Open water zooplankton communities in North African wetland lakes: the CASSARINA Project

Aquatic Ecology **35:** 319-333, 2001.

Mohammed Ramdani[1], Najat Elkhiati[2], Roger J. Flower[2], with contributions from Hilary H. Birks[4] Mejdidine M. Kraïem[5], Adel A. Fathi[6], and Simon T. Patrick[3]

[1]*Institut Scientifique, D´epart. Zoologie et Ecologie Animale, Charia Ibn Batota, B.P. 703, 10106 Rabat, Morocco (Fax: +212 7 77 45 40; E-mail: ramdanimohamed@yahoo.fr);*
[2]*Faculté des Sciences Ain Chock, Départ. Biologie, km 8 Route d'Eljadida, BP 5366, Casablanca, Morocco;*
[3]*Environmental Change Research Centre, Department of Geography, University College London, 26 Bedford Way, London WC1H OAP, UK;*
[4] *Botanical Institute, University of Bergen, Allégaten 41, N-5007 Bergen, Norway (Fax: +47 55589667; E-mail hilary.birks@bio.uib.no);*
[5]*Faculté des Sciences, Dept. de Biologie, Campus Universitaire, 1060 Tunis, Tunisia;*
[6]*Department of Botany, University of El Minia, El Minia 61111, Egypt*

Accepted 10 April 2001

Key words: biodiversity, North Africa, wetland lakes, zooplankton

Abstract

Zooplankton (Copepoda, Cladocera, Ostracoda, Rotifera and Diptera larvae) in nine North African lakes was collected from open water areas over twenty months during 1997/99. The results were used to monitor changes in the pelagic micro-invertebrate fauna of these sites with the purpose of exploring diversity structure and regional species occurrences.

The studied sites formed three distinct groups based on hydrology and water quality criteria: (i) acid water with no marine connection (Megene Chitane); (ii) alkaline freshwater/brackish with no marine connection (Merja Sidi Bou Rhaba and Merja Bokka); (iii) freshwater/brackish with marine connection (Merja Zerga, Lac de Korba, Garaet El Ichkeul and three Nile Delta lakes). However, cluster analysis of the zooplankton data alone indicated four groups with Korba being separated because of its prevalence of species tolerant of summer hypersalinity.

The total regional zooplanktonic species richness found was 88 taxa and these were characterized by species tolerant of widely fluctuating environmental conditions. However, some recorded species were very rare for North African freshwaters (e.g. *Alonella excisa*, *Leydigia quadrangularis* and, *Ilyocryptus sordidus*) and generally indicate favourable environmental conditions of low salinity and temperature. The sites influenced by marine waters generally exhibited slightly lower numbers of species but which generally demonstrate cosmopolitan distributions. Distinct seasonal patterns in species distributions were more similar to those observed in European lakes rather than to those of lower latitudes sites.

Zooplankton play a key role in maintaining aquatic ecosystem quality in the North African study lakes and the community distributions described for the late 20th century help set biodiversity base-line data for future studies. If the remaining wetland lakes in this region are to persist as important resources during the 21st century, they will need to be managed in a way that ensures that aquatic diversity is maintained.

Introduction

Wetlands are important zones for biodiversity but they are exposed to widely fluctuating environmental conditions with periodic changes in inundation, temperature and water quality. Furthermore, they are often exposed to high levels of human pollution/disturbance. Despite these stresses, wetland lakes are natural resources that often support valuable fisheries and provide excellent habitats for birds as well as contributing to regional aquatic diversity. The hydrozoological communities are a particularly important component of wetland lake diversity and, in the North African region, are often characterized by high numbers of Crustacea (Copepoda, Cladocera, Ostracoda, Phyllopoda), Rotifera, Diptera larvae (Chironomidae, Culicidae) and Mollusa (Gurney, 1911, 1926; Roy & Gauthier, 1927; Gauthier, 1928; Elster et al., 1960; Ramdani, 1986, 1988a,b;Athersuch et al., 1990; Slack et al., 1995). Assessing the diversity of these communities by estimating species abundances/occurrences in valued wetland lakes is one way by which aquatic populations can be compared between sites and be used to help monitor ecosystem quality.

Within a particular lake, the species composition of aquatic communities is closely linked with seasonal and hydrologic cycles. Many species of zooplankton and aquatic invertebrates can however tolerate changing conditions by both physiological and life cycles adaptations (Gauthier, 1928; Dussart, 1967; Margaritora, 1983; Ramdani, 1988a). For example, the resistant eggs of Ostracoda, Cladocera and Copepoda (Diaptomidae) can tolerate dry periods. Diptera can avoid adverse conditions by retarding egg hatching and some adult species of Copepoda (Cyclopoidae) can transform into a dormant stage (Dussart, 1969). However, when environmental changes exceed species tolerance limits community change at species level usually ensues. This has occurred at many sites where human activities have promoted environmental change (e.g., Finlayson & Moser, 1992).

In shallow wetland lakes most micro-invertebrates groups are well adapted to fluctuating environmental conditions. They have wide environmental tolerances and many species have very widespread distributions (e.g., *Cyprideis torosa littoralis*, *Eucypris virens*, *Chydorus sphaericus*, *Daphnia magna*, *Sarscypridopsis aculeata*, *Chironomus plumosus*) (e.g., Ramdani, 1986). These species are characteristic inhabitants of continental standing waters of the North African region as well as in Europe. Because of the southern Mediterranean climate, North African standing waters usually experience more variation in salinity (Gauthier, 1928; Ramdani, 1980, 1981, 1986, 1988a,b; Ramdani et al., 1989) than similar sites elsewhere in Europe and, consequently, some groups are good indicators of highly fluctuating conditions. The dynamics of zooplankton populations also vary according to a variety of within lake factors (e.g., Scheffer, 1998) but, in North African standing waters, morphometry is particularly important since this can vary considerably during hydrologic cycles and so affect habitat differentiation. Particularly for those sites that have some link with the marine environment, daily and seasonal amplitude changes in water level can influence markedly many variables, including temperature, pH, dissolved oxygen, salinity and habitat diversity characteristics.

In this study differences in zooplankton communities of nine North African wetland lakes are assessed and the work formed part of the CASSARINA Project on recent environmental change in this region (see Flower, 2001). The results of autecological analysis of zooplankton and micro-invertebrate samples acquired from these lakes during 1997–1999 are given. Additionally, results are compared with bibliographic information from previous surveys of Cladocera, Ostracoda, Chironomidae and Rotifera in Tunisia (Gauthier, 1928, 1931, 1934; Dussart, 1967, 1969, 1980; Pourriot, 1965; Dumont et al., 1979), in Morocco (Ramdani, 1980, 1981, 1982, 1986, 1988a,b; Morgan & Boy, 1980, 1982), in Italy (Margaritora, 1983), and in Egypt (Gurney, 1911, 1926, 1927; El Hawary, 1960; Elster et al., 1960; El Maghraby et al., 1963; Samaan & Aleem, 1972; Rzoska, 1976; Dumont, 1984; Anonymous, 1987; El Sherif & Aboul Ezz, 1988; Gharib & Soliman, 1998). In addition to establishing baseline information on species distribution and occurrences, the relationships between different species and the primary ecological factors that characterize the zooplankton communities are examined using a classification of the sites based on species occurrences.

Sites, materials and methods

Sites

The nine lakes examined in this study, Merja Sidi Bou Rhaba, Merja Zerga, Merja Bokka (Morocco), Megene Chitane, Garaet El Ichkeul and Lac de Korba (Tunisia), and Edku, Burullus and Manzala lakes (Egypt). They are all shallow coastal (all <3 m deep) or near coastal sites and site characteristics are described in detail elsewhere (see Ramdani et al., 2001a). The lakes form three natural groups (see below) depending on water quality (acid or alkaline, see Fathi et al., 2001) and whether there is direct contact with sea water.

Sampling

Plankton samples for Crustacea, Diptera and Rotifera were collected with standard 20 cm diameter plankton nets of 100 μm-mesh size. Sampling at each site followed the same procedure. The net was drawn over a distance of ca. 20 m in the open water region near the end of each CASSARINA vegetation transect line (Ramdani et al., 2001a). The semi-quantitative samples can therefore only be considered as representative of the zooplankton present at the sampling point in each lake. The resulting semi-quantitative filtrates were fixed and preserved in formalin on collection. The lakes were sampled on six occasions during 1997– 1999. Sample timing at the nine sites was selected according to the different seasons. Because all the lakes were shallow, the samples sometimes contained high proportions of detritus as well as large numbers of organisms. Sub-sampling was therefore necessary, and we used a Dollfus Vat to fractionate the samples and to facilitate counting of the zooplankton (Pourriot, 1965; Ramdani, 1986, 1988a; Paterson, 1993). The number of species in each sample was estimated for Copepoda, Cladocera, Rotifera and Diptera using techniques from Dussart (1967, 1969), Pourriot (1965), Ramdani (1986), Rougier and Lam Hoai (1997). These involved estimating the total number of zooplankton, following critical identification of all specimens at magnification x40. The relative abundance of each species was then calculated. No corrections were made for variations in net filtering rate and net clogging was not a problem except occasionally at Merja Sidi Bou Rhaba when blue-green *Microcystis aeruginosa* blooms were encountered.

Numerical analysis

Cluster analysis of the micro-invertebrate assemblages present in the nine study lakes was performed using the FORTRAN Program '*STATISTICA'*. This performs weighted pair group cluster analysis (WPGA) and was used to classify the zooplanktonic assemblages. WPGA arranges the samples into a hierarchical classification based on the abundant taxa. Initially, the similarity is computed between all possible sample pairs using Pearson's r correlation coefficient.

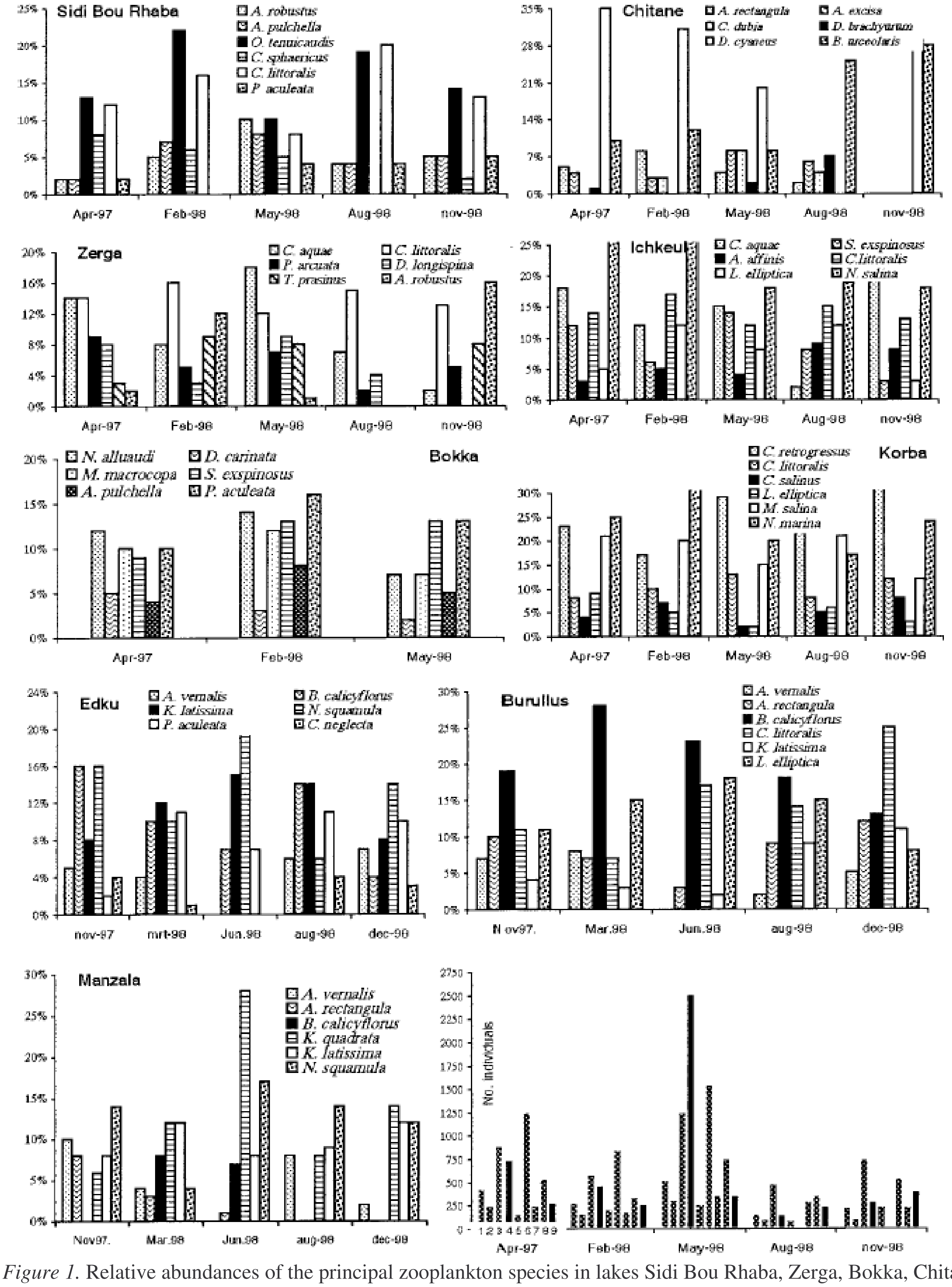

Figure 1. Relative abundances of the principal zooplankton species in lakes Sidi Bou Rhaba, Zerga, Bokka, Chitane, Ichkeul and Korba and the Delta lakes, Edku, Burullus and Manzala during 1997 and 1998. The histogram (lower right) shows the total number of zooplankton individuals collected on each sampling occasion (see text), where bars 1, 2, 3, 4, 5, 6, 7, 8 and 9 refer to Sidi Bou Rhaba, Zerga, Bokka, Chitane, Ichkeul, Korba, Edku, Burullus and Manzala, respectively.

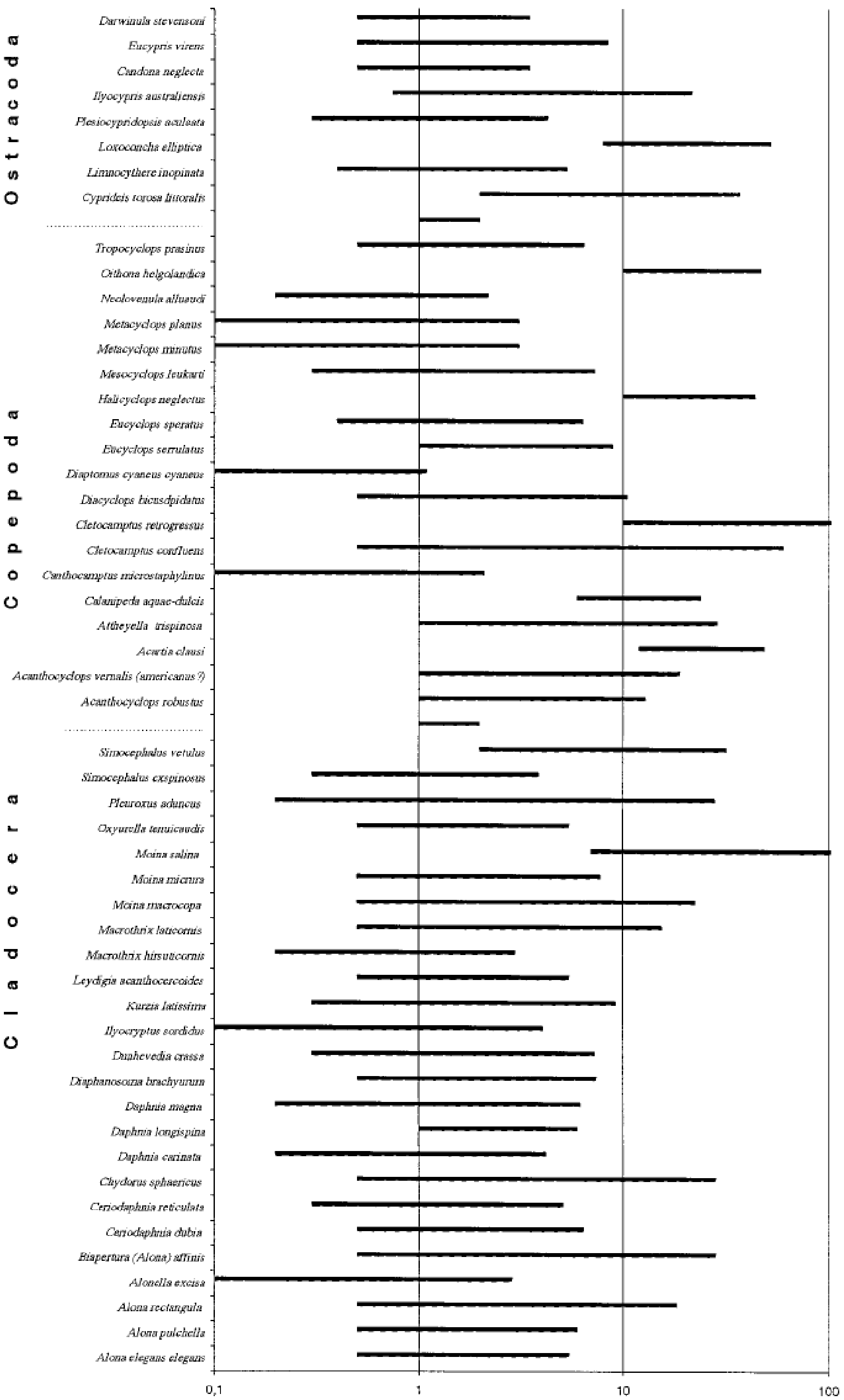

Figure 2. The salinity range distributions of the principal zooplankton taxa identified in the nine CASSARINA lakes (1997–99). Note the log scale salinity abscissa.

Results and discussion

Species abundances and occurrences

Species in samples collected from all the investigated lakes during the 20 month-monitoring period were identified and abundances estimated. The results refer to Copepoda, Cladocera, Ostracoda, Rotifera, Chironomidae and Culicidae and are presented in Tables 1–5 and Figure 1.

The zooplankton communities identified in CASSARINA lakes comprised predominantly of herbivorous taxa within the Cladocera, Copepoda, Ostracoda- Rotifera and, Diptera (larvae). Notably, Chironomidae and Culicidae were frequently present but these are facultative benthic species present in many North African zooplankton assemblages (Gauthier, 1928; Samaan & Aleem, 1972; Rzoska, 1976; Dumont, 1984; El Sherif & Aboul Ezz, 1988; Gharib & Soliman, 1998).

The zooplankton community structure and diversity during the sampling period is indicated by the species recorded in Tables 1–5. The total zooplanktonic species richness was 88 taxa. The sites influenced by marine water showed slightly lower numbers of species (Figure 1). Nine species that are very rare in North African wetland lakes were recorded and all are indicators of good environmental conditions (low salinity, temperature and pollution). They comprise three Copepoda, five Cladocera and three Ostracod taxa (see below).

Water salinity in the CASSARINA lakes ranged between ~1 and 50 g l^{-1} (Fathi et al., 2001) and this variable appeared to exert a strong influence on the zooplankton species distributions (cf., Dussart, 1967–1969; Tourenq, 1975; Negrea, 1983; De Deckker, 1981). Many taxa are however able to tolerate widely fluctuating conditions and, regarding the salinity ranges, the tolerances are indicated in Figure 2. Large seasonal variation in salinity was recorded in several sites (Zerga, Korba and Ichkeul; Fathi et al., 2001) and here the zooplanktonic communities are mainly mixed fresh and brackish water species. In such conditions, freshwater species are stressed when salinity increases and vice versa.

Based on hydrology and water quality (Ramdani et al., 2001a; Fathi et al., 2001), the study sites can be placed into three distinct groups:

– Acid soft water with no marine connection (Megene Chitane);
– Alkaline freshwater/brackish with no marine connection (Sidi Bou Rhaba and Merja Bokka);
– Freshwater/brackish with marine connection (Merja Zerga, Lac de Korba, Garaet El Ichkeul and three Nile Delta lakes).

Specific characteristics of the zooplankton communities over time

Soft water sites (Megene Chitane)

This small lake supports a particularly important zooplankton fauna (Figure 1 and Tables 1–5) and represents an unusual ecological habitat in North Africa since its water is slightly acid. The zooplankton inventory for this site reveals a total of twenty species with a remarkably species-rich cladoceran (nine species) community that indicates abundant phytoplankton and large habitat diversity with low predation. The Cladocera species *Alonella excisa*, *Leydigia quadrangularis* and, *Ilyocryptus sordidus* are rare in North Africa, especially so in Tunisia where they occur solely in the north-western part of the country. These species all prefer temperate zone freshwater habitats (Margaritora, 1983; Ramdani, 1986). Dumont et al. (1979) noted *A. excisa* in pool near Nefza, a catchment near Tabarka (Northeastern Tunisia). This species has high abundances from April to August (see Figure 3 and Table 2). *Diaphanosoma brachyurum* is indicative of larger lakes and dams. It was previously recorded in Tunisia only once, in an artificial lake at Nebhana (Dumont et al., 1979). Its presence indicates permanent clean water and in Chitane it occurred during May and August but with low abundances (Figure 3). The Copepod *Diaptomus cyaneus cyaneus* is also a typical freshwater species (Dussart, 1967; Ramdani, 1986; Ramdani et al., 1989a) and its presence in Chitane is probably explained by relatively low temperatures during the humid seasons and the acid conditions. The geographical distribution of this sub-species is limited to lakes of the colder zones of Algeria, Italy, Corsica and the south of France (Dussart, 1967; Ramdani et al., 1989). In Morocco, it is replaced by *D. c. admotus,* a species very common in the cool Atlas Mountain lakes (Ramdani et al., 1986). Only once before has *D. c. cyaneus* been recorded in Tunisia, by Gauthier (1928) from a drainage ditch near Ferryville (Menzel Bourguiba). The typical biologic cycle of this species is that it is very common in winter, spring and autumn but is absent during summer (Figure 3, Table 1). This cycle is also characteristic of the species in Italy and Corsica (Dussart, 1967). The rotiferan *Brachionus urceolaris* is also a very characteristic species in Chitane (Figure 3, Table 4), it feeds on picoplankton (Pourriot, 1965; Lair, 1978) and reaches relative high abundances here (Figure 3). Ostracods were rare in Chitane; these organisms require calcium carbonate in the water for their tests and only *Cypris ophtalmica* was noted during the yearly cycle and it was poorly calcified. Chironomid species were represented by species common and widespread in European and North African freshwaters (Tourenq, 1975). It is noteworthy that during 1997/98 many amphibians, especially *Rana ridibunda* and *Hyla arborea* occupied the lake margins.

Table 1. Copepoda taxa identified in the nine CASSARINA lakes with minimum and maximum % abundances calculated from the total number of animals recorded

	Rhaba	Zerga	Bokka	Chitane	Ichkeul	Korba	Edku	Burullus	Manzala
Acanthocyclops robustus	2–10%	0–16%			0–4%				
A. vernalis (americanus?)							0–7%	0–8%	0–10%
Acartia clausi		1–15%							
Attheyella trispinosa					0–4%				
Calanipeda aquae-dulcis		2–18%			2–21%				
Canthocamptus microstaphylinus				0–4%					
Cletocamptus confluens	3–8%								
Cletocamptus retrogressus		7–18%				17–35%			
Diacyclops bicusdpidatus							2–7%	1–5%	0–9%
Diaptomus cyaneus cyaneus				0–35%					
Eucyclops serrulatus	0–9%	0–12%		0–8%	0–7%				
Eucyclops speratus							3–5%	0–3%	3–12%
Halicyclops neglectus						1–6%			
Mesocyclops leukarti							0–3%	3–10%	4–10%
Metacyclops minutus				0–8%					
Metacyclops planus			7–14%						
Neolovenula alluaudi			1–2%						
Oithona helgolandica		0–13%							
Tropocyclops prasinus	0–5%	0–9%							

Alkaline freshwater/brackish sites with no marine connection (Sidi Bou Rhaba and M. Bokka)

At *Merja Sidi Bou Rhaba* the open water zooplankton community comprised twenty-two species (Figure 1 and Tables 1–5). February and September were characterized by fewer species and low numerical abundances of individuals. During April and May, species richness reached nineteen taxa and most of these were represented by a high numbers of individuals (Figure 3). Of note during these periods was the high percentage of juvenile forms (68–75%). December was also characterized by high species richness (twenty species) but individuals were numerically much less and mainly dominated by adults (88%). Of the Crustacea fauna, *Oxyurella tenuicaudis* (*Cladocera*, *Chydoridae*) and *Cyprideis torosa littoralis* (Ostracoda) were dominant during the study period (Figure 2). *Alona elegans*, *Alona pulchella*, *Acanthocyclops robustus*, *Eucypris virens* and *Potamocypris arcuata* were also present from February to December (Figure 3 and Tables 1–3) and life cycles of these species overlap. *Oxyurella tenuicaudis* is a widespread species (in holarctic and neotropical lakes) but it is uncommon in North Africa (Ramdani, 1986) and within CASSARINA lakes it was only encountered at Sidi Bou Rhaba. *Brachionus plicatilis* and *Sarscypridopsis aculeata* were generally present in small numbers (7–25 individuals per sample). The other species of Crustacea frequently present have short life cycles (2–3 months) and only occurred in small numbers. Of the Insecta, four Chironomid species were common in April and December; they were *Chironomus riparius*, *C. plumosus*, *Procladius choreus* and *Cricotopus sylvestris.* During summer, their development was inhibited by unfavourable conditions in the lake, mainly high temperature and salinity, and reduction of aquatic vegetation (*Chara* and *Ruppia* were replaced by *Na ias marina* and *Chaetomorpha linum*). *Chironomus halophilus* and *Tanytarsus horni* were also represented but numbers were very few. Both these species tolerate large salinity and alkalinity ranges (Tourenq, 1975; Ramdani & Tourenq, 1982).

Table 2. Cladocera taxa identified in the nine CASSARINA lakes with minimum and maximum % abundances calculated from the total number of animals recorded

	Rhaba	Zerga	Bokka	Chitane	Ichkeul	Korba	Edku	Burullus	Manzala
Alona pulchella	2–8%		4–8%						
Alona elegans elegans	4–12%								
Alona rectangula				2–8%			0–3%	3–12%	0–8%
Alonella excisa				0–8%					
Biapertura (Alona) affinis					3–9%				
Ceriodaphnia dubia	0–12%		0–3%	0–8%					
Ceriodaphnia reticulata							0–9%		0–7%
Chydorus sphaericus	0–8%		3–7%	0–8%			0–8%	0–3%	0–8%
Daphnia carinata			2–5%						
Daphnia longispina		0–9%							
Daphnia magna			1–2%						
Diaphanosoma brachyurum				0–7%					
Dunhevedia crassa			6–8%				1–12%		1–8%
Ilyocryptus sordidus				0–2%					
Kurzia latissima							8–15%	2–11%	8–12%
Leydigia acanthocercoides				0–7%					
Macrothrix hirsuticornis				0–14%					2–15%
Macrothrix laticornis					3–8%				
Moina micrura							0–9%	1–6%	0–7%
Moina macrocopa			7–12%						
Moina salina						12–21%			
Oxyurella tenuicaudis	10–22%								
Pleuroxus aduncus			2–5%						
Simocephalus exspinosus			9–13%		3–14%				
Simocephalus vetulus				0–4%					

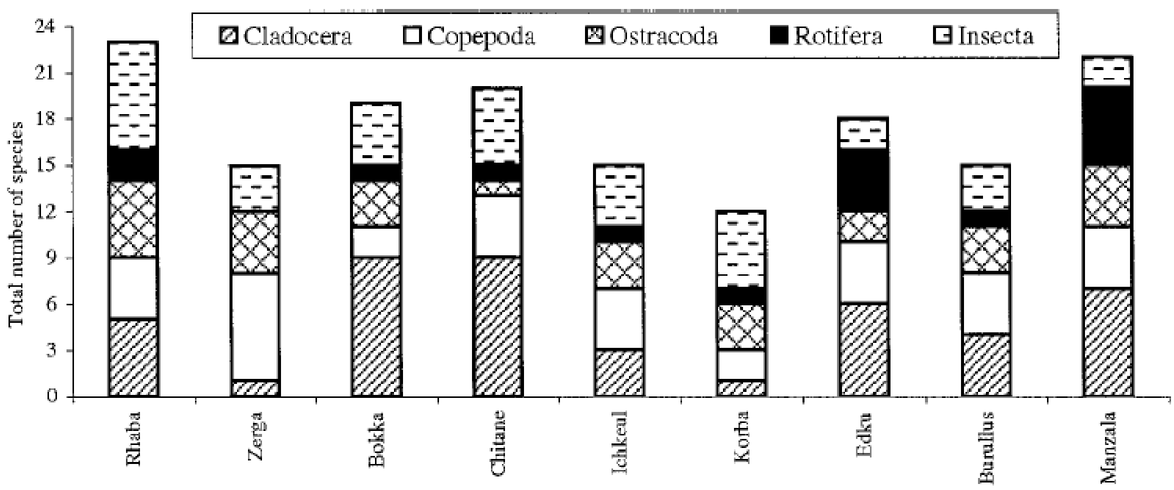

Figure 3. Total richness of zooplanktonic *sensu lato* communities sampled in 9 CASSARINA lakes.

Merja Bokka was sampled on three occasions only (Figure 3 and Tables 1–5) since after May 1998 the lake was completely dry. Twenty-four species were identified in the open water communities and *Neolovenula alluaudi* (Copepoda, Diaptomidae), *Sarscypridopsis aculeata*, *Eucypris virens*, *Moina macrocopa* and *Simocephalus expinosus* constituted most of the zooplankton community (Figure 3 and Tables 1–5), prior to mid 1998. These species are well adapted to fluctuating environments in temporary wetlands (ponds, temporary pools, and swamps) and produce dormant eggs during adverse conditions (Ramdani, 1986). Other taxa at this site, resistant to such conditions, were rotifers and chironomids. They were always represented by small numbers of individuals (Table 5) and the species are typical of both temporary and permanent wetlands in North Africa (Gauthier, 1928; Ramdani, 1986; Azzouzi et al., 1992). Most crustacean species identified in Bokka have a very short biologic cycle (2–5 months) and pass the dry period as resistant eggs (ephippia). They included *Triops cancriformis mauritanicus*, *Daphnia carinata*, *Daphnia magna*, *Pleuroxus aduncus*, and *Moina macrocopa* (Table 2). In 1997, the lake supported a few introduced small carp and many amphibians, especially the newt *Pleurodeles waltli* and the toad *Bufo mauritanicus.*

Table 3. Ostracoda taxa identified in the CASSARINA lakes with minimum and maximum % abundances calculated from the total number of animals recorded

	Rhaba	Zerga	Bokka	Chitane	Ichkeul	Korba	Edku	Burullus	Manzala
Candona neglecta							0–4%		
Cypria ophtalmica				0–7%					
Cyprideis torosa littoralis	8–20%	12–16%			12–17%	8–13%		7–25%	
Heterocypris salina						2–8%			
Darwinula stevensoni									0–4%
Eucypris virens	3–8%		6–12%						
Ilyocypris australiensis		1–5%			1–4%				
Ilyocypris getica	0–5%		0–1%						
Limnocythere inopinata								8–18%	0–5%
Loxoconcha elliptica		8–13%			3–12%	2–9%		8–18%	
Sarscypridopsis aculeata	0–5%		10–16%				2–11%		5–10%
Potamocypris arcuata	4–11%	2–9%							
Potamocypris variegata									0–2%

Table 4. Rotifera taxa identified in the nine CASSARINA lakes with minimum and maximum % abundances calculated from the total number of animals recorded

	Rhaba	Zerga	Bokka	Chitane	Ichkeul	Korba	Edku	Burullus	Manzala
Brachionus plicatilis	0–7%								0–4%
Brachionus urceolaris			0–7%	8–28%					
Brachionus calicyflorus f.amiceros							4–16%	13–28%	0–8%
Colurella uncinata	0–4%						0–18%		2–15%
Keratella quadrata							0–4%		6–28%
Notholca marina						17–32%			
Notholca salina					18–27%				
Notholca squamula							6–22%		4–17%

Freshwater/brackish sites with marine connections (Merja Zerga, Lac de Korba, Garaet El Ichkeul and the Nile Delta lakes)

Merja Zerga contained a mixture of fifteen marine and brackish water species (Tables 1–5). Two typically marine copepods *Acartia clausi* and *Oithona helgolandica* were frequently present. Their relative abundances were especially important in August and December, periods coinciding with low freshwater contributions to the lagoon (very low rainfall during these periods). The majority of species present in the zooplanktonic community here are typical of brackish (mixohaline) waters (Figure 3, Tables 1–5). *Calanipeda aquae-dulcis*, *Cletocamptus retrogressus*, and *Loxochonca elliptica* are more frequent in estuaries and lagoon ecosystems (Dussart, 1969; Dussart & Defaye, 1983). *Eucyclops serrulatus*, *Daphnia longispina*, *Tropocyclops prasinus, Acanthocyclops robustus* and *Potamocypris arcuata* are more typical of permanent freshwater and brackish water habitats. *Calanipeda aquae-dulcis* and *Cletocamptus retrogressus* can tolerate fluctuating and high salinities (Figure 3) and are frequently common in coastal brackish water ecosystems (Dussart, 1969; Dussart and Defaye, 1983) were *C. retrogressus* can tolerate 120 g l−1 salinity (Dussart, 1967). In Zerga, the zooplankton constitute a valuable local food resource for tufted duck (*Aythya fuligula*), shovelers (*Anas clypeata*) and fish (Campredon et al., 1982). The chironomids species collected in this lagoon are widespread taxa and occur in many brackish water ecosystems in North Africa and elsewhere (Tourenq, 1975; Ramdani, 1981; Kettani et al., 1995; Azzouzi& Laville, 1987; Azzouzi et al., 1992).

Table 5. Chironomidae and Culicidae taxa identified in the nine CASSARINA lakes with minimum and maximum % abundances calculated from the total number of animals recorded

	Rhaba	Zerga	Bokka	Chitane	Ichkeul	Korba	Edku	Burullus	Manzala
Chironomus halophilus	0–3%								
Chironomus piger	0–2%	0–4%							
Chironomus plumosus	0–2%	0–3%	0–3%	2–5%			0–8%	0–7%	0–8%
Chironomus riparius	0–2%								
Corynoneura sp.					18–27%				
Cricotopus sp.								0–8%	
Cricotopus sylvestris	0–2%	0–5%							
Cryptochironomus deribae						0–2%			
Dicrotendipes fusconotatus						1–4%			
Dicrotendipes perengueyanus				0–3%					
Eutanytarsus sp.					1–4%				
Orthocladius sp.			0–5%						
Orthocladius thienmanni				0–6%					
Procladius coreus	0–2%								
Tanypus sp.					1–4%				
Tanytarsus horni	0–3%		0–2%						
Tanytarsus sp.				2–8%			0–7%	0–1%	0–1%
Trichotanypus sp.					0–4%				
Aedes detritus						0–3%			
Culex pipiens			0–5%	0–4%					
Theobaldia annulata						0–3%			
Ephydra cf macellaria						1–6%			

Garaet El Ichkeul contained only a few species typical of freshwater environments (*Simocephalus expinosus*, *Macrothrix laticornis*, *Biapertura affinis* and *Chydorus sphaericus*). The brackish water elements (*Calanipeda aquae dulcis, Acanthocyclops robustus, Cyprideis torosa littoralis, Loxoconcha elliptica, Ilyocypris australiensis, Notholca salina* and *Atyeaphyra desmaresti*) were more common. Gauthier already noted the species heterogeneity of this lake in 1928 and this no doubt stems form the large seasonal changes in salinity experienced at the site. *Notholca salina*, *Calanipeda aquae dulcis*, *Cyprideis torosa littoralis*, and *Simocephalus exspinosus* constituted the typical zooplanktonic fauna of this lagoon during the spring phase of the hydrologic cycle. The chironomid species present were also characteristic of brackish water; they are widespread and common throughout the Mediterranean region (Tourenq, 1975). The number of organisms was generally low in all samples, indicating low productivity in this well mixed but turbid water brackish lake.

In *Korba Lake* twelve species constituted the zooplanktonic fauna. They are all species typical of saline habitats in coastal wetlands in regions neighbouring the Mediterranean Sea (Gauthier, 1928; Margaritora, 1983; Dussart, 1969; Ramdani, 1988, 1988a). Only six species were consistently present during the whole sampling period (Figure 6). They were: *Cletocamptus retrogressus* (Copepoda), *Notholca marina* (Rotifera), *Moina salina* (Cladocera), *Cyprideis torosa littoralis*, *Loxoconcha elliptica*, and *Cyprinotus salinus* (= *Heterocypris salina*) (Ostracoda). The latter species is generally characteristic of less saline water (Meisch, 2000). Other species of Crustacea and Chironomidae (*Cryptochironomus deribae* and *Dicrotendipes fusconotatus*) have a short life cycle and were only present in small numbers. Small numbers of individuals, represented by five species of Diptera, were present throughout the sampling period. In the *Egyptian Delta Lakes* the zooplankton communities were all typical of permanent freshwater or weakly brackish water conditions. Nine zooplanktonic species characterized all three of the Egyptian lakes: Rotifera (*Keratella quadrata*, *Notholca squamula*, *Brachionus calicyflorus*, and *Colurella uncinata*), Ostracoda (*Darwinula stevensoni*, *Limnocythere inopinata* and *Candona neglecta*), Cladocera (*Kurzia latissima*) and Copepoda (*Acanthocyclops americanus* and *Mesocyclops leuckarti*). (It was difficult to distinguish between *A. americanus* and *A. vernalis* and we followed the diagnosis given by Halim & Guergess, 1978).

Edku Lake supported sixteen zooplankton species, mainly dominated by the rotifers, *Notholca squamula, Brachionus calicyflorus* and *Colurella uncinata. Mesocyclops leuckarti* and *Acanthocyclops americanus* are cosmopolitan and fairly stenotherm zooplanktoners, tolerant of up to about 7 g l^{-1} salt; they are typical of large lakes (Margaritora, 1983; Dussart, 1967). *Kurzia latissima* was also well represented and it is a holarctic, Ethiopian and subtropical species characteristic of brackish inshore zones (Margaritora, 1983). It frequents shallow lakes, ponds, pools, ditches, and swamps and prefers muddy substrates covered by macrophytes or plant detritus. It is a sporadic thermophil species and common in eastern Mediterranean coastal wetlands (Margaritora, 1983). The ostracod *Candona neglecta* occurred here and is widely distributed throughout Europe and North Africa. It is typical of freshwater ponds, lakes, marshes, ditches and oligohaline creeks (salinity 0–15 g l^{-1}). Typically, it lives on soft and muddy sediments with one generation annually and mature individuals occurring during in winter and spring. *Chydorus sphaericus*, considered a cosmopolitan euryhaline cladoceran species, is very common in continental freshwaters and weakly brackish waters (lakes, lagoons, temporary pools, brackish ponds, ditches and marshes). It prefers shores rich in vegetation e.g., (*Ceratophyllum*, *Potamogeton*, *Typha* and, *Phragmites*) and particularly the presence Cyanophyceae. Edku Lake consequently provides an excellent habitat for this species. It resists low concentrations of dissolved oxygen (to 3%) and tolerates acid and alkaline water (pH 3.4–9.2). It is a generalist feeder, filtering seston (diatoms and flagellates) as well as fine detritus on sediments. This species is distributed across Europe, Asia, N. America and in the southern hemisphere (Goulden, 1964; Margaritora, 1983). The whole zooplankton fauna of Edku Lake is distinctly freshwater in character. This indicates that, despite the sea connection, diversity is not currently influenced strongly by marine water. Being halophobes, *Bosmina longirostris* and *Brachyurum excisum* were however common only in the freshwater inflows to Edku. El Hawary (1960) noted *D. excisum* in some places near the freshwater Edku Drain. *Canuella perplexa* (Copepod) and *Nauplius* larvae (Cirripeda) were more common in the lake area in the 1950s (cf. El Hawary, 1960). These latter species have apparently disappeared progressively from Edku as the proportion of freshwater in the lake increased (see Samaan, 1977; Birks et al., 2001; Ramdani et al., 2001a).

Burullus Lake contained twelve zooplanktonic species but with low species abundances. The number of individuals per sample, in chronological order, was 75, 95 and 86. Four species were dominant during the whole survey period (Figure 2, Table 1–5); they were *Brachionus calicyflorus* (Rotifera), *Limnocythere inopinata*, *Loxoconcha elliptica* and *Cyprideis torosa littoralis.* The three species of Ostracoda indicate that brackish water conditions prevailed in the lake. Indeed, *Loxoconcha elliptica* and *Limnocythere inopinata* are euryhaline but prefer oligohaline waters (Ghetti & McKenzi, 1981). Burullus Lake supported a mixed fauna of freshwater (*Alona rectangula*, *Mesocyclops leuckarti* and *Moina micrura*) and brackish water animals (e.g., *Cyprideis torosa littoralis*, *Loxoconcha elliptica* and *Limnocythere inopinata*) but with a quantitative predominance of the latter, indicating that the marine influence remained marked at this site.

Manzala Lake possessed higher biodiversity with nineteen zooplankton species and here species richness is associated with a relatively high number of individuals per sample (compared with the other two Egyptian lakes). All the zooplankton species identified (Figure 3, Tables 1–5) indicate predominantly freshwater conditions. However, the presence of *Limnocythere inopinata* in low relative abundances reflected some brackish water influences. It is notable that in this and the other two Egyptian lakes, species of Chironomidae were poorly represented in the collected samples. This poverty is probably related to the method sampling. Sampling the bottom surface sediment is required to capture the maximum numbers of these taxa. Indeed, chironomid larvae are often benthic forms that rarely go up to the water surface.

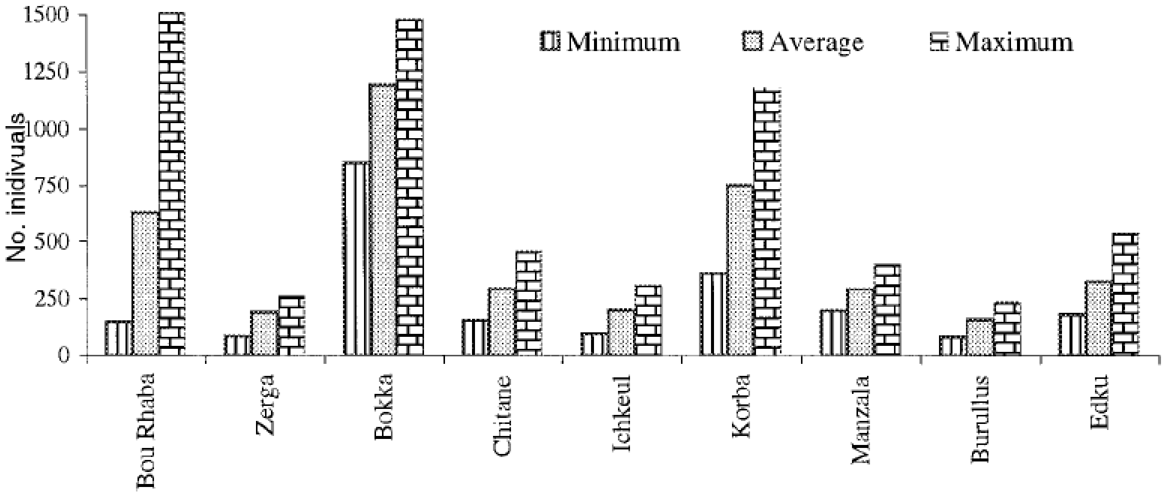

Figure 4. Maximum, minimum and average number of zooplankton individuals collected at each of the nine CASSARINA lakes over the 1997–1998 sampling period.

Numerical analysis

Cluster analysis groups the lakes with the highest similarities first. The other sites were clustered in subsequent iterations and the results are displayed in a dendrogram (Figure 5). In this preliminary analysis, weighted pair group cluster analysis of 54 samples based on the occurrence of 88 species in the nine lakes yielded four distinct lakes clusters (Figure 5). A distinctive association of zooplanktonic Crustacea, Rotifera, and Diptera characterize each cluster. The analysis defines four main associations:

Association 1

This weak association groups the lakes Sidi Bou Rhaba, Bokka and Chitane; they are linked by the presence of common species. The similarity between Bokka and Sidi Bou Rhaba is relatively weak (0.025) despite their geographical proximity. The large number of characteristic species in each individual lake accounts for this weak similarity. Differences in water chemistry (salinity, conductivity, and organic matter) probably account for much of the faunistic individuality of these sites. Merja Bokka contains nine characteristic species: *Daphnia carinata*, *Daphnia magna*, *Metacyclops planus*, *Moina macrocopa*, *Neolovenula alluaudi*, *Orthocladius* sp. 1, *Pleuroxus aduncus*, *Simocephalus exspinosus* and *Triops cancriformis mauritanicus.* This is an assemblage typical ofmany temporary ponds in the circum-Mediterranean region (Gauthier, 1928; Margaritora, 1983; Ramdani, 1986, 1988). Megene Chitane has more affinity with Bokka than with the other lake. This weak similarity (0.029) is produced by the following species in common: *Eucyclops serrulatus*, *Alona rectangula*, *Ceriodaphnia dubia*, *Chydorus sphaericus*, *Brachionus urceolaris*, *Chironomus plumosus* and *Culex pipiens.* These species are all common in fresh and weak brackish waters throughout North Africa (Gauthier, 1928; Dumont et al., 1979; Ramdani, 1982, 1986, 1988a,b).

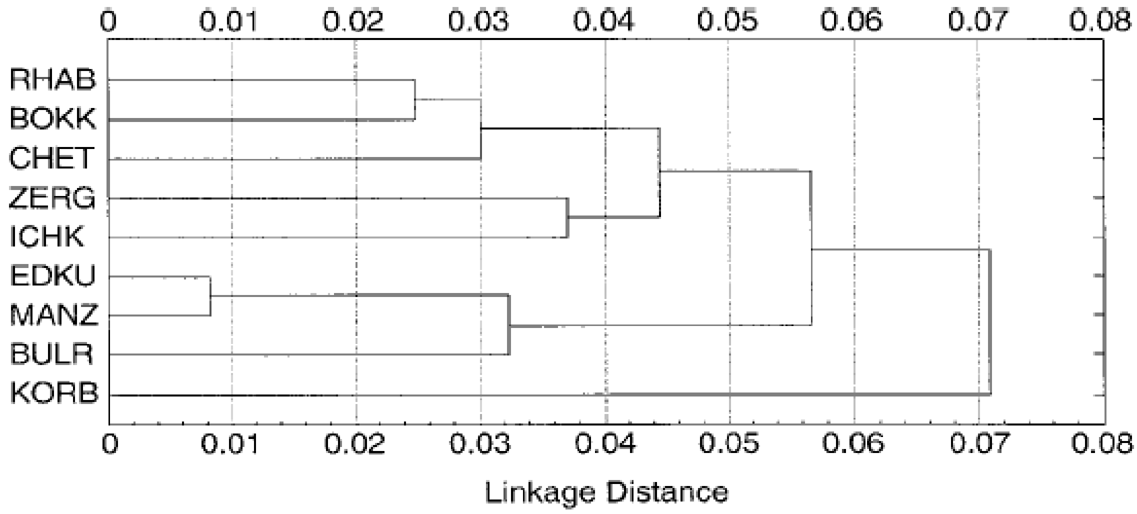

Figure 5. Numerical analysis of the nine CASSARINA lakes: cluster diagram (see text) based on zooplankton species occurrences recorded at each site.

Association 2

Edku and Manzala lakes showed the highest similarity (0.07) and had nine species in common: *Kurzia latissima*, *Tropocyclops prasinus*, *Ceriodaphnia dubia*, *Dunhevedia crassa*, *Sarscypridopsis aculeata*, *Potamocypris variegata*, *Colurella uncinata*, *Notholca squamula* and *Tanytarsus* sp. Burullus Lake is also included in this association with a weak similarity (0.031) and there are eight species in common between the three sites: *Acanthocyclops vernalis*, *Eucyclops serrulatus*, *Alona rectangula*, *Chydorus sphaericus*, *Brachionus calicyflorus*, *Chironomus plumosus*, *Moina brachiata* and *Limnocythere inopinata.* Associations 1 and 2 have a significant similarity (0.04) and all these lakes have freshwater or slightly brackish water. They have the following species in common: *Eucyclops serrulatus*, *Alona rectangula*, *Ceriodaphnia dubia*, *Chydorus sphaericus*, *Dunhevedia crassa*, *Macrothrix hirsuticornis*, *Chironomus plumosus* and *Tanytarsus* sp.

Association 3

The lagoons Zerga and Ichkeul have seven species in common: *Calanipeda aquae dulcis* (very typical of this type of lake), *Acanthocyclops robustus*, *Eucyclops serrulatus*, *Cyprideis torosa littoralis*, *Loxoconcha elliptica*, *Ilyocypris australiensis*, and *Chironomus plumosus.* A mixture of zooplanktonic species, mainly dominated by forms with a brackish preference, reflected the mixture of freshwater and brackish water in these two lakes.

Association 4

The fauna of Korba lagoon has very low similarity (0.007) with the other eight sites. Water quality and the strong marine and even hypersaline conditions characterize this site. Eleven of the twelve species recorded at this site are characteristic of high salt habitats and they were encountered only in this CASSARINA lake. These species-based associations indicate a slightly different site grouping than indicated by the hydrological and water quality characteristics (see above). Because of the presence of several species in common between acid Chitane and the Moroccan sites (Sidi Bou Rhaba and Bokka), the analysis associates all the three sites. The presence of rare species and species specific to Chitane do in fact suggest that separation of this site into a separate category is appropriate. On the other hand, the cluster analysis separates Korba from all the other sites because of the prevalence of species that are tolerant the strong summer hypersalinities of this site (despite its hydrological similarities to Ichkeul and Zerga).

Conclusions

The micro-invertebrates communities in the nine North African lakes investigated during this study display considerable species variation which is doubtless related to a variety of environmental variables. Salinity is however probably the most important. Many of the species found at these sites are typical for shallow standing waters in North Africa and southern Europe but at two sites, Megene Chitane and Lac de Korba, the species groups present are distinctive. The former has acid water and this is very unusual forNorth Africa and consequently several species therein are characteristic of more northerly European sites. Species present at the latter site are distinctive because they are tolerant of high salinity; Korba is strongly hypersaline during summer months (see Fathi et al., 2001). Both these lakes are biologically unusual compared with the other CASSARINA sites, as indicated by their zooplankton.

With the exception of Megene Chitane, many of the species described in this study are well known and recorded previously for the region. Gauthier (1928) collected many of the same species. Those in sebkhas and in very saline environments of Tunisia and Algeria are the same as those recorded here at Korba. Gauthier proposed that the paucity of zooplanktonic species (Cladocera and Copepods) in the coastal saline areas was due to high salinity. The zooplankton composition of Korba and the other marine influenced sites (Ichkeul and Zerga) agrees with his proposal. Later, collecting by Ramdani (1986) also provided evidence that the majority of standing water sites in the western North African region were characterized by cosmopolitan euryhaline micro-invertebrates. In this study, only in Zerga is a significant part of the zooplankton community probably derived directly from marine coastal waters. Evidence for this is the presence of neritic copepods *Acartia clausi* and *Oithona helgolandica* brought in during inflow of marine water from the strongly tidal Atlantic.

The three lakes in the Nile Delta are rather different from the western sites sampled in the CASSARINA Project. They are not only fairly fresh and have become increasingly so in recent decades (Flower, 2001) but are relatively much larger (Ramdani et al., 2001a). The zooplankton communities are predominantly freshwater in character but CASSARINA sampling location (away from marine channels) emphasize the incidence of freshwater forms. Nevertheless, older publications do indicate that in past decades micro-invertebrates and other animals frommarine environments were more common in these lakes (see El-Hawary, 1960; Elster & Vollenweider, 1961). The former higher abundances of marine invertebrates at these sites during the earlier part of the 20th century is confirmed by palaeoecological evidence (Ramdani et al., 2001b; Birks et al., 2001). At the sites in the western North African region, a comparison of the species listed here with previous survey indicates some changes in the structure of zooplankton communities (Roy & Gauthier, 1927; Gauthier, 1928, 1933; Dumont, 1979; Morgan & Boy, 1980, 1982). Nevertheless, differences in sampling strategies means that trends in species abundances over long periods of time are best inferred from sediment records (Ramdani et al., 2001b).

On a shorter time scale and although sampled at rather irregular intervals, the monitoring results from the North African zooplankton communities sampled during 1997/99 also demonstrated considerable variation in species abundances, according to the season sampled. These successional changes appear to be closely linked with intra-annual climate change. They are therefore more similar to those species changes recorded in many northern European and North Amer ica lakes (e.g., Fitzsimmons & Andrew, 1993; Whiteside, 1974; Whiteside et al., 1978) than to the much more attenuated successional changes reported for the lower latitude regions of Africa (e.g., Talling & Lemoalle, 1998).

With the partial exception of Megene Chitane, most of the species typical of the CASSARINA sites are typically abundant in wetland lakes throughout the Mediterranean region. The results of this survey of the occurrences and abundances of North African aquatic micro-invertebrates are important for several reasons. First, it shows that despite the intensity of land-use change and disturbance affecting many North African wetland lakes (Flower et al., 1989, Ramdani et al., 2001a), most of the sites studied still support rich and diverse zooplankton communities. These are generally well adapted to tolerating moderate levels of disturbance and periods of higher salinity following freshwater shortages. However, at sites where changes in freshwater supply have been sustained the zooplankton communities are species poor. Second, many of these sites, especially Sidi Bou Rhaba and Zerga in Morocco, Ichkeul and Korba in Tunisia and all three Nile Delta lakes are important sites for fisheries and/or for water birds. These valued groups depend entirely on the maintenance of viable aquatic ecosystems and the zooplankton is a key community supporting this viability. If the remaining North African wetland lakes are to persist during the 21st century as important centres for aquatic biodiversity, as well as sustainable resources for birds and fish, they will need to be managed in a conservationally sound manner. The information on micro-invertebrate diversity presented in this study should help assess the nature and pace of future changes in these lakes and lagoons.

Acknowledgements

We wish to thank all those people in both the North African and European partner countries who helped with fieldwork and made this project possible. The Eaux et Forets Ministry (Rabat) kindly facilitated site access in Morocco. This work was supported by the EU-INCO programme contact # C18-CT96-0029.

References

Anonymous (1987) Limnological studies on the Manzalah Lake. Wastewater Re-use Project Report. Acad Sci Research and Tech Nation Inst Oceanogr Fish, Alexandria, pp 1–85

Athersuch J, Horne DJ and Whittaker I (1990) Marine and brackish water Ostracods. Synopses British Fauna (New series), 24: 1–198

Azzouzi A and Laville H (1987) Premier inventaire faunistique des Chironomidés (Diptera) du Maroc. Ann Limnol 23: 217–224

Azzouzi A, Laville H and Reiss F (1992) Nouvelles récoltes de Chironomidés au Maroc. Ann Limnol 28: 225–232

Birks HH, Peglar SM, Boomer I, Flower RJ, Ramdani M, with contributions from Appleby PG, Bjune AE, Patrick ST, Kraïem MM, Fathi AA and Abdelzaher HMA (2001) Palaeolimnological responses of nine North African lakes in the CASSARINA Project to recent environmental changes and human impacts detected by plant macrofossil, pollen, and faunal analyses. Aquat Ecol 35: 405–430

Campredon S, Campredon P, Pirot JY and Tamisier A (1982) Manuel d'analyse des contenus stomacaux de canards et de foulques. CNRS, Centre d'Ecologie de Camargue. 87 pp.

De Deckker P (1981) Taxonomy and ecological notes of some ostracods from Australian inland waters. Trans Roy Soc South Australia, 105: 91–138

Dumont HJ, Laureys P and Penseart J (1979) Anostraca, Conchostrata, Cladocera and Copepoda from Tunisia. Hydrobiologia 66: 259–274

Dumont HJ (1984) The zooplankton of the Nile. In: Davis BR and Walker KF (eds.), The Ecology of the River Systems. Monographiae Biologicae

Dussart B (1967) Les Copépodes des eaux continentales. Tome I, Calanoïdes et Harpacticoïdes. Boubée et Cie Edit. Paris, 500 pp

Dussart B (1969) Les Copépodes des eaux continentales. Tome II, Cyclopoïdes et Biologie quantitative. Boubée et Cie Edit. Paris, 292 p

Dussart B and Defaye D (1983) Répertoire mondial des Criustacés Copépodes des eaux intérieures. I-Calanoïdes. Editions CNRS, 224 p

El Hawary MA (1960) The zooplankton of the Egyptian lakes. A preliminary study on the zooplankton of Lake Maryut and Lake Edku. Alexandria Inst Hydrobiol Fish Notes and Mem 52, 12 pp

El Maghraby AM,Wahby SD and Shaheen AH (1963) The ecology of zooplankton in Lake Manzala. Alexandria Inst Hydrobiol Fish Notes Mem 70, 43 p.

El Sherif ZM and Aboul Ezz SM (1988) Preliminary study on phytoplankton-zooplankton relationship in Lake Burollus, Egypt. Ull. Inst. Oceanogr Fish. AR Egypt 14: 23–30

Elster HJ and Vollenweider R (1961) Beitrage zur Limnologie Agyptens. Arch Hydrobiol 57: 241–343

Elster HJ, Hawary M, Schroeder R and Schwoerber J (1960) Populations dynamics on zooplankton in the Nozha hydrodrome near Alexandria. *Arctodiaptomus salinus* Daday and *Diaphanosoma excisum* Sars. Alexandria Inst Hydrobiol Notes Rec Mem, 50 p.

Fathi AA, Abdelhazer HMA, Flower RJ, Ramdani M and Kraïem MM (2001) Phytoplankton communities of North African wetland lakes: the CASSARINA Project. Aquat Ecol 35: 303–318

Finlayson M and Moser M (Eds) (1992) Wetlands. Facts on File, Oxford, 224 pp

Fitzsimmons AG and Andrew TE (1993) The seasonal succession of the zooplankton of Lough Neagh. In: Lough Neagh, The Ecology of a Multipurpose Water Resourse. RB Wood and RV Smith (eds.), Monographiae Biologicae 69, Kluwer Academic Publishers, Dordrecht, pp. 281–326

Flower RJ (2001) ChAnge, Stress, Sustainability and Aquatic ecosystem Resilience In North African wetland lakes during the 20th century: an introduction to integrated biodiversity studies within the CASSARINA Project. Aquat Ecol 35: 261–280

Gauthier H (1928) Recherches sur la faune des eaux continentales de l'Algérie et de la Tunisie. Minerva, Alger, 419 pp

Gauthier H (1933) Nouvelles recherches sur la faune des eaux continentales de l'Algérie et de la Tunisie. Bull Soc Hist Afr Nord 24: 63–68

Gharib SM and Soliman SM (1998) Some water characteristics and phyto-zooplankton relationship in Lake Edku (Egypt) and adjacent sea. Bull Fac Sci Alex 38: 25–44

Ghetti PF and McKenzie K (1981) Guide per il riconosciemento selle species animali delle aque interne italiane. Ostracodi (Crustacea, Ostracoda). Con Nation Ricetch Aqu 11: 1–83

Goulden CE (1964) The history of the cladoceran fauna in Esthwaite Water (England) and its limnological significance. Arch. Hydrobiol 60: 1-52

Gurney R (1911) On some freshwater Entomostraca from Egypt and the Sudan Ann Mag Nat Hist 7: 25–33

Gurney R (1926) 8th Report on the Crustacea: Copepoda and Cladocera of the plankton. Cambridge Expedition to the Suez Canal. Trans Zool Soc London XXII

Gurney R (1927) 33rd Report on the Crustacea: Copepoda (littoral and semi parasitic). Cambridge Expedition to the Suez Canal. Trans Zool Soc London XXII

Halim Y and Guerguess SK (1978) Coastal lakes of the Nile Delta. Lake Manzalah. Coastal Lagoon Research, Present and Future 1981. Proceeding of an UNESCO/IABO Seminar. Duke University Marine Labo Beaufort, USA B70: 135–172

Kettani K, Vilchez Quero A, Calle Martinez D and T Elouazzani, (1995) Nouvelles récoltes de Chironomidés Diptera du Maroc: Les Chironomidae de l'Oued Martil (Rif). Ann Limnol 31: 253–261

Margaritora F (1983) Guide per il riconoscimento delle specie animali delle acque interne italiane: Cladoceri (Crustacea: Cladocera). Consig Nazion Ricerch AQ/1/197, 22: 1–169

Meisch C (2000) Freshwater Ostracoda of Western and Central Europe. Suesswaser Flora vonMitteleuropa (Hrsg. von J. Schwoerbel and P. Zwick) Band 8/3. Spekr. Akad. Verlag GmbH, Heidelberg, Berlin, 522 pp

Morgan NC and Boy V (1980) An ecological survey of standing water in north west Africa: I: Rapid classification. Biol Cons 24: 81–101

Morgan NC and Boy V (1982) An ecological survey of standing water in north west Africa: III: Site descriptions for Morocco. Biol Cons 24: 5–44, 161–182

Paterson M (1993) The distribution of micro-crustacea in the littoral zone of a freshwater lake. Hydrobiologia 263: 173–183

Pourriot R (1965) Recherches sur l'écologie des Rotifères. Vie and Milieu (suppl.) 21: 1–224

Ramdani M (1980) Recherches hydrobiologiques sur un plan d'eau des environs de Rabat, la merja de Sidi Bou Rhaba (Maroc). Thèse 3◦ cycle, unpublished, 134 pp

Ramdani M (1981) Recherches hydrobiologiques sur la merja Sidi Boughaba, littoral atlantique du (Maroc): étude physicochimique et analyse faunistique. Bull Inst Sci Rabat 5: 37–137

Ramdani M (1982) Les entomostracés de la merja Sidi Bou Rhaba. Bull Inst Sci Rabat 6: 105–117

Ramdani M (1986) Ecologie des Crustacées (Copépodes, Cladocères et Ostracodes) des mares temporaires marocaines. Doct Etat Marseille I, 217 pp

Ramdani M (1988a) Les eaux stagnantes au Maroc: études biotypologique et biogéographique du zooplancton. Trav Inst Sci Rabat, Zool. n◦ 43, 40 pp

Ramdani M (1988b) Hydrobiology of sebkhas and gueltas in the Khnifiss-La'youne region. In: The Khnifiss Lagoon and its Surrounding Environment. Trav Inst Sci Rabat Mém (hors série): 87–94
Ramdani M and Tourenq JN (1982) Notes sur les Chironomides de la merja Sidi Bou Rhaba. Bull Inst Sci Rabat 6: 179–185
Ramdani M, Champeau A and Pont D (1989) Le genre *Diaptomus* (Copépodes, Diaptomidés) au Maroc. Bull Inst Sci Rabat 13: 99–104
Ramdani M, Flower RJ, Elkhiati N, Kraïem MM, Fathi AA, Birks HH and Patrick ST (2001a) North African wetland lakes: characterization of nine sites included in the CASSARINA Project. Aquat Ecol 35: 281–302
Ramdani M, Elkhiati N, Flower RJ, with contributions from Birks HH, Kraïem MM, Fathi AA and Patrick ST (2001b) Open water zooplankton communities in North African wetland lakes: the CASSARINA Project. Aquat Ecol 35: 319–333
Rougier C and Lam Hoai T (1997) Biodiversity through two groups of micro zooplankton in a coastal lagoon (Etang de Thau, France). Vie Milieu 47: 387–394
Roy Y and Gauthier H (1927) Sur les Copépodes d'Algérie et de Tunisie des eaux douces et saumâtres. Bull Soc Zool France 52: 558–575
Rzoska J (1976) The Nile. Biology of an ancient River. Monographiae Biologicae 29. Dr W. Junk, The Hague, 417 pp
Samaan AA and Aleem RR (1972) The Ecology of zooplankton in Lake Maryut. Bull Inst Oceanogr Fish Cairo 234–273
Samaan AA (1977) Distribution of zooplankton in Lake Edku. Bull Inst Oceanogr Fish Acad Sci Res Egypt 6: 157–196
Scheffer M (1998) Ecology of Shallow Lakes. Chapman and Hall, London, 357 pp
Slack JM, Kontrovovitz M and Stanely DJ (1995) Ostracoda from Lake Manzala, Nile Delta, Egypt. In: J Riha (ed.), Ostracods and Biostraigraphy. AA Balkema, Rotterdam, pp. 333-342
Talling JF and Lemoalle J (1998) Ecological Dynamics of Tropical Inland Waters. Cambridge University Press, Cambridge, 441 pp
Tourenq JN (1975) Recherches écologiques sur les Chironomidés (Diptera) de Camargue. Thèse d'Etat, Univ. P. Sabatier, Toulouse, 424 p
Whiteside MC (1974) Chydorid (Cladocera) ecology: seasonal patterns and abundance of populations in Elk Lake. Minnesota. Ecology 55: 538–550
Whiteside MC, Williams JB and White CP (1978) Seasonal abundance and pattern of Chydorid Cladocera in mud and vegetative habitats. Ecology 59: 1177–1188