now established by CASSARINA and these set reference points for the late 20th century and can be used to assess future changes within a scientific context.

V. Harmonised sampling and regulated laboratory procedures (for biology and chemistry) were established in the CASSARINA laboratory groups so improving database integrity. Validated results can now be used to help contribute to protocols about effectively managing North African wetland lakes for biodiversity.

Water quality and hydrological changes have clearly had major impacts on the aquatic diversity of these wetland lakes during the 20th century but the nature of change relevant to biodiversity is largely site dependant. Pollution by agro-chemicals (pesticides and fertilizers) is a secondary problem at some sites, but industrial pollution (heavy metals) is not yet a major widespread issue in North African lakes although two sites show an increase in sedimentary lead concentrations. However, it should be emphasized that sample sites within the larger Delta lakes were selected in the least disturbed areas. Lake Manzala is a good example of this regionalization, where the southwest sector of the lake is relatively undisturbed but the southeast sector is heavily contaminated by waste water (Siegal *et al.* 1994, Drainage Research Institute 1997). Pollution is partially contained by the network of reed beds (see recommendations) but if future salinization occurs this internal protection mechanism will fail as macrophytes die back. Multiple use of several CASSARINA sites as bird reserves and/or profitable fisheries together with waste disposal and land reclamation is clearly unsustainable. Management of some North African wetland lakes is practised but is rarely the result of a balanced appreciation of the development economy, society and biodiversity values.

We believe that the work begun by CASSARINA is exemplary in its application to environmental issues facing North African wetland lakes and we can begin to establish relevant environmental protection protocols (see recommendations) following publication of the scientific results. However, the monitoring programme established by CASSARINA is insufficiently long to draw any conclusions about temporal environmental changes and here trends are obtained from palaeoecology. Although necessarily selective, CASSARINA has provided evidence that North Africa's wetland lakes have been subjected to high stress mainly from human activity during the 20th century. However, high internal resilience to this stress has enabled some sites to retain remarkably high diversity, especially in the Delta region. Nevertheless, all are currently threatened and undergoing rapid environmental change that is linked with local or potential loss of diversity and habitat quality. Unless checked, environmental stress will undoubtedly accelerate in the 21st. century and must lead to widespread ecosystems degradation and economic losses. In the longer-term, climate change and, for the Delta lakes, land subsidence gives cause for concern but it is the ca. 10 year or less time-scale changes, driven primarily by land-use intensification, reclamation and hydrological disturbance, that imminently threaten the sustainability of many North African wetlands. Merja Bokka is already lost, suffering a fate no doubt similar to that experienced by hundreds of former small North African lakes in agricultural regions. Unfortunately we have no clear record of the overall loss of wetland lakes, a detailed national inventory of wetland sites is only available for Tunisia (Hughes *et al.* 1997). This is based on cartographic information collected in the 1980s or earlier and is already partly out of date with many of the inland sites listed now lost, mainly by water abstraction for agriculture (cf. El Amani 1977).

Environmental degradation is the main challenge facing many African countries (GEO-2000 1999) and in the Northern region, ever increasing and largely unplanned demand for water will inevitably diminish wetland lake ecosystems. Only through a greater appreciation of biodiversity and the importance of aquatic ecosystems can wetland conservation be promoted in many developing countries (Wetzel & Gopal 1999). The MedWet Programme has made exemplary progress in promoting Mediterranean wetland values and stimulating local appreciation of environmental issues, particularly in North Africa (e.g. Skinner & Zalewski 1995, Pearse 1996). However, basic research on environmental change and on the structure and function of the aquatic ecosystems that sustain each wetland lake is fundamental for effective long-term management policy. Without the techniques employed in CASSARINA, many of the longer term (>3 yr.) trends and fluctuations in biogeochemistry would be unrecognised and past variability underestimated. More specifically, palaeoecology has provided the only way to reveal some of the ecological effects of lake disturbance during the 20th century (cf. Flower *et al.* 1988, Smol 1992), as well as providing species level data on past aquatic biota. On the other hand, some biological attributes cannot be obtained from sediment records and, by monitoring, CASSARINA has established modern late 20th century baselines for water quality, littoral macrophytes, plankton and fish.

Recommendations: CASSARINA has made a start on integrated environmental monitoring in North African wetland lakes and there are several ways in which the achievements of this project can be built upon. In any future work, the programme should be extended so that the number of sites is increased to include running waters and more emphasis is placed on spatial studies, especially of the larger lakes. More countries should be included and initial contacts have already been made with interested wetland scientists in Algeria, Libya and Lebanon. Because 20th century biological change trends are already established for CASSARINA sites, less emphasis on palaeoecological work is required in future. It is clear that at the larger sites, large spatial gradients in environmental conditions exist and strengthening this dimension of the assessment work is required. In any next phase, work should focus on these spatial aspects and on future prediction. One obvious way forward is to use remote sensing techniques combined with ground survey and monitoring to construct relationships between time variable site characteristics such as vegetation type and area with water quality and lake area change. CASSARINA monitoring has established North African data for the late 1990s but in the UK the Acid Water Monitoring Network (Patrick *et al.* 1995) showed that at least ten years of seasonal data are required to show trends in water quality and biological data. Furthermore, only long-term monitoring will enable the effects of climate change to be disentangled from those of local anthropogenic activity. A feasible way to do this is to use automated techniques for measuring water quality so that sampling times are harmonised. This would doubtless also improve data quality and quantity and simplify field logistics. Facilitating non-automated tasks could be achieved by involving more junior scientists (cf. the EU linked INTAS programme for FSU countries). Networking between groups in each partner country should be encouraged despite major attitude differences in science administration and practise remaining in North African Institutions. In the long term however we anticipate a convergence of scientific capacity.

Recommendations can be summarized according to the results of the initial CASSARINA study and for further work as follows:

This study:

I. Where freshwater supply is now reduced by water abstraction (Morocco and Tunisia) effective management is needed to correct the problem. Extending irrigation networks from barrages rather than exploiting local water resources is one solution to this problem of reconciling freshwater supply conflicts. Those sites already destroyed by abstraction (M. Bokka) cannot feasibly be restored so that extra protection should be given to similar surviving sites.

II. Emergent aquatic macrophytes are essential components of several of the wetland lake ecosystems, they should receive effective protection or be restored where they are no longer significantly present (Zerga, Ichkeul) by reducing salinity and/or preventing grazing.

III. Use the monitoring results to assess future changes, especially in aquatic macrophyte, diatoms zooplankton and benthic molluscs. Also these data need further examination to reveal more details the relationships between water quality and aquatic organisms.

IV. The species data made available by CASSARINA can allow prioritization for conservation, for example the acidophilous species found at threatened Megene Chitane urgently require protection. Similarly the refuge areas remaining in the Delta lakes and the clear water Southwest part of Manzala, particularly, still retains high diversity and as yet has relatively little contamination.

Future work:

I. Monitoring spatial changes in emergent macrophytes (due to loss of growing area, harvesting and/or water quality change) is particularly amenable to remote sensing and this technique should be combined with future ground survey at the species level.

II. Water quality fluctuates markedly at many of these coastal sites and assessing and the relationship of ecological quality with water quality needs further research before models relating the two can be proposed. Biodiversity gradients that incorporate more spatial information combined with remote sensing and automated daily measurements of water quality offers a promising way forward.

III. Establishing long-term data on biological, hydrological and physicochemical characteristics is the only assured way of separating the effects of local changes from those of climate change. Again automated monitoring techniques should be involved in this strategy.

IV. In North Africa government agencies are often more involved with monitoring work and need to be more involved in this work so that to access national information is facilitated and closer links with development planning and to inform policy makers can be made.

The continuation of chemical and biological monitoring of the important North African wetland lakes is essential and urgent, if these valuable sites are to be managed in a sustainable way. Unfortunately the restricted themes announced in 1999 for the 5th Framework Programme of INCO-MED funding has precluded an immediate follow-up programme for the CASSARINA aquatic ecosystem work at the present time. Enhanced international co-operation with the southern Mediterranean countries is however essential during the 21st century, not only to help protect and monitor vital biodiversity resources but also to promote and integrate scientific activity for the region. The Global Environment Facility (GEF) has recently (1999) agreed to support a major programme for Mediterranean wetlands in co-operation with the French Government. This is a excellent plan for the management and promotion of wetlands but the aquatic diversity that under-pins these ecosystems is under represented. Hopefully this aspect will be picked up in forthcoming rounds of EU INCO-MED initiatives.

Project success: CASSARINA has gone a long way in achieving the preliminary aims of establishing protocols with analytical quality control and validation of techniques necessary for effective environmental monitoring. Establishing working links between active scientists in Morocco, Tunisia, Egypt and elsewhere in North Africa and in Europe was particularly necessary in this joint work and has facilitated the generation, exchange and storage of data between countries. Through this collaboration and by other different but parallel programmes (e.g. MedWet), awareness of the value of North African wetland lake ecosystems is being at last promoted. However, sustained long-term international support is needed to conserve these vital resources and to support continuity in aquatic ecosystem monitoring. Studies at the *species level* is a major priority. The continuation of fixed transect monitoring for macrophyte communities, established by CASSARINA, together with regular sampling for aquatic biology and chemistry will enable future impacts of on-going processes to be assessed. Clearly at the larger sites, any future assessment programme should, as indicated in the recommendations subsection, include satellite surveillance as a means monitoring whole lake attributes. Nevertheless, the Project has already provided much strong evidence about the nature and pace of biodiversity change in these threatened North African habitats.

The CASSARINA Project is only a success in the sense that a scientific multidisciplinary assessment programme has begun on the aquatic ecosystems that support these important wetland lakes. On its own, CASSARINA cannot change the exploitation of these sites. However, if unregulated development for increasing food production and population growth continues without effective conservation measures, then those North African wetland lakes not maintained artificially or by seawater, will surely disappear by the mid-21st century. Human pressures on biological resources are intense in North Africa and especially so in the Egyptian Delta region (Biswas 1993, Sultan *et al.* 1999). Human usage of lakes will inevitably causes some disturbance to the structure and function of these aquatic ecosystems and long-term sustainability requires careful management. Nevertheless, as long as some freshwater water supply is maintained and disturbance is curbed, the resilience of these sites is such they will remain important biological resources as long as thresholds are not exceeded. Effective minimum management can lead to sustainability. Unfortunately, societal response is slow compared with rates of environmental degradation and this leads to an irreversible loss of options for mitigation (Kasperson *et al.* 1999).

Where problems are recognised and finance is available restoration management can be activated as exemplified by Louisiana's Mississippi Delta lakes programme (Boesch *et al.* 1994, Van Heerden 1994). Enhanced societal aspirations can be compatible with wetland conservation objectives and, in the long term, natural and cultural heritage values will be given equal importance. The conservation ethic is part of African environmental policy (UNECA 1991) but, realistically, achieving protection for wetland biodiversity will need not only international effort but the will at a national level to implement appropriate management. If national or international societal interests begin to place more emphasis on biodiversity ethics in this region then CASSARINA has provided a foundation stone for achieving future conservation goals.

PUBLICATIONS

In addition to the CASSARINA reports on the annual workshops and on methods and protocols, two papers were published in 1998; one (Patrick *et al* 1998) presented an overview of the CASSARINA project and one (Flower *et al.* 1998) described the CASSARINA Project in outline and discussed the potential of co-ordinating the results of CASSARINA aquatic macrophyte monitoring with whole lake estimates of vegetation cover using remote sensing. This was given at this time to set a precedence for the next phase of CASSARINA work. In December 1999, Dr Ramdani (IS-RABAT) gave an oral presentation on the CASSARINA coastal sites to the Magrebian Congress on Marine Sciences. During CASSARINA meetings in 1999, a suite of research papers based on the results of the 1996-1999 CASSARINA results was planned and these have now been accepted in principle for publication in the scientific journal *Aquatic Ecology* (Editor Dr R. Gulati). Initial draft copies of all the proposed papers were reviewed at the last CASSARINA workshop (February 2000) where it was agreed to submit manuscripts to the Project co-ordinators by April 2000 for final revisions.

Since CASSARINA is divided in two work themes, the draft papers are divided accordingly, the first group is concerned with describing the contemporary environmental status of each wetland lake: Ramdani *et al.* (2001a), gives an account of the characteristics of each site and the results of the vegetation transect surveys, Ramdani *et al.* (2001b), describes the results of zooplankton analysis in each lake, Fathy *et al.* 2001, present the results of water chemistry and phytoplankton monitoring and Kraiem *et al.* 2001, gives an account of fish diversity and growth rates at selected sites. The second group is concerned with palaeolimnological assessment of recent environmental changes, Appleby *et al.* (2001) describe sediment chronologies and the estimation of sediment accumulation rates; Birks *et al.* (2001a) give an account of the vegetation record of each site, Flower *et al.* (2001) uses sedimentary diatoms to reconstruct salinity changes, Ramdani *et al.* (2001c) uses zooplankton remains to infer past changes in water quality and diversity, and Peters *et al.* (2001) presents results of pesticide analyses. In the final paper (Birks & Birks 2001) provide a numerical analysis of some of these fore-going data.

Reports produced as a result of CASSARINA workshops and field work.

Flower R.J. & Patrick S. (Eds.) 1997. CASSARINA Project Manual: Suggested Fieldwork Procedures and Laboratory Techniques. ECRC *Research Report,* No. 48. University College London.

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Ramdani, M. & El Khiati, N. 2000. Vegetation transects, water analysis, zooplankton analysis of open waters, zooplanktonic and benthonic fauna analyses in sediments cores of all investigated lakes. Final CASSARINA Results Report. Internal report: Dept. of Zoology and Animal Ecology, Institute Scientifique, Rabat and Dept. of Biology, Faculty of Sciences, University of Ain Chok, Casablanca. Morocco.

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Flower, R.J., Ramdani, M., Kraiem, M., Fathy, A., Al-Khudhary, D.H.A., Birks, H. H., Patrick, S..& Stevenson, A.C. 1998. The CASSARINA Project and the application of remote sensing techniques. In: *Satellite-based Observation: A Tool for the Study of the Mediterranean Basin* (Ed. J.L. Fellous *et al.*). Proc. of an International Symposium, Tunis 23-27th November 1998. 219-224. Centre National d'Etudes Spatial, Toulouse.

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Papers provisionally accepted (in Aquatic Ecology)

Appleby, P.G. & Flower, R.J. with contributions from Birks, H.H., Rose, N., Ramdani, M., Kraiem, M. & Fathy. A.A. Recent environmental change in North African wetland lakes: radiometric dating and recent sediment accumulation rates in sediment cores from nine sites in the CASSARINA Project. *Aquatic Ecology*, 36.

Birks, H.H., Peglar, S.M., & Boomer, I., with contributions from Flower, R.J., Appleby, P.G., Ramdani, M., Kraiem, M., Fathy, A.A. & Abdelzaher, H. 2001 Palaeolimnological responses of nine North African Lakes to recent environmental changes and human impacts detected by macrofossil and pollen analyses. *Aquatic Ecology*, 36.

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Flower, R.J., Dobinson, S., Shilland, E., Ramdani, M., El Khiati, N., Kraiem, M., Ben Hamza, C., Fathy, A.A, Abdelzaher, H., Birks, H.H., Appleby, P. & Patrick. S. 2001 Recent environmental change in North African wetland lakes: diatom and other stratigraphic evidence from nine sites in the CASSARINA Project. *Aquatic Ecology*, 36.

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Ramdani, M., El Khiati, N., Kraiem, M., Fathy, A.A. & Flower, R.J. with contributions from Abdelzaher, H., Ben Hamza, C. & Birks, H.H. 2001b Open water zooplankton communities in North African wetland lakes: the CASSARINA Project. *Aquatic Ecology*, 36

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ANNEX 2 CASSARINA SAMPLE RESULTS, SUMMARY TABLES AND FIGURES

Table 1 Vegetation transect for Burullus Lake in Egypt.

Lake Burullus - 15.11.97 - Vegetation transect - Transect 1, Start 31.26182⁰ N, 30.38496⁰ E; Finish 31.25893⁰ N, 30.38503⁰ E. Quadrat sampling at 30 m intervals.			
Quadrat Number	**Distance (m)**	**Plant species**	**Remarks**
1	0	*Typha* 100%	Starting point at lake edge: a post 6 m from house.
2	30	*Typha* 100%	Boat mooring and temperature logger emplacement.
3	60	*Typha* 100%	
4	90	*Typha* 80% *Eichhorina* 20%	
5	120	Shelly sediment 100%	Open water, no submerged plants
6	150	*P. pectinatus* 80% *Najas armata* 20%	Open water channel
7	180	*P.pectinatus* 90% *N.armata* 10%	Open water channel
8	210	*N. armata* 100%	Open water channel
9	240	*P. pectinatus* 100%	Open water channel
10	270	*Typha* 90% *Phragmites* 10%	2nd island of *Typha*
11	300	*Typha* 100%	Macrophyte stand c. 15m wide
12	330	*Typha* 100%	Macrophyte stand c. 5m wide
13	360	*P. pectinatus* 90% *N. armata* 10%	Open water channel
14	390	*P. pectinatus* 95% *N. armata* 5%	Open water channel
15	420	*P.pectinatus 99%* *Phragmites* 1%	Open water channel
16	450	*P. pectinatus* 100%	Open lake water

Table 2 Water Chemistry, field measurements and cations and anion concentrations for Lake Manzala, Egypt.

I- Field data

MANZALLA								
Determinand	Temp.	pH		Conductivity (uS/cm)	O2 content	Chl-a	Water depth	Visibility
Time period	(°C)	Field	Lab.	Field	mg/l	ug/l	Cm	Cm
Nov.97	19.00	8.00	8.00	2200.00				
Mar/98	18.00	7.70	7.80	1600.00	13.6 ± 0.0	55.29	58.00	45.00
Jun./98	24.00	8.70	8.75	900.00	5.12 ± 0.02	64.15	55.00	32.00
Aug. 98	30.00	8.29	8.35	2500.00	17.8 ± 0,00	31.01	55.00	35.00
Dec./98	15.00	8.30	8.30	900.00	9.0 ± 0.00	55.21	48.00	33.00

II- Cation and anion concentrations.

MANZALLA					
Parameters	Nov.97	Mar./98	Jun/98	Aug.98	Dec./98
T.D.S g/l	1.408	1.024	0.576	1.600	0.576
Alkalinity (Lab) mg/l	253	232.7 ± 0.20	212 ± 0.00	325 ± 0.30	240 ± 0.00
Sodium mg/l	319	279.46 ± 0.29	156.95 ± 0.20	217.32 ± 0.20	245.14 ± 0.00
Potassium mg/l	31	28.31 ± 0.10	24.06 ± 0.00	32.00 ± 0.20	12.87 ± 0.00
Magnesium mg/l	51	16.70 ± 0.60	39.00 ± 0.50	76.00 ± 0.00	45.00 ± 0.00
Calcium mg/l	28.5	20 ± 0.00	47 ± 0.00	72 ± 0.00	52.00 ± 0.00
Chloride mg/l	420	275 ± 0.60	200 ± 0.00	360 ± 0.50	220 ± 0.00
Nitrate-N mg/l	4,433	0.720 ± 0.00	5.162 ± 0.00	1.629± 0.00	4.060 ± 0.00
Phospahate-P mg/l	0.083	0.032 ± 0.00	0.065 ± 0.00	0.082 ± 0.00	0.069 ± 0.00
Total- P mg/l	0.58	0.496 ± 0.00	0.282 ± 0.00	0.692 ± 0.00	0.252 ± 0.00
Sulphate mg/l	157	151 ± 0.00	135 ± 0.20	182.15 ± 0.30	181.17 ± 0.35
Silicate mg/l	.3.28	4.0 ± 0.00	3.23 ± 0.30	4.73 ± 0.15	2.92 ± 0.05
COD mg/l	13	50 ± 0.50	11.65 ± 0.20	18.5 ± 0.20	15.90 ± 0.00
Inorganic carbon mg/l	63.25	5.80 ± 0.40	49.92 ± 0.20	78.00 ± 0.00	57.60 ± 0.00

Table 3 Percentage composition of the zooplankton communities in Lac Sidi Bou Rhaba and Merja Zerga, Morocco, in 1997/98.

LAC SIDI BOU RHABA (Morocco)	April97	Febr.98	May 98	Sept 98	Dec. 98
Acanthocyclops robustus	2%	5%	10%	4%	5%
Eucyclops serrulatus	8%	9%	4%	0%	8%
Tropocyclops prasinus	5%	0%	5%	2%	5%
Cletocamptus confluens	4%	6%	3%	8%	8%
Brachionus plicatilis	5%	0%	7%	4%	7%
Alona pulchella	2%	7%	8%	4%	5%
Alona elegans elegans	5%	12%	5%	7%	4%
Oxyurella tenuicaudis	13%	22%	10%	19%	14%
Chydorus sphaericus	8%	6%	5%	0%	2%
Ceriodaphnia dubia	12%	0%	9%	0%	3%
Chironomus halophilus	0%	0%	2%	3%	3%
Chironomus riparius	2%	0%	0%	0%	1%
Chironomus plumosus	2%	0%	0%	0%	2%
Procladius coreus	2%	0%	2%	0%	0%
Tanytarsus horni	0%	0%	1%	1%	3%
Cricotopus sylvestris	2%	0%	2%	0%	0%
Gambusia affinis	2%	0%	2%	3%	2%
Cyprideis torosa littoralis	12%	16%	8%	20%	13%
Eucypris virens	7%	8%	8%	5%	3%
Ilyocypris getica	1%	3%	0%	5%	2%
Plesiocypridopsis aculeata	2%	0%	4%	4%	5%
Potamocypris arcuata	4%	6%	5%	11%	5%

MERJA ZERGA (Morocco)	April97	Febr.98	May 98	Sept 98	Dec. 98
Calanipeda aquae-dulcis	14%	8%	18%	7%	2%
Cletocamptus retrogressus	12%	14%	7%	18%	13%
Eucyclops serrulatus	12%	10%	0%	0%	10%
Cyprideis torosa littoralis	14%	16%	12%	15%	13%
Loxoconcha elliptica	11%	12%	13%	9%	8%
Potamocypris arcuata	9%	5%	7%	2%	5%
Daphnia longispina	8%	3%	9%	4%	0%
Oithona helgolandica	4%	0%	4%	13%	0%
Tropocyclops prasinus	3%	9%	8%	0%	8%
Acanthocyclops robustus	2%	12%	1%	0%	16%
Cricotopus sylvestris	2%	0%	3%	5%	3%
Gambusia affinis	2%	0%	2%	4%	2%
Chironomus piger	2%	0%	4%	2%	3%
Chironomus plumosus	2%	1%	3%	0%	0%
Ilyocypris australiensis	1%	5%	1%	2%	4%
Acartia clausi	1%	2%	[illegible]	15%	13%
Chironomus halophilus	1%	0%	2%	4%	0%
Tanytarsus horni	0%	3%	1%	0%	0%

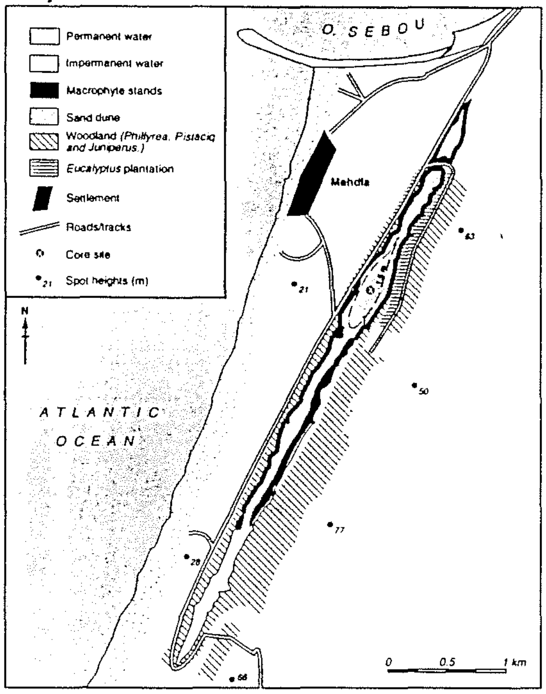
Table 4 Summary of pesticide residues in CASSARINA sediment cores

g-HCH		Conc. / ng.g dw^{-1}		Flux / $\mu g.m^{-2}.y^{-1}$		
		min	max	min	max	max year
Morocco	RHAB2	0.11	8.6	0.015	1.6	1996
	BOKK1	0.98	5.6	0.1	2.4	1996
	ZERG1	<0.15	52	<0.057	19	1996
Tunisia	SHEE1	<0.019	0.39	<0.005	0.17	1963
	ICHK2	<0.012	0.97	<0.005	0.52	1988
	KORB1	<0.071	0.61	<0.14	0.48	1960
Egypt	IDKU1	1.2	3.4	N.A.	N.A.	??
	BURL1	<0.10	0.60	N.A.	N.A.	??
	MANZ1	<0.16	3.8	<0.007	0.16	1984

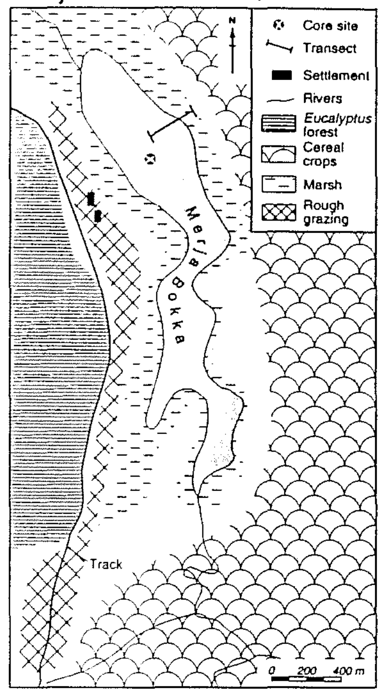
pp-DDE		Conc. / ng.g dw^{-1}		Flux / $\mu g.m^{-2}.y^{-1}$		
		min	max	min	max	max year
Morocco	RHAB2	0.21	11	0.020	3.5	1990
	BOKK1	2.2	15	0.50	6.6	1996
	ZERG1	3.5	7.9	1.3	2.9	1996
Tunisia	SHEE1	0.45	18	0.010	9.4	1963
	ICHK2	2.9	6.1	<0.005	3.0	1974
	KORB1	<0.71	7.4	<0.14	5.8	1960
Egypt	IDKU1	2.7	4.4	N.A.	N.A.	??
	BURL1	<0.10	0.20	N.A.	N.A.	??
	MANZ1	<0.16	0.31	<0.007	0.013	1970

Figures 1-6 Site maps for the nine CASSARINA wetland lakes showing the locations of sediment cores and vegetation transects and features of topographical importance.

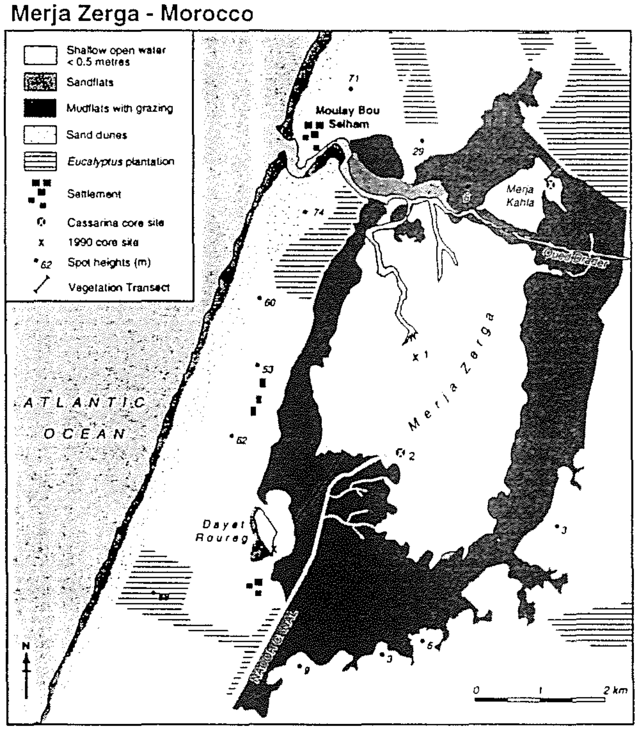
Merja Sidi Bou Rhaba - Morocco



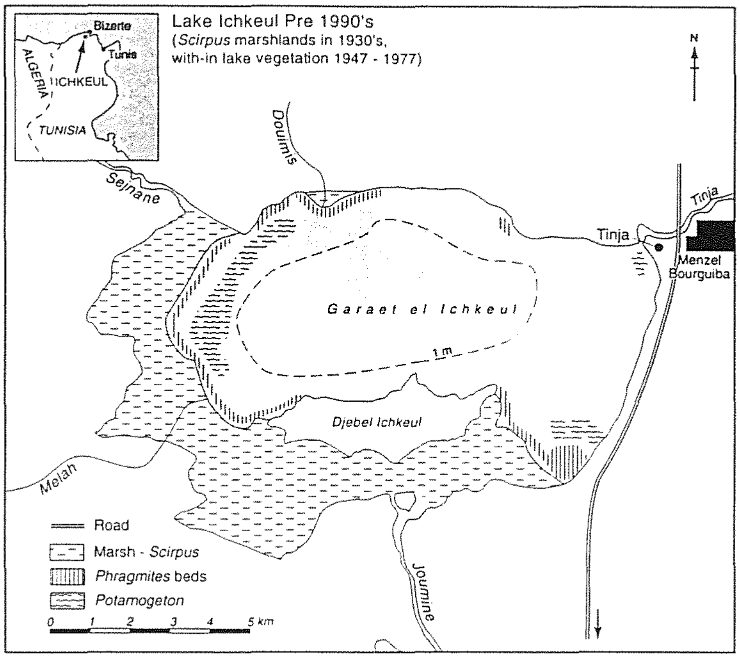
Merja Bokka - Morocco

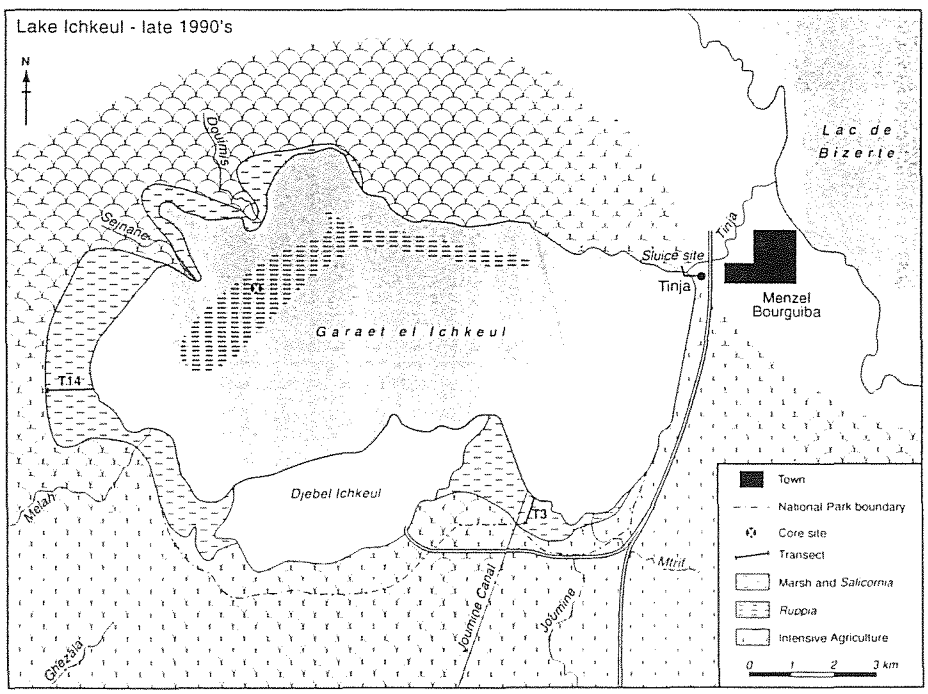


Merja Zerga - Morocco

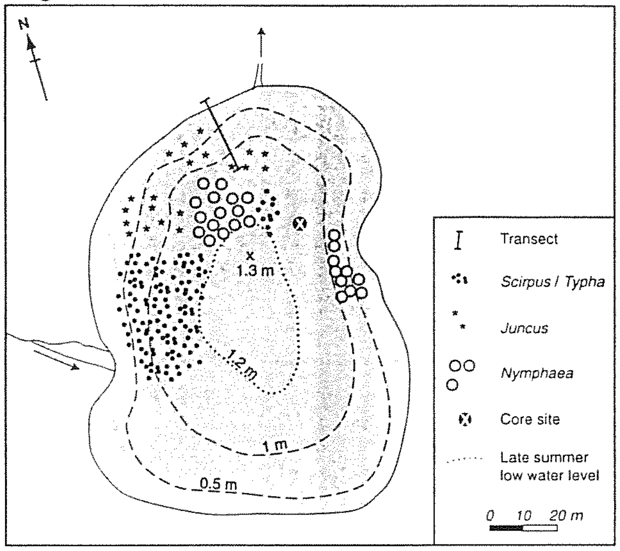


Garaet El Ichkeul - Tunisia

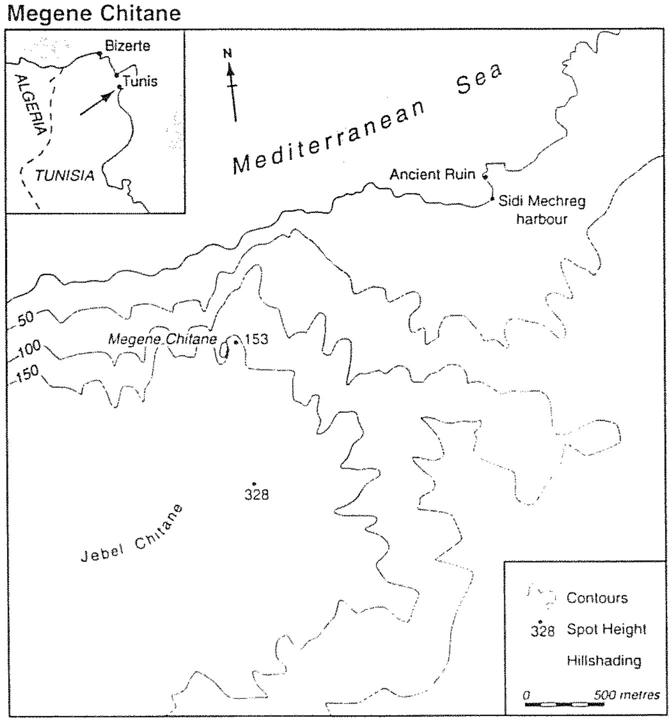




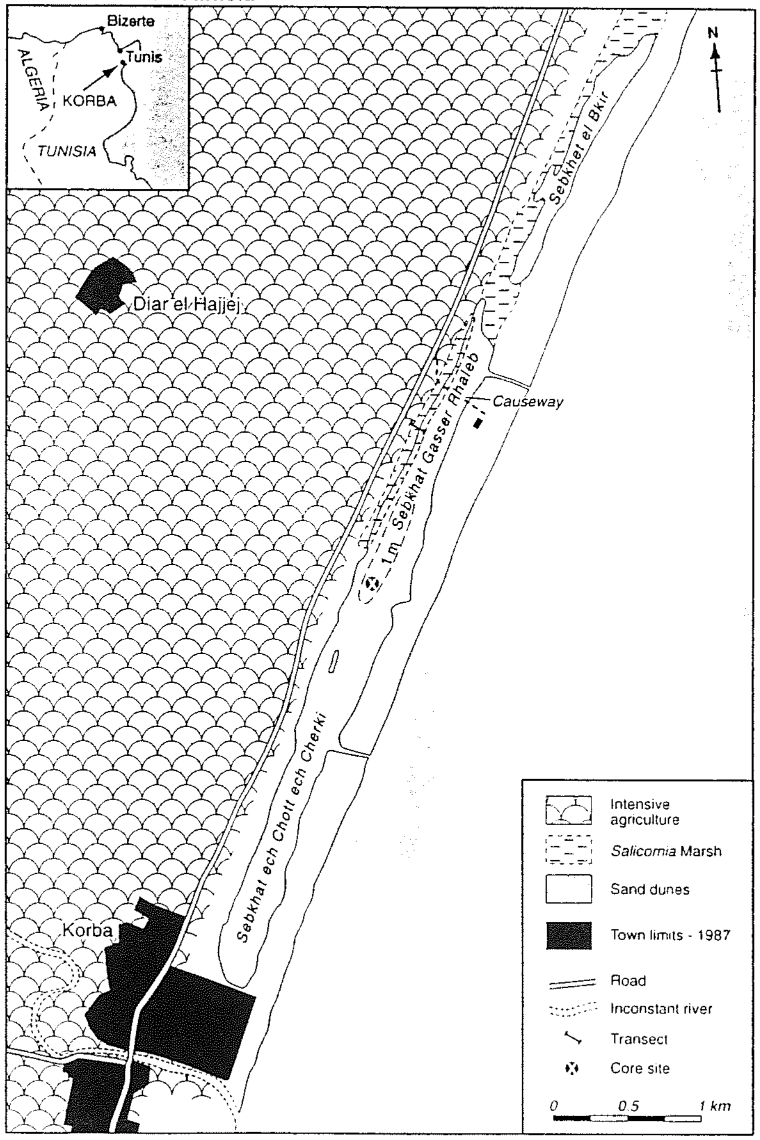
Megene Chitane Catchment - Tunisia



Megene Chitane

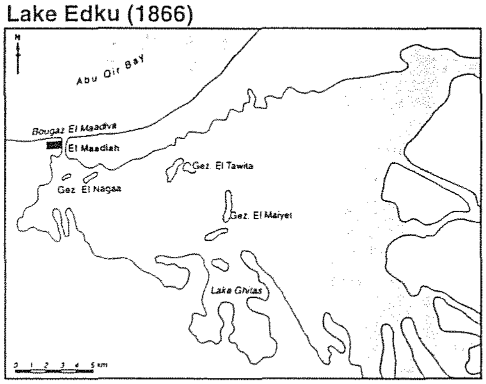


Lac de Korba - Tunisia

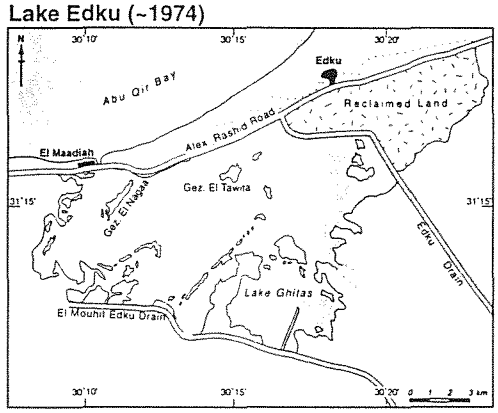


Lake Edku - Egypt

Lake Edku (1866)



Lake Edku (~1974)



Lake Edku - 1995

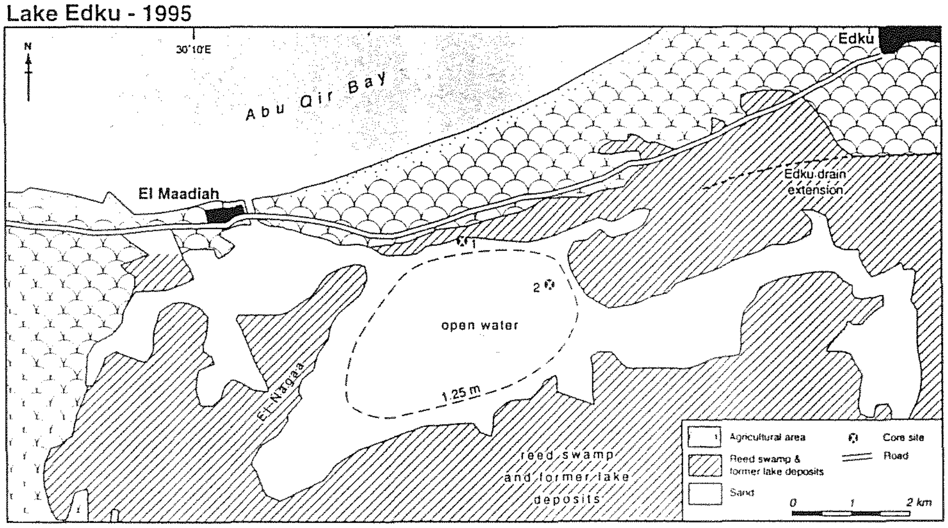
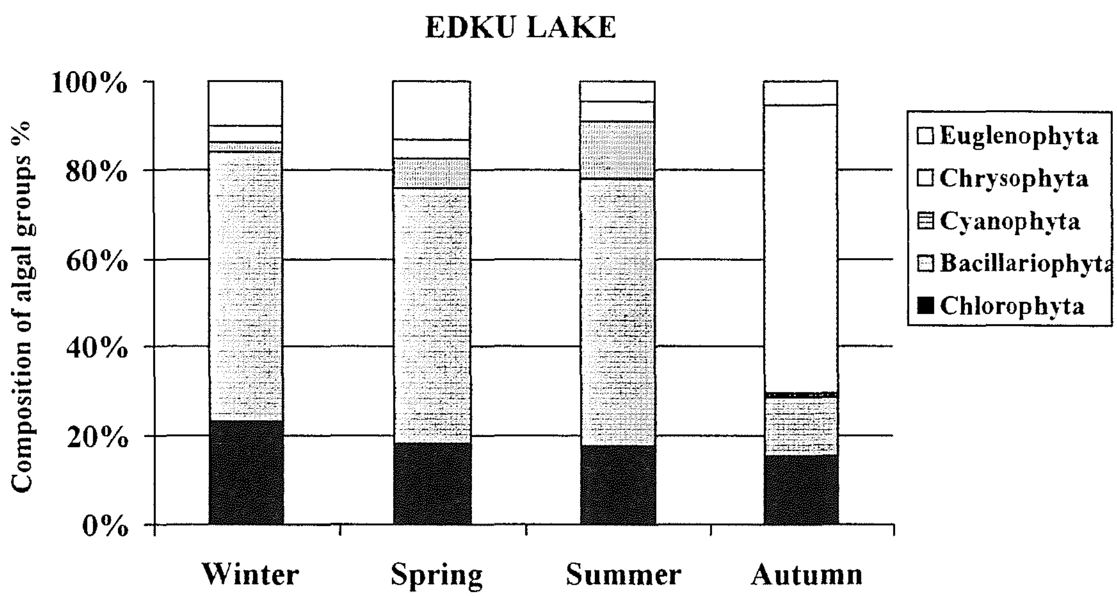


Figure 7 Percentage composition of the main phytoplanton groups in Edku Lake during the period of CASSARINA monitoring in 1998.



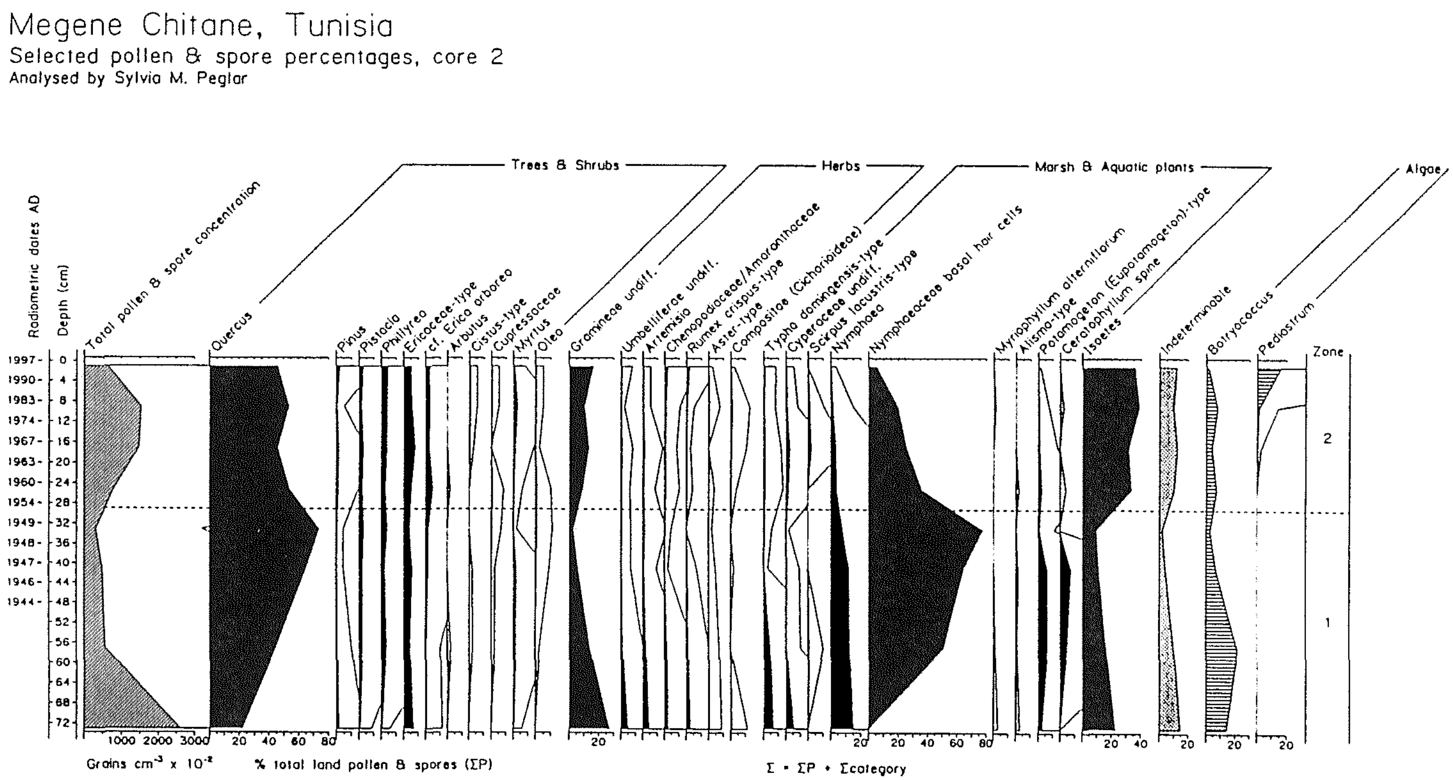


Figure 12 The pollen diagram from sediment core SHET2, Megene Chitane in Tunisia

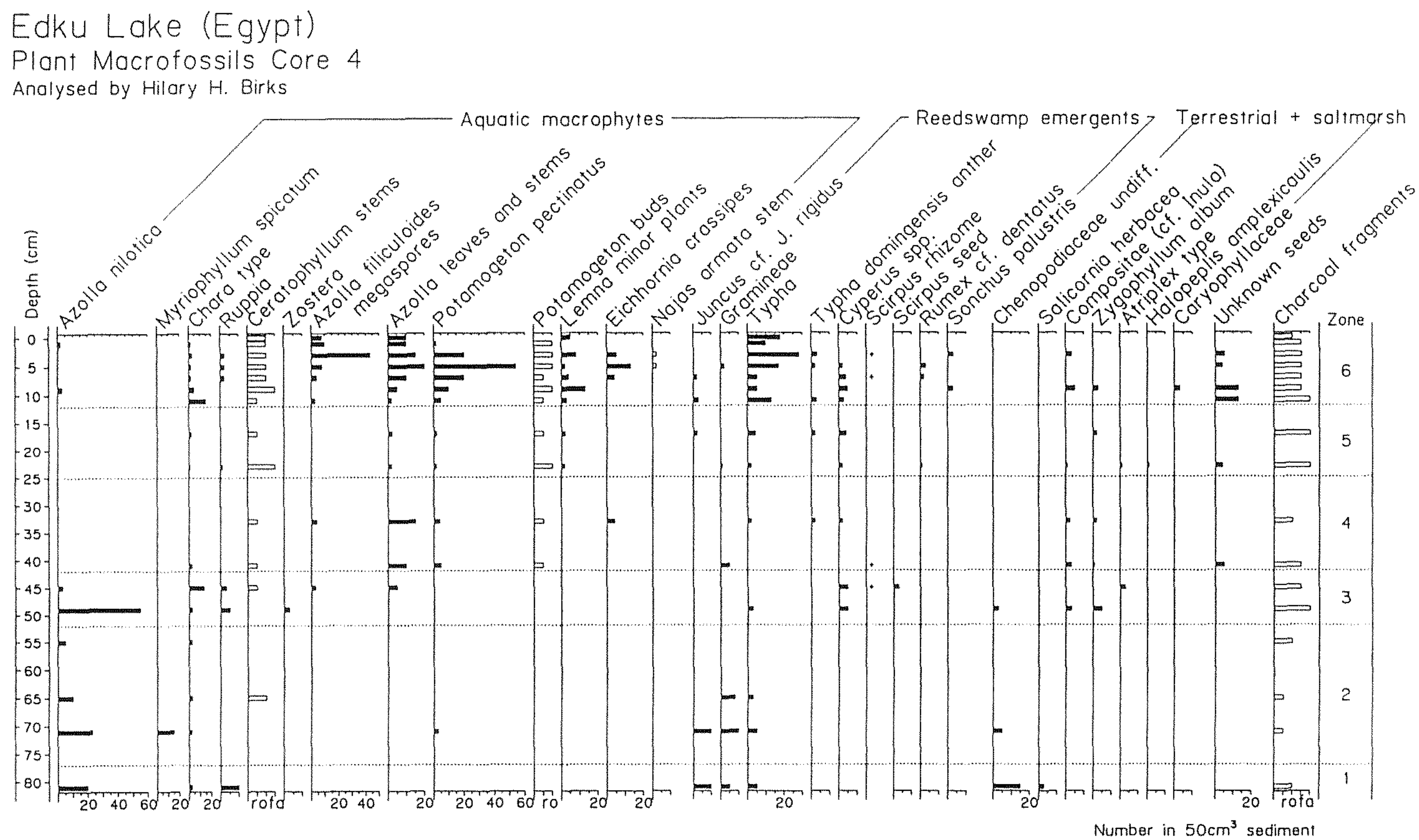


Figure 13 The plant macrofossil diagram from Edku Lake sediment core IDKU3, Nile Delta, Egypt

ANNEX 3 SEDIMENT CORE RECORD SUMMARIES OF 20th CENTURY ENVIRONMENTAL CHANGES OCCURRING AT EACH CASSARINA SITE

Table 1 The main 20th century environmental change events recorded in sediment cores collected from the three Moroccan CASSARINA sites. Inferences are made from the past to the present using multi-proxy biostratigraphic evidence (see Birks *et al.* 2001, Flower *et al.* 2001 and Ramdani *et al* 2001). N/A indicates an absent sediment record caused by sedimentological problems. Note that pre-1950 dates for Bokka are by extrapolation.

Period	M. SIDI BOU RHABA	MERJA ZERGA	MERJA BOKKA
1960s-1990s	Salinity increase post 1980. Grammineae decline further, Pesticides increase, Salinity decline in 1960s as Chydorus increases.	Cereals & pesticides increase and aquatic plants decline. Post mid-1980s increase in salinity and siltation, further Ruppia & Mollusca decline	Salinity increases, rapid mineral soil siltation. Some Ostracods increase. Mollusca and aquatic plants decline and carbonates. Pesticides increase. Crop plants present. Water level reduced.
1930s-1950s	Pesticides present, trees stable (but with Eucalyptus), aquatics stable. sedimentation rate increases	Late 1950s salinity lower, decline in some forams, ostracods, mollusca & Ruppia. Early 1950s, marine mollusca common, marine/saline conditions.	Freshwater conditions persist. Ruderal and emergent aquatic plants increase, submerged aquatic plants and Chenopods begin to decline. Sediment carbonates decline.
1900s-1920s	Trees continue to increase as Gramineae decline, aquatics stable	N/A	Fresh open water with increasing cladocera zooplankton, ostracods & aquatic plants.
late 19th century- ~1900	Salinity increases (post-1880), trees increase. Gramineae, Chydorus & Characeae decline	N/A	Slightly brackish shallow water, molluscs indicate flowing and still conditions. Calcareous sediment.

Table 2 The main 20th century environmental change events recorded in sediment cores collected from the three Tunisian CASSARINA sites. Inferences are made from the past to the present using mulit-proxy biostratigraphic evidence. N/A indicates an absent sediment record caused by sedimentological problems. Pre-1930 dates are extrapolated for Chitane and Ichkeul. Because of poor preservation diatom, records of salinity are absent for Korba and only present for the most recent Ichkeul sediment.

Period	M. CHITANE	GARAET EL ICHKEUL	LAC DE KORBA
1960s- late 1990s	Decline in water acidity & sediment accumulation, eutrophication begins, diatoms & cladocera change, Isoetes recover. Emergent plants increase. Higher salinity period in 1960s. Pesticides decline.	Hydrological changes with fresher conditions from ca 1960. Initial increase in cladocera and Ruppia but decline in forams, marine mollusca, ostracods & pesticides. Some sediment mixing indicated for 1990s	Saline. Fairly stable conditions but Pb contamination increasing. Pesticides peak in the 1980s. Decline in Charaphyceae, very few marine molluscs remaining.
1930s-1950s	Acid oligotrophy persists but major increase in sediment accumulation and organic remains (Nymphaea), Isoetes & some cladocera decline. Pesticide contamination.	Salinity increases. Marine molluscs & forams increase. Ostracods change. Trees stable but Eucalypus present. Ruppia increases. Pesticide contamination	Decline in marine molluscs, contamination begins with increasing Pb then pesticides
1900-1920s	Oligotrophy, acid diatoms, aquatic plants (Nymphaea) & Cladocera abundant. Trees increase.	Ostracods decline, forams change, increasing Potamogeton. sediment carbonates decline.	Fairly stable ecosystem. Some changes in forams, Characeae common.
Late 19th century - ~1900	N/A	Increasing salinity. Isoetes, forams & Ostracods common	Saline. Declines in emergent plants & chenopods. Marine molluscs, forams common.

Table 3 The main 20th century environmental change events recorded in sediment cores collected from the three Egyptian CASSARINA sites. Inferences are made from the past to the present using mulit-proxy biostratigraphic evidence. N/A indicates an absent sediment record caused by sedimentological problems. Early 20th century dates are extrapolated and/or inferred from exotic pollen occurrences. Because of poor preservation diatom, records of salinity are absent for the lower sections of the Edku and Manzala cores.

Period	EDKU LAKE	BURULLUS LAKE	MANZALA LAKE
1960s-1990s	Salinity declines: marked decline in marine mollusca. Forams scarce. Aquatic plants (Typha & Azolla) increase but Potamogeton declines in 1980s.	Diatoms indicate fairly low but slightly increasing salinity. Typha and Potamogeton increase further, marine mollusca virtually disappear & Ruppia declines.	Small salinity increase: freshwater diatoms decline in 1970s; sediment organics increase further but carbonates decline. Charophyceae present. Forams scarce.
1930s-1950s	Mixed salinity: marked increases of both marine & freshwater mollusca & of freshwater cladocera	Salinity declines. Marine mollusca decline; Typha & Potamogeton & sediment carbonate increases. Few freshwater mollusca appear.	Less saline conditions. Typha increases & Ruppia declines. Cladocera increase. Forams and marine mollusca decline further.
1900s-1920s	Salinity declines, decline in forams; Potamogeton, cladocera & some ostracods & mollusca all increase. Sediment more calcareous	Marine conditions. Marine mollusca common, Ruppia increases and diatoms disappear.	Mixed salinity but fresh-water diatoms increasing. Sediment organic material & carbonates increase as do Ruppia & Ceratophyllum.
Late 19th century-~1900s	Fluctuating but essentially marine conditions, forams abundant, Phragmites common, begins to decline	Mixed conditions but salinity increasing. Grammineae decline, forams and marine mollusca increase	Declining marine conditions. Sediment carbonates increasing. Forams common, marine mollusca present

ANNEX 3 SEDIMENT CORE RECORD SUMMARIES OF 20th CENTURY ENVIRONMENTAL CHANGES OCCURRING AT EACH CASSARINA SITE

Table 1 The main 20th century environmental change events recorded in sediment cores collected from the three Moroccan CASSARINA sites. Inferences are made from the past to the present using multi-proxy biostratigraphic evidence (see Birks *et al.* 2001, Flower *et al.* 2001 and Ramdani *et al* 2001). N/A indicates an absent sediment record caused by sedimentological problems. Note that pre-1950 dates for Bokka are by extrapolation.

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1930s-1950s	Pesticides present, trees stable (but with *Eucalyptus*), aquatics stable. sedimentation rate increases	Late 1950s salinity lower, decline in some forams, ostracods, mollusca & *Ruppia*. Early 1950s, marine mollusca common, marine/saline conditions.	Freshwater conditions persist. Ruderal and emergent aquatic plants increase, submerged aquatic plants and Chenopods begin to decline. Sediment carbonates decline.
1900s-1920s	Trees continue to increase as Gramineae decline, aquatics stable	N/A	Fresh open water with increasing cladocera zooplankton, ostracods & aquatic plants.
late 19th century- ~1900	Salinity increases (post-1880), trees increase. Gramineae, *Chydorus* & Charophytes decline	N/A	Slightly brackish shallow water, molluscs indicate flowing and still conditions. Calcareous sediment.

Table 2 The main 20th century environmental change events recorded in sediment cores collected from the three Tunisian CASSARINA sites. Inferences are made from the past to the present using mulit-proxy biostratigraphic evidence. N/A indicates an absent sediment record caused by sedimentological problems. Pre-1930 dates are extrapolated for Chitane and Ichkeul. Because of poor preservation diatom, records of salinity are absent for Korba and only present for the most recent Ichkeul sediment.

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1930s-1950s	Acid oligotrophy persists but major increase in sediment accumulation and organic remains (*Nymphaea*), *Isoetes* & some cladocera decline. Pesticide contamination.	Salinity increases. Marine molluscs & forams increase. Ostracods change. Trees stable but *Eucalypus* present. *Ruppia* increases. Pesticide contamination	Decline in marine molluscs, contamination begins with increasing Pb then pesticides
1900-1920s	Oligotrophy, acid diatoms, aquatic plants (*Nymphaea*) & Cladocera abundant. Trees increase.	Ostracods decline, forams change, increasing *Potamogeton*. sediment carbonates decline.	Fairly stable ecosystem. Some changes in forams, Charophytes common.
Late 19th century - ~1900	N/A	Increasing salinity. *Isoetes*, forams & Ostracods common	Saline. Declines in emergent plants & chenopods. Marine molluscs, forams common.

Table 3 The main 20th century environmental change events recorded in sediment cores collected from the three Egyptian CASSARINA sites. Inferences are made from the past to the present using mulit-proxy biostratigraphic evidence. N/A indicates an absent sediment record caused by sedimentological problems. Early 20th century dates are extrapolated and/or inferred from exotic pollen occurrences. Because of poor preservation diatom, records of salinity are absent for the lower sections of the Edku and Manzala cores.

Period	EDKU LAKE	BURULLUS LAKE	MANZALA LAKE
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1930s-1950s	Mixed salinity: marked increases of both marine & freshwater mollusca & of freshwater cladocera	Salinity declines. Marine mollusca decline; *Typha* & *Potamogeton* & sediment carbonate increases. Few freshwater mollusca appear.	Less saline conditions. *Typha* increases & *Ruppia* declines. Cladocera increase. Forams and marine mollusca decline further.
1900s-1920s	Salinity declines, decline in forams; *Potamogeton*, cladocera & some ostracods & mollusca all increase. Sediment more calcareous	Marine conditions. Marine mollusca common, *Ruppia* increases and diatoms disappear.	Mixed salinity but fresh-water diatoms increasing. Sediment organic material & carbonates increase as do *Ruppia* & *Ceratophyllum*.
Late 19th century--~1900s	Fluctuating but essentially marine conditions, forams abundant, *Phragmites* common, begins to decline	Mixed conditions but salinity increasing. Grammineae decline, forams and marine mollusca increase	Declining marine conditions. Sediment carbonates increasing. Forams common, marine mollusca present

During monitoring trips to the nine CASSARINA sites in 1997-99 diatom epiphyton samples from submerged aquatic macrophytes were collected for subsequent analysis. Siltation effects, differences in macrophyte host type and loss of several samples during transit make detailed time-space floristic comparisons difficult however the samples give a good indication of species present at each site during the sampling period. These data are therefore useful as base-line ecological reference material for late 20th century and it is noteworthy that one site (BOKKA) has already been lost through drainage culminating in the cultivation of the entire basin in late 1998.

Sid Bou Rhaba -Epiphyton 1997-1999	2.4.97	29.1.98	7.5.98*	5.12.98
Achnanthes submarina	0	1	0	2
Amphipleura pellicida	0	4	0	0
Amphora acutiuscula	0	10	0	2
Amphora coffeaeformis	0	23	8	41
Amphora pediculus	0	0	0	2
Amphora robusta	0	0	2	0
Anomeoeneis spherophora	0	0	3	0
Brachysira aponina	0	10	0	0
Campylodiscus clypeus	0	0	1	0
Cocconeis placentula	105	12	0	32
Cyclotella meneghiniana	0	5	22	0
Cymbella microcephala	0	1	0	0
Cymbella pusilla	6	23	0	63
Mastogloia baltica	0	1	0	0
Mastogloia brauni	2	1	0	7
Mastogloia smithii v. lacustris	0	0	0	1
Navicula cincta	0	2	0	9
Navicula gregaria	0	1	0	0
Navicula halophila	1	10	0	1
Navicula pseudocrassirostris	0	2	0	0
Navicula recens	0	3	0	0
Navicula rhyncocephala	0	2	0	0
Navicula sp.	1	1	0	3
Navicula tripunctata	1	0	0	0
Nitzschia communis	0	0	0	2
Nitzschia elegantula	0	19	0	0
Nitzschia frustulum	0	6	0	0
Nitzschia sp.	0	0	3	5
Synedra hartii	0	50	0	15
Synedra pulchella	1	0	4	0
Tabularia fasciculata	70	3	10	0
Grand Total	187	190	53	185
SPECIES RICHNESS	**8**	**23**	**8**	**15**

Epiphyton - % data	2.4.97	29.1.98	7.5.98	5.12.98
Achnanthes submarina	0.0	0.5	0.0	1.1
Amphipleura pellicida	0.0	2.1	0.0	0.0
Amphora acutiuscula	0.0	5.3	0.0	1.1
Amphora coffeaeformis	0.0	12.1	15.1	22.2
Amphora pediculus	0.0	0.0	0.0	1.1
Amphora robusta	0.0	0.0	3.8	0.0
Anomeoeneis spherophora	0.0	0.0	5.7	0.0
Brachysira aponina	0.0	5.3	0.0	0.0
Campylodiscus clypeus	0.0	0.0	1.9	0.0
Cocconeis placentula	56.1	6.3	0.0	17.3
Cyclotella meneghiniana	0.0	2.6	41.5	0.0
Cymbella microcephala	0.0	0.5	0.0	0.0
Cymbella pusilla	3.2	12.1	0.0	34.1
Mastogloia baltica	0.0	0.5	0.0	0.0
Mastogloia brauni	1.1	0.5	0.0	3.8
Mastogloia smithii v. lacustris	0.0	0.0	0.0	0.5
Navicula cincta	0.0	1.1	0.0	4.9
Navicula gregaria	0.0	0.5	0.0	0.0
Navicula halophila	0.5	5.3	0.0	0.5
Navicula pseudocrassirostris	0.0	1.1	0.0	0.0
Navicula recens	0.0	1.6	0.0	0.0
Navicula rhyncocephala	0.0	1.1	0.0	0.0
Navicula sp.	0.5	0.5	0.0	1.6
Navicula tripunctata	0.5	0.0	0.0	0.0
Nitzschia communis	0.0	0.0	0.0	1.1
Nitzschia elegantula	0.0	10.0	0.0	0.0
Nitzschia frustulum	0.0	3.2	0.0	0.0
Nitzschia sp.	0.0	0.0	5.7	2.7
Synedra hartii	0.0	26.3	0.0	8.1
Synedra pulchella	0.5	0.0	7.5	0.0
Tabularia fasciculata	37.4	1.6	18.9	0.0

*Diatoms scarce in this sample

Merja Zerga -Epiphyton			
1997-1998	7.4.97	18.7.98*	15.12.98
Achnanthes brevipes v. intermedia	7	0	0
Amphora coffeaeformis	0	0	3
Berkeleya rutilans	45	0	0
Cocconeis placentula	34	3	8
Cocconeis scutellum	0	0	7
Cyclotella meneghiniana	1	0	0
Gyrosigma attenuatum	0	0	13
Gyrosigma eximium	0	0	1
Gyrosigma macrum	2	0	2
Gyrosigma spenceri	0	0	5
Melosira jurgensii	4	0	0
Navicula gregaria	0	0	8
Navicula mutica	1	0	0
Navicula phylletpa	49	0	22
Navicula ramosissima	0	0	1
Navicula recens	3	0	4
Navicula sp.	0	0	6
Navicular gregaria	10	0	8
Nitzschia constricta	0	0	17
Nitzschia frustulum	9	0	0
Nitzschia hungarica	0	0	1
Nitzschia hustedtiana	0	0	2
Nitzschia scapelliformis	0	0	5
Nitzschia sp.	4	1	7
Pleurosigma elongatum	0	0	5
Stauroneis wislouchi	0	0	3
Surirella ovalis	0	0	4
Tabularia fasciculata	21	98	5
Grand Total	**94**	**102**	**137**
SPECIES RICHNESS	**13**	**3**	**22**

*Diatoms scarce in this sample

Epiphyton - % data			
	7.4.97	18.7.98	15.12.98
Achnanthes brevipes v. intermedia	3.7	0.0	0.0
Amphora coffeaeformis	0.0	0.0	2.2
Berkeleya rutilans	23.7	0.0	0.0
Cocconeis placentula	17.9	2.9	5.8
Cocconeis scutellum	0.0	0.0	5.1
Cyclotella meneghiniana	0.5	0.0	0.0
Gyrosigma attenuatum	0.0	0.0	9.5
Gyrosigma eximium	0.0	0.0	0.7
Gyrosigma macrum	1.1	0.0	1.5
Gyrosigma spenceri	0.0	0.0	3.6
Melosira jurgensii	2.1	0.0	0.0
Navicula gregaria	0.0	0.0	5.8
Navicula mutica	0.5	0.0	0.0
Navicula phylletpa	25.8	0.0	16.1
Navicula ramosissima	0.0	0.0	0.7
Navicula recens	1.6	0.0	2.9
Navicula sp.	0.0	0.0	4.4
Navicular gregaria	5.3	0.0	5.8
Nitzschia constricta	0.0	0.0	12.4
Nitzschia frustulum	4.7	0.0	0.0
Nitzschia hungarica	0.0	0.0	0.7
Nitzschia hustedtiana	0.0	0.0	1.5
Nitzschia scapelliformis	0.0	0.0	3.6
Nitzschia sp.	2.1	1.0	5.1
Pleurosigma elongatum	0.0	0.0	3.6
Stauroneis wislouchi	0.0	0.0	2.2
Surirella ovalis	0.0	0.0	2.9
Tabularia fasciculata	11.1	96.1	3.6

Merja Bokka-Epiphyton
(epiphyton on Sparganium*)

	8.4.97	1998**
Amphora veneta	32	
Amphora veneta v. capitata	36	
Cyclotella atomus	8	
Navicula accomoda	4	
Navicula cuspidata	6	
Navicula halophila	2	
Navicula halophiloides	4	
Navicula hungarica	1	
Navicula recens	4	
Navicula sp.	4	
Navicula veneta	28	
Nitzschia cf. archibaldii	10	
Nitzschia frustulum	2	
Nitzschia hungarica	18	
Nitzschia palaea v. delibilis	14	
Nitzschia sp. A	1	
Nitzschia tryblionella	4	
Nitzschia tryblionella v. levidensis	4	
TOTAL	182	

* silt covered fronds
**Lake dried up in 1998

Species richness **18**

Epiphyton % data

	8.4.97
Amphora veneta	17.6
Amphora veneta v. capitata	19.8
Cyclotella atomus	4.4
Navicula accomoda	2.2
Navicula cuspidata	3.3
Navicula halophila	1.1
Navicula halophiloides	2.2
Navicula hungarica	0.5
Navicula recens	2.2
Navicula sp.	2.2
Navicula veneta	15.4
Nitzschia cf. archibaldii	5.5
Nitzschia frustulum	1.1
Nitzschia hungarica	9.9
Nitzschia palaea v. delibilis	7.7
Nitzschia sp. A	0.5
Nitzschia tryblionella	2.2
Nitzschia tryblionella v. levidensis	2.2

Megene Chitane
Epiphyton

1997-1999	2.4.97	11.2.98	21.8.98	16.11.98	30.5.99
Achnanthes exigua	0	0	2	3	3
Achnanthes minutissima	0	0	1	0	115
Brachysira vitrea	70	0	72	4	1
Cocconeis placentula	0	0	2	0	0
Cyclotella pseudostelligera	0	0	0	0	1
Cyclotella kutzingiana	0	0	0	0	1
Eunotia exigua	78	0	0	0	0
Eunotia curvata	0	0	1	0	1
Eunotia minutissima	1	7	10	6	0
Eunotia pectinalis	0	230	0	6	20
Eunotia rhomboidea	0	0	0	0	4
Eunotia vanheurckii v. intermedia	25	3	100	35	84
Frustulia rhomboides v. saxonica	0	0	0	2	0
Navicula cocconeiformis	0	0	0	0	1
Nitzschia aerophila	11	0	0	0	0
Nitzschia archibaldii	4	0	1	102	0
Nitzschia cf. clausii	1	0	0	0	0
Nitzschia frustulum	1	0	0	1	0
Nitzschia sp.	0	0	1	1	1
Nitzschia tubicola v. capitata	10	1	0	14	0
Pinnularia acoricola	20	0	1	19	0
Pinnularia bicepes	5	1	0	1	0
Pinnularia subcapitata v. hilseana	3	0	1	1	.
Stauroneis cf. tackei	0	0	0	0	1
Surirella sp.	0	0	1	2	0
TOTAL	**229**	**242**	**193**	**197**	**233**
slide number	18597	18598	18623	18624	-
SPECIES RICHNESS	**12**	**5**	**12**	**14**	**12**

Epiphyton % data

	2.4.97	11.2.98	21.8.98	16.11.98	30.5.99
Achnanthes exigua	0	0	1.0	1.5	1.3
Achnanthes minutissima	0.0	0.0	0.5	0.0	49.4
Brachysira vitrea	30.6	0.0	37.3	2.0	0.4
Cocconeis placentula	0.0	0.0	1.0	0.0	0.0
Cyclotella pseudostelligera	0.0	0.0	0.0	0.0	0.4
Cyclotella kutzingiana	0.0	0.0	0.0	0.0	0.4
Eunotia exigua	34.1	0.0	0.0	0.0	0.0
Eunotia curvata	0.0	0.0	0.5	0.0	0.4
Eunotia minutissima	0.4	2.9	5.2	3.0	0.0
Eunotia pectinalis	0.0	95.0	0.0	3.0	8.6
Eunotia rhomboidea	0.0	0.0	0.0	0.0	1.7
Eunotia vanheurckii v. intermedia	10.9	1.2	51.8	17.8	36.1
Frustulia rhomboides v saxonica	0.0	0.0	0.0	1.0	0.0
Navicula cocconeiformis	0.0	0.0	0.0	0.0	0.4
Nitzschia aerophila	4.8	0.0	0.0	0.0	0.0
Nitzschia archibaldii	1.7	0.0	0.5	51.8	0.0
Nitzschia cf. clausii	0.4	0.0	0.0	0.0	0.0
Nitzschia frustulum	0.4	0.0	0.0	0.5	0.0
Nitzschia sp.	0.0	0.0	0.5	0.5	0.4
Nit. tubicola v. capitata	4.4	0.4	0.0	7.1	0.0
Pinnularia acoricola	8.7	0.0	0.5	9.6	0.0
Pinnularia bicepes	2.2	0.4	0.0	0.5	0.0
Pinnularia subcapitata v. hilseana	1.3	0.0	0.5	0.5	0.0
Stauroneis cf. tackei	0.0	0.0	0.0	0.0	0.4
Surirella sp.	0.0	0.0	0.5	1.0	0.0

Ichkeul - Epiphyton on Ruppia 1997-1999	20.4.97	8.2.98	23.8.98	8.11.98	2.6.99
Achnanthes amoena	0	0	4	0	2
Amphora acutiuscula	0	0	1	0	5
Amphora coffeaeformis	8	0	14	4	0
Amphora cymbamphora	0	0	0	0	5
Berkeleya rutilans	0	10	0	0	0
Brachysira aponina	0	1	0	0	0
Cocconeis placentula	60	0	175	32	202
Cyclotella meneghiniana	2	0	0	0	0
Gyrosigma attenuata	2	0	0	0	0
Navicula cf. salinicola	0	0	0	0	5
Navicula cincta	0	0	13	0	4
Navicula phyllepta	0	64	0	20	0
Navicula ramosissima	18	8	4	72	8
Navicula recens	0	0	0	3	0
Navicula sp.	1	0	4	12	0
Navicula tripunctata	0	0	1	1	1
Navicula viridula	0	1	0	0	0
Nitzschia cf. amphibia	0	0	0	9	0
Nitzschia constricta	17	1	2	2	0
Nitzschia corpulenta	2	0	0	0	0
Nitzschia frustulum	6	0	7	0	6
Nitzschia hustedtiana	0	0	1	1	0
Nitzschia paleacea	0	90	0	0	0
Nitzschia scapeliformis	0	0	0	9	0
Nitzschia sp.	0	0	2	1	6
Surirella ovalis	4	0	0	0	0
Synedra acus	2	0	0	0	0
Synedra ulna	1	0	0	0	0
Tabularia fasciculata	0	1	0	17	0
TOTAL	**123**	**176**	**226**	**156**	**238**
Slide number		18609		18610	
SPECIES RICHNESS	**12**	**8**	**12**	**13**	**10**

Epiphyton % data

	20.4.97	8.2.98	23.8.98	8.11.98	2.6.99
Achnanthes amoena	0.0	0.0	1.8	0.0	0.8
Amphora acutiuscula	0.0	0.0	0.4	0.0	2.0
Amphora coffeaeformis	6.5	0.0	6.1	2.2	0.0
Amphora cymbamphora	0.0	0.0	0.0	0.0	2.0
Berkeleya rutilans	0.0	5.7	0.0	0.0	0.0
Brachysira aponina	0.0	0.6	0.0	0.0	0.0
Cocconeis placentula	48.8	0.0	76.8	17.5	82.8
Cyclotella meneghiniana	1.6	0	0	0	0
Gyrosigma attenuata	1.6	0	0	0	0
Navicula cf. salinicola	0.0	0.0	0.0	0.0	2.0
Navicula cincta	0.0	0.0	5.7	0.0	1.6
Navicula phyllepta	0.0	36.4	0.0	10.9	0.0
Navicula ramosissima	14.6	4.5	1.8	39.3	3.3
Navicula recens	0.0	0.0	0.0	1.6	0.0
Navicula sp.	0.8	0.0	1.8	6.6	0.0
Navicula tripunctata	0.0	0.0	0.4	0.5	0.4
Navicula viridula	0.0	0.6	0.0	0.0	0.0
Nitzschia cf. amphibia	0.0	0.0	0.0	4.9	0.0
Nitzschia constricta	13.8	0.6	0.9	1.1	0.0
Nitzschia corpulenta	1.6	0	0	0	0
Nitzschia frustulum	4.9	0.0	3.1	0.0	2.5
Nitzschia hustedtiana	0.0	0.0	0.4	0.5	0.0
Nitzschia paleacea	0.0	51.1	0.0	0.0	0.0
Nitzschia scapeliformis	0.0	0.0	0.0	4.9	0.0
Nitzschia sp.	0.0	0.0	0.9	0.5	2.5
Surirella ovalis	3.3	0	0	0	0
Synedra acus	1.6	0	0	0	0
Synedra ulna	0.8	0	0	0	0
Tabularia fasciculata	0.0	0.6	0	9.3	0.0

Korba - Epiphytes
Epiphytes on Cladophora

1997-1998	21.4.97	22.2.98	22.8.98*
Achnanthes brevipes v. intermedia	95	3	1
Achananthes delicatula	3	0	0
Amphiprora paludosa	0	0	11
Amphora coeffeaeformis	0	0	5
Amphora pediculus	0	3	2
Amphora sp.	13	1	0
Chaetoceros 'spores'	0	0	1
Cocconeis placentula	7	30	1
Fragilaria brevistriata	1	0	0
Fragilaria elliptica	2	0	0
Fragilaria pinnata v. rotunda	45	0	0
Fragilaria sp.	0	0	0
Gomphonema gracile	0	0	1
Navicula recens	0	3	4
Navicula sp.	0	0	0
Navicula tripunctata	0	0	4
Nitzschia frustulum	0	1	0
Nitzschia sp.	1	1	1
Tabularia fasciculata	0	135	0
Thalassiosira weissflogii	1	0	0
TOTAL	**168**	**40**	**26**

*Diatoms very scarce in this sample

SPECIES RICHNESS	**9**	**8**	**10**

Epiphyton % data

	21.4.97	22.2.98	22.8.98*
Achnanthes brevipes v. intermedia	56.5	1.7	3.2
Achananthes delicatula	1.8	0	0
Amphiprora paludosa	0.0	0	35.5
Amphora coeffeaeformis	0.0	0	16.1
Amphora pediculus	0.0	1.7	6.5
Amphora sp.	7.7	0.6	0
Chaetoceros 'spores'	0.0	0	3.2
Cocconeis placentula	4.2	16.9	3.2
Fragilaria brevistriata	0.6	0	0
Fragilaria elliptica	1.2	0	0
Fragilaria pinnata v. rotunda	26.8	0	0
Fragilaria sp.	0.0	0	0
Gomphonema gracile	0.0	0	3.2
Navicula recens	0.0	1.7	12.9
Navicula sp.	0.0	0	0
Navicula tripunctata	0.0	0	12.9
Nitzschia frustulum	0.0	0.6	0
Nitzschia sp.	0.6	0.6	3.2
Tabularia fasciculata	0.0	76.3	0
Thalassiosira weissflogii	0.6	0	0

Edku - Epiphyton on Potomogeton

1997-1999	14.11.97	7.3.98	3.6.98	22.8.98	1.1.99	17.5.99	17.5.99*
Achnanthes delicatula	0	0	0	0	0	2	0
Amphiprora paludosa	1	0	0	0	0	0	0
Amphora cf. coffeaeformis	7	1	0	4	0	1	0
Amphora coffeaeformis	0	0	0	5	0	0	0
Amphora libyca	3	1	0	2	3	0	0
Amphora pediculus	0	7	2	5	4	0	0
Amphora strigosa	0	1	2	2	1	0	0
Amphora veneta	2	0	3	1	0	0	0
Bacillaria paradoxa	1	6	0	2	18	0	1
Berkeleya rutilans	0	1	0	0	0	0	0
Sellaphora pupula	0	0	0	1	0	0	0
Cocconeis placentula	0	90	2	0	3	7	26
Cyclotella atomus	1	0	0	2	0	1	1
Cyclotella meneghiniana	3	17	3	102	2	3	4
Cyclotella ocellata	0	0	0	0	0	1	0
Diploneis elliptica	0	0	0	2	2	0	0
Epithemia adnata	0	0	0	2	0	0	0
Fallacia pygmaea	0	1	0	2	0	0	0
Fragilaria brevistriata	0	0	0	4	1	0	0
Gomphonema affine	2	0	3	2	1	2	0
Gomphonema augur	0	0	3	2	0	0	0
Gomphonema cf. parvulum	0	1	0	0	2	1	0
Gomphonema gracile	1	1	0	0	2	0	0
Gomphonema intricatum	0	0	0	1	0	0	0
Gomphonema lagenula	0	0	0	0	2	20	0
Gomphonema truncatum	2	0	1	0	0	3	0
Navicula hungarica	0	0	0	6	20	0	0
Navicula phyllepta	0	0	0	3	0	0	0
Navicula pseudocrssirostris	0	0	0	1	0	0	0
Navicula recens	114	35	10	17	52	14	2
Navicula rhyncocephala	0	0	0	1	0	0	0
Navicula salinarum	0	0	0	2	0	0	0
Navicula sp.	2	1	2	3	0	0	0
Navicula subminiscula	0	0	0	0	0	6	2
Navicula tenera	0	0	0	5	1	0	1
Navicula tripunctata	0	0	2	2	0	0	0
Navicula viridula	0	3	0	0	0	0	0
Nitzschia amphibia	0	0	1	6	4	0	0

EDKU - % Data

	14.11.97	7.3.98	3.6.98	22.8.99	01.1.99	17.5.99	17.5.99*
Achnanthes delicatula	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Amphiprora paludosa	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Amphora cf. coffeaeformis	2.6	0.4	0.0	1.7	0.0	0.5	0.0
Amphora coffeaeformis	0.0	0.0	0.0	2.1	0.0	0.0	0.0
Amphora libyca	1.1	0.4	0.0	0.9	1.3	0.0	0.0
Amphora pediculus	0.0	3.0	0.8	2.1	1.8	0.0	0.0
Amphora strigosa	0.0	0.4	0.8	0.9	0.4	0.0	0.0
Amphora veneta	0.7	0.0	1.3	0.4	0.0	0.0	0.0
Bacillaria paradoxa	0.4	2.5	0.0	0.9	8.0	0.0	0.5
Berkeleya rutilans	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Sellaphora pupula	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Cocconeis placentula	0.0	38.0	0.8	0.0	1.3	3.4	13.0
Cyclotella atomus	0.4	0.0	0.0	0.9	0.0	0.5	0.5
Cyclotella meneghiniana	1.1	7.2	1.3	43.8	0.9	1.4	2.0
Cyclotella ocellata	0.0	0.0	0.0	0.0	0.0	0.5	0.0
Diploneis elliptica	0.0	0.0	0.0	0.9	0.9	0.0	0.0
Epithemia adnata	0.0	0.0	0.0	0.9	0.0	0.0	0.0
Fallacia pygmaea	0.0	0.4	0.0	0.9	0.0	0.0	0.0
Fragilaria brevistriata	0.0	0.0	0.0	1.7	0.4	0.0	0.0
Gomphonema affine	0.7	0.0	1.3	0.9	0.4	1.0	0.0
Gomphonema augur	0.0	0.0	1.3	0.9	0.0	0.0	0.0
Gomphonema cf. parvulum	0.0	0.4	0.0	0.0	0.9	0.5	0.0
Gomphonema gracile	0.4	0.4	0.0	0.0	0.9	0.0	0.0
Gomphonema intricatum	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Gomphonema lagenula	0.0	0.0	0.0	0.0	0.9	9.6	0.0
Gomphonema truncatum	0.7	0.0	0.4	0.0	0.0	1.4	0.0
Navicula hungarica	0.0	0.0	0.0	2.6	8.9	0.0	0.0
Navicula phyllepta	0.0	0.0	0.0	1.3	0.0	0.0	0.0
Navicula pseudocrssirostris	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Navicula recens	42.1	14.8	4.2	7.3	23.2	6.7	1.0
Navicula rhyncocephala	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Navicula salinarum	0.0	0.0	0.0	0.9	0.0	0.0	0.0
Navicula sp.	0.7	0.4	0.8	1.3	0.0	0.0	0.0
Navicula subminiscula	0.0	0.0	0.0	0.0	0.0	2.9	1.0
Navicula tenera	0.0	0.0	0.0	2.1	0.4	0.0	0.5
Navicula tripunctata	0.0	0.0	0.8	0.9	0.0	0.0	0.0
Navicula viridula	0.0	1.3	0.0	0.0	0.0	0.0	0.0
Nitzschia amphibia	0.0	0.0	0.4	2.6	1.8	0.0	0.0

EDKU: EPIPHYTON (CONT.)															
Nitzschia angustatula	0	0	0	0	0	0	1	Nitzschia angustutala	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Nitzschia calida	0	1	0	0	0	0	0	Nitzschia calida	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Nitzschia cf. archibaldii	0	0	1	0	15	7	0	Nitzschia cf. archibaldii	0.0	0.0	0.4	0.0	6.7	3.4	0.0
Nitzschia communis/pusilla	12	0	0	0	0	61	12	Nitzschia communis/pusilla	4.4	0.0	0.0	0.0	0.0	29.3	6.0
Nitzschia compressa	1	0	0	0	0	0	0	Nitzschia compressa	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Nitzschia constricta	1	1	0	1	6	0	0	Nitzschia constricta	0.4	0.4	0.0	0.4	2.7	0.0	0.0
Nitzschia corpulenta	1	0	0	0	0	0	0	Nitzschia corpulenta	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Nitzschia desertorum	0	0	11	0	7	7	2	Nitzschia desertorum	0.0	0.0	4.6	0.0	3.1	3.4	1.0
Nitzschia fonticola	0	0	0	0	1	0	0	Nitzschia fonticola	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Nitzschia frustulum	3	0	1	2	3	2	2	Nitzschia frustulum	1.1	0.0	0.4	0.9	1.3	1.0	1.0
Nitzschia gracilis	0	2	0	1	0	0	0	Nitzschia gracilis	0.0	0.8	0.0	0.4	0.0	0.0	0.0
Nitzschia hungarica	0	0	0	0	1	0	0	Nitzschia hungarica	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Nitzschia inconspicua	100	50	150	21	47	64	140	Nitzschia inconspicua	36.9	21.1	63.0	9.0	21.0	30.8	70.0
Nitzschia obtusa	1	0	0	0	2	0	0	Nitzschia obtusa	0.4	0.0	0.0	0.0	0.9	0.0	0.0
Nitzschia palaea	2	4	0	0	0	4	1	Nitzschia palaea	0.7	1.7	0.0	0.0	0.0	1.9	0.5
Nitzschia panduriformis	1	0	0	0	0	0	0	Nitzschia panduriformis	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Nitzschia sp.	7	4	1	0	5	0	1	Nitzschia sp.	2.6	1.7	0.4	0.0	2.2	0.0	0.5
Nitzschia species 'A'	0	0	40	20	3	0	0	Nitzschia species 'A'	0.0	0.0	16.8	8.6	1.3	0.0	0.0
Nitzschia stompsii	1	2	0	0	0	0	0	Nitzschia stompsii	0.4	0.8	0.0	0.0	0.0	0.0	0.0
Pleurosigma sp.	0	0	0	1	0	0	0	Pleurosigma sp.	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Rhoicosphenia curvata	0	0	0	0	2	1	0	Rhoicosphenia curvata	0.0	0.0	0.0	0.0	0.9	0.5	0.0
Thalassiosira weissflogii	0	0	0	0	0	0	1	Thalassiosira weissflogii	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Stephanodiscus hantzschii	0	1	0	0	0	0	0	Stephanodiscus hantzschii	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Synedra acus	0	1	0	0	0	0	1	Synedra acus	0.0	0.4	0.0	0.0	0.0	0.0	0.5
Synedra ulna	1	1	0	0	1	1	1	Synedra ulna	0.4	0.4	0.0	0.0	0.4	0.5	0.5
Tabularia fasiculata	1	4	0	0	13	0	1	Tabularia fasiculata	0.4	1.7	0.0	0.0	5.8	0.0	0.5
Grand Total	**271**	**237**	**238**	**233**	**224**	**208**	**200**		100.0						

* epiphytes on Ceratophyllum

SPECIES RICHNESS	**25**	**25**	**18**	**33**	**29**	**20**	**18**

Burullus- Epiphyton on Potamogeton 1997-1999	15.11.97	6.3.98	1.6.98	24.8.98	29.1.99	21.5.99
Achnanthes cf. kluebsii	0	0	4	5	0	0
Achnanthes hungarica	0	0	0	0	1	0
Achnanthes minutissima	1	0	1	0	35	11
Achnanthes sp.	0	0	1	0	0	0
Amphiprora paludosa	1	0	0	0	0	0
Amphora acutiuscula	0	0	0	0	0	3
Amphora coeffeaeformis	4	2	3	12	1	3
Amphora strigosa	0	0	6	2	0	0
Amphora veneta	7	2	1	0	5	0
Bacillaria paradoxa	0	0	0	0	1	0
Berkelya rutilans	0	2	12	1	6	10
Brachysira aponina	44	17	4	82	0	0
Cocconeis pediculus	0	0	0	0	1	0
Cocconeis placentula	0	5	21	13	3	9
Cyclotella atomus	1	0	0	1	1	1
Cyclotella capsia	0	0	1	2	0	0
Cyclotella meneghiniana	7	7	1	17	3	9
Cymbella cf. microcephala	0	0	0	0	25	1
Cymbella pusilla	2	6	24	16	1	7
Cymbella strigosa	0	0	0	0	0	1
Cynbella affinis	0	0	0	0	5	0
Diploneis elliptica	0	0	1	1	0	0
Epithemia adnata	0	0	0	0	1	2
Fragilaria brevistriata	0	0	2	0	1	0
Fragilaria elliptica	0	0	2	0	0	1
Gomphonema intricatum	0	0	0	0	3	0
Gomphonema pseudoaugur	0	0	0	0	4	0
Gomphonema sp.	0	0	2	0	0	0
Mastogloia baltica	3	3	44	3	2	42
Mastogloia braunii	3	0	18	2	1	7
Mastogloia elliptica	3	0	4	2	1	5
Mastogloia elliptica v. dansei	3	3	7	0	1	0
Mastogloia smithii v. lacustris	0	0	1	2	2	27
Navicula cf. salinicola	0	0	0	0	0	1
Navicula cincta	0	2	0	0	2	0
Navicula crytocephala	1	0	0	0	0	0

Epiphyton % Data	15.11.97	6.3.98	1.6.98	24.8.98	29.1.99	21.5.99
Achnanthes cf. kluebsii	0.0	0.0	1.8	2.1	0.0	0.0
Achnanthes hungarica	0.0	0.0	0.0	0.0	0.5	0.0
Achnanthes minutissima	0.4	0.0	0.5	0.0	16.8	5.4
Achnanthes sp.	0.0	0.0	0.5	0.0	0.0	0.0
Amphiprora paludosa	0.4	0.0	0.0	0.0	0.0	0.0
Amphora acutiuscula	0.0	0.0	0.0	0.0	0.0	1.5
Amphora coeffeaeformis	1.5	0.9	1.4	5.0	0.5	1.5
Amphora strigosa	0.0	0.0	2.7	0.8	0.0	0.0
Amphora veneta	2.6	0.9	0.5	0.0	2.4	0.0
Bacillaria paradoxa	0.0	0.0	0.0	0.0	0.5	0.0
Berkelya rutilans	0.0	0.9	5.4	0.4	2.9	5.0
Brachysira aponina	16.5	7.4	1.8	34.3	0.0	0.0
Cocconeis pediculus	0.0	0.0	0.0	0.0	0.5	0.0
Cocconeis placentula	0.0	2.2	9.5	5.4	1.4	4.5
Cyclotella atomus	0.4	0.0	0.0	0.4	0.5	0.5
Cyclotella capsia	0.0	0.0	0.5	0.8	0.0	0.0
Cyclotella meneghiniana	2.6	3.1	0.5	7.1	1.4	4.5
Cymbella cf. microcephala	0.0	0.0	0.0	0.0	12.0	0.5
Cymbella pusilla	0.8	2.6	10.9	6.7	0.5	3.5
Cymbella strigosa	0.0	0.0	0.0	0.0	0.0	0.5
Cynbella affinis	0.0	0.0	0.0	0.0	2.4	0.0
Diploneis elliptica	0.0	0.0	0.5	0.4	0.0	0.0
Epithemia adnata	0.0	0.0	0.0	0.0	0.5	1.0
Fragilaria brevistriata	0.0	0.0	0.9	0.0	0.5	0.0
Fragilaria elliptica	0.0	0.0	0.9	0.0	0.0	0.5
Gomphonema intricatum	0.0	0.0	0.0	0.0	1.4	0.0
Gomphonema pseudoaugur	0.0	0.0	0.0	0.0	1.9	0.0
Gomphonema sp.	0.0	0.0	0.9	0.0	0.0	0.0
Mastogloia baltica	1.1	1.3	19.9	1.3	1.0	20.8
Mastogloia braunii	1.1	0.0	8.1	0.8	0.5	3.5
Mastogloia elliptica	1.1	0.0	1.8	0.8	0.5	2.5
Mastogloia elliptica v. dansei	1.1	1.3	3.2	0.0	0.5	0.0
Mastogloia smithii v. lacustris	0.0	0.0	0.5	0.8	1.0	13.4
Navicula cf. salinicola	0.0	0.0	0.0	0.0	0.0	0.5
Navicula cincta	0.0	0.9	0.0	0.0	1.0	0.0
Navicula crytocephala	0.4	0.0	0.0	0.0	0.0	0.0

Burullus: EPIPHYTON (CONT.)

Navicula pseudocrassirostris	6	1	1	34	0	1	Navicula pseudocrassirostris	2.3	0.4	0.5	14.2	0.0	0.5
Navicula recens	0	0	2	0	54	0	Navicula recens	0.0	0.0	0.9	0.0	26.0	0.0
Navicula rhyncocephala	0	0	0	0	0	1	Navicula rhyncocephala	0.0	0.0	0.0	0.0	0.0	0.5
Navicula yaarensis	0	0	1	0	0	0	Navicula yaarensis	0.0	0.0	0.5	0.0	0.0	0.0
Nitrzschia constricta	0	0	0	0	2	0	Nitrzschia constricta	0.0	0.0	0.0	0.0	1.0	0.0
Nitzschia archibaldii	1	1	0	0	0	0	Nitzschia archibaldii	0.4	0.4	0.0	0.0	0.0	0.0
Nitzschia cf. stompsii	11	3	2	8	2	0	Nitzschia stompsii	4.1	1.3	0.9	3.3	1.0	0.0
Nitzschia elegantula	1	12	13	4	1	6	Nitzschia elegantula	0.4	5.2	5.9	1.7	0.5	3.0
Nitzschia frustulum	2	1	2	0	4	4	Nitzschia frustulum	0.8	0.4	0.9	0.0	1.9	2.0
Nitzschia microcephala	0	0	1	0	0	2	Nitzschia microcephala	0.0	0.0	0.5	0.0	0.0	1.0
Nitzschia palaea v. delibilis	0	0	0	0	1	5	Nitzschia palaea v. delibilis	0.0	0.0	0.0	0.0	0.5	2.5
Nitzschia sp.	0	0	0	0	3	6	Nitzschia sp.	0.0	0.0	0.0	0.0	1.4	3.0
Nitzshia cf. perspicua	0	0	0	0	0	2	Nitzshia cf. perspicua	0.0	0.0	0.0	0.0	0.0	1.0
Rhopalodia gibba	0	0	18	0	2	5	Rhopalodia gibba	0.0	0.0	8.1	0.0	1.0	2.5
Rhopalodia musculus	0	2	2	0	0	1	Rhopalodia musculus	0.0	0.9	0.9	0.0	0.0	0.5
Synedra hartii	165	160	15	31	28	15	Synedra hartii	62.0	69.9	6.8	13.0	13.5	7.4
Synedra pulchella	0	0	0	0	1	0	Synedra pulchella	0.0	0.0	0.0	0.0	0.5	0.0
Synedra ulna	0	0	0	0	1	0	Synedra ulna	0.0	0.0	0.0	0.0	0.5	0.0
Tabularia fasciculata	0	0	4	1	1	14	Tabularia fasciculata	0.0	0.0	1.8	0.4	0.5	6.9
Thalassiosira cf. proshkinae	0	0	0	0	2	0	Thalassiosira cf. proshkinae	0.0	0.0	0.0	0.0	1.0	0.0
Total	**266**	**229**	**221**	**239**	**208**	**202**							
Slide no		18604	18606	18607	-	-							
SPECIES RICHNESS	**19**	**17**	**32**	**20**	**36**	**29**							

MANZALA - epiphyton on Ceratophyllum

1997-1999	19.11.97	5.3.98	1.6.98	1.8.98	31.1.99	22.5.99
Amphiprora paludosa	1	0	0	0	1	0
Amphora coffeaeformis	1	1	0	0	0	0
Amphora libyca	3	0	0	0	0	0
Amphora pediculus	3	6	10	2	3	1
Amphora strigosa	16	0	2	6	1	1
Amphora veneta	0	2	1	0	0	2
Anomoeoneis spherophora	1	0	0	0	0	0
Aulacoseira granulata	0	0	0	0	0	7
Bacillaria paradoxa	13	0	0	0	15	2
Caloneis bacillum	1	0	0	1	0	0
Cocconeis placentula	45	43	173	2	0	0
Cyclotella atomus	12	1	10	33	0	7
Cyclotella meneghiniana	16	6	10	44	5	76
Cyclotella pseudostelligera	1	0	0	0	0	1
Cymbella microcephala	2	0	0	0	0	0
Cymbella pusilla	1	0	0	0	0	0
Cymbella sp.	1	0	0	0	0	0
Diploneis elliptica	6	0	0	0	0	0
Epithemia adnata	10	0	0	1	0	1
Epithemia zebra	4	0	0	0	0	0
Fallacia pygmaea	1	0	0	0	0	0
Gomphonema affine	2	2	0	2	5	0
Gomphonema cf. parvulum	1	2	2	1	1	0
Gomphonema gracile	3	1	0	43	0	2
Gomphonema pseudoaugur	0	8	0	0	6	7
Gomphonema trucatum	0	0	0	2	0	2
Mastogloia elliptica	1	0	0	0	0	0
Melosira moniliformis	0	0	1	0	3	0
Navicula cincta	1	0	1	0	0	0
Navicula cryptocephala	0	0	5	0	1	0
Navicula halophila	1	1	0	0	0	0
Navicula radiosa v. tenella	0	0	0	2	0	0
Navicula recens	1	64	27	21	107	16
Navicula rhyncoceplala	3	0	0	0	0	0
Navicula sp	3	1	2	2	0	0
Navicula tripunctata	0	0	2	0	0	0
Navicula veneta	1	0	0	0	0	0
Navicula viridula	0	0	1	0	0	0

Epiphyton % data

	19.11.97	5.3.98	1.6.98	1.8.98	31.1.99	22.5.99
Amphiprora paludosa	0.4	0.0	0.0	0.0	0.5	0.0
Amphora coffeaeformis	0.4	0.4	0.0	0.0	0.0	0.0
Amphora libyca	1.3	0.0	0.0	0.0	0.0	0.0
Amphora pediculus	1.3	2.4	3.6	1.0	1.4	0.5
Amphora strigosa	7.0	0.0	0.7	2.9	0.5	0.5
Amphora veneta	0.0	0.8	0.4	0.0	0.0	0.9
Anomoeoneis spherophora	0.4	0.0	0.0	0.0	0.0	0.0
Aulacoseira granulata	0.0	0.0	0.0	0.0	0.0	3.3
Bacillaria paradoxa	5.7	0.0	0.0	0.0	6.9	0.9
Caloneis bacillum	0.4	0.0	0.0	0.5	0.0	0.0
Cocconeis placentula	19.8	17.6	62.7	1.0	0.0	0.0
Cyclotella atomus	5.3	0.4	3.6	15.9	0.0	3.3
Cyclotella meneghiniana	7.0	2.4	3.6	21.3	2.3	35.3
Cyclotella stelligera	0.4	0.0	0.0	0.0	0.0	0.5
Cymbella microcephala	0.9	0.0	0.0	0.0	0.0	0.0
Cymbella pusilla	0.4	0.0	0.0	0.0	0.0	0.0
Cymbella sp.	0.4	0.0	0.0	0.0	0.0	0.0
Diploneis elliptica	2.6	0.0	0.0	0.0	0.0	0.0
Epithemia adnata	4.4	0.0	0.0	0.5	0.0	0.5
Epithemia zebra	1.8	0.0	0.0	0.0	0.0	0.0
Fallacia pygmaea	0.4	0.0	0.0	0.0	0.0	0.0
Gomphonema affine	0.9	0.8	0.0	1.0	2.3	0.0
Gomphonema cf. parvulum	0.4	0.8	0.7	0.5	0.5	0.0
Gomphonema gracile	1.3	0.4	0.0	20.8	0.0	0.9
Gomphonema pseudoaugur	0.0	3.3	0.0	0.0	2.8	3.3
Gomphonema trucatum	0.0	0.0	0.0	1.0	0.0	0.9
Mastogloia elliptica	0.4	0.0	0.0	0.0	0.0	0.0
Melosira moniliformis	0.0	0.0	0.4	0.0	1.4	0.0
Navicula cinta	0.4	0.0	0.4	0.0	0.0	0.0
Navicula cryptocephala	0.0	0.0	1.8	0.0	0.5	0.0
Navicula halophila	0.4	0.4	0.0	0.0	0.0	0.0
Navicula radiosa v. tenella	0.0	0.0	0.0	1.0	0.0	0.0
Navicula recens	0.4	26.1	9.8	10.1	49.5	7.4
Navicula rhyncoceplala	1.3	0.0	0.0	0.0	0.0	0.0
Navicula sp	1.3	0.4	0.7	1.0	0.0	0.0
Navicula tripunctata	0.0	0.0	0.7	0.0	0.0	0.0
Navicula veneta	0.4	0.0	0.0	0.0	0.0	0.0
Navicula viridula	0.0	0.0	0.4	0.0	0.0	0.0

Manzala: Continued

Nitschia cf. gracilis	12	0	0	0	0	0	Nitschia cf. gracilis	5.3	0.0	0.0	0.0	0.0	0.0
Nitzschia amphibia	8	0	0	3	0	1	Nitzschia amphibia	3.5	0.0	0.0	1.4	0.0	0.5
Nitzschia angustatula	0	0	0	4	0	0	Nitzschia angustatula	0.0	0.0	0.0	1.9	0.0	0.0
Nitzschia cf. archibaldii	13	11	10	14	13	10	Nitzschia cf. archibaldii	5.7	4.5	3.6	6.8	6.0	4.7
Nitzschia cf. communis/pusilla	0	31	0	1	0	0	Nitzschia cf. communis/pusilla	0.0	12.7	0.0	0.5	0.0	0.0
Nitzschia clausii	0	0	0	0	19	0	Nitzschia clausii	0.0	0.0	0.0	0.0	8.8	0.0
Nitzschia constricta	0	0	0	0	0	2	Nitzschia constricta	0.0	0.0	0.0	0.0	0.0	0.9
Nitzshia dissipata	0	0	0	0	0	1	Nitzshia dissipata	0.0	0.0	0.0	0.0	0.0	0.5
Nitzschia elegantula	5	0	0	0	0	1	Nitzschia elegantula	2.2	0.0	0.0	0.0	0.0	0.5
Nitzschia gracilis	0	0	0	0	0	2	Nitzschia gracilis	0.0	0.0	0.0	0.0	0.0	0.9
Nitzschia microcephala	0	0	0	0	0	1	Nitzschia microcephala	0.0	0.0	0.0	0.0	0.0	0.5
Nitzschia frustulum (small)	1	7	9	9	9	17	Nitzschia frustulum (small)	0.4	2.9	3.3	4.3	4.2	7.9
Nitzschia inconspicua	0	0	0	0	5	0	Nitzschia inconspicua	0.0	0.0	0.0	0.0	2.3	0.0
Nitzschia microcephala	0	2	0	2	0	1	Nitzschia microcephala	0.0	0.8	0.0	1.0	0.0	0.5
Nitzschia palaea	0	4	0	0	0	2	Nitzschia palaea	0.0	1.6	0.0	0.0	0.0	0.9
Nitzschia sp	3	2	3	1	7	1	Nitzschia sp	1.3	0.8	1.1	0.5	3.2	0.5
Nitzschia cf. sublanceolata	0	0	0	0	4	3	Nitzschia cf. sublanceolata	0.0	0.0	0.0	0.0	1.9	1.4
Rhoicosphenia curvata	0	11	1	0	1	0	Rhoicosphenia curvata	0.0	4.5	0.4	0.0	0.5	0.0
Rhopalodia gibba	0	0	0	3	0	0	Rhopalodia gibba	0.0	0.0	0.0	1.4	0.0	0.0
Rhopalodia musculus	0	2	0	0	0	0	Rhopalodia musculus	0.0	0.8	0.0	0.0	0.0	0.0
Stephanodiscus hantzschii	0	14	0	0	0	5	Stephanodiscus hantzschii	0.0	5.7	0.0	0.0	0.0	2.3
Stephanodiscus invisitatus	1	3	1	1	0	9	Stephanodiscus invisitatus	0.4	1.2	0.4	0.5	0.0	4.2
Synedra acus	26	3	0	0	0	0	Synedra acus	11.5	1.2	0.0	0.0	0.0	0.0
Synedra acus v. oxyrhyncus	2	4	0	0	0	0	Synedra acus v. oxyrhyncus	0.9	1.6	0.0	0.0	0.0	0.0
Synedra hartii	0	1	0	0	0	2	Synedra hartii	0.0	0.4	0.0	0.0	0.0	0.9
Synedra ulna	1	3	3	2	0	13	Synedra ulna	0.4	1.2	1.1	1.0	0.0	6.0
Tabularia fasiculata	0	6	2	4	10	11	Tabularia fasiculata	0.0	2.4	0.7	1.9	4.6	5.1
Thalassiosira weissflogii	0	3	0	1	0	8	Thalassiosira weissflogii	0	1.2	0	0.5	0.0	3.7
Grand Total	**227**	**245**	**276**	**207**	**216**	**215**							
SPECIES RICHNESS	**39**	**29**	**21**	**26**	**19**	**31**							