Chapter 5
Flora

AQUATIC MACROPHYTES

Major changes have occurred in the flora of the Nile system in Egyptian Nubia in recent years, following the completion of the Aswan High Dam in 1964. In 1963, the area of the Nile Valley which was to become Lake Nasser had a relatively rich submerged and emergent flora (57 species, of which 6 were euhydrophytes) before the construction of the Aswan High Dam (AHD) (Boulos 1966). After the construction of AHD, Springuel & Murphy (1991) during 1980-1986 recorded 9 species of euhydrophytes, while Ali (1987) recorded 7 species only. Changes in aquatic vegetation may be due to changes in the water level regime and/or changes in the physico-chemical factors following waterbody regulation (Ali *et al*. 1995). The latter author discussed the effect of physico-chemical factors of both water and hydrosoil on the distribution of macrophyte vegetation in the River Nile in Upper Egypt (Lake Nasser, Aswan Reservoir and the Nile).

Erosion of the littoral zone is a natural phenomenon occurring in regulated bodies and is often linked closely with wave action (Smith *et al.* 1982). Ali *et al.* (1995) show that the littoral zone of Lake Nasser is characterised by a coarse hydrosoil texture, which may be formed due to the water level fluctuation and exposure to waves. As a result of the construction of the AHD, the new littoral zone of Lake Nasser has mainly a sandy substrate, as the submerged area was previously a desert. Most of the silt which had been brought by the floods, was accumulated behind the dam. Such accumulation of silt, in the north section of the Lake, gave a hydrosoil texture of clay loam. This texture is reflected in the species composition, being similar to that of the southern section of Aswan Dam. Thus, abundant growth of *Najas horrida* was recorded in both zones. Some of the silt was deposited on the shores and khors on both sides of the Lake. Due to the water level fluctuation and wave action, the accumulated silt is washed from the banks and accumulated in the main channel, leaving behind sandy or sandy loamy sand banks where *Potamogeton lucens* (= *P. schweinfurthii*) and *Najas marina* subsp. *armata* are the dominant plants.

It seems that the abundance of a species differs with different water level fluctuation regimes. An extended range of water level fluctuation results in the mortality of aquatic vegetation caused by the absence of low light conditions (Rorslett 1989). Therefore, extreme changes in water levels give rise to communities that are extremely species poor or absent and so the littoral zone is impoverished (Smith *et al.* 1982).

Springuel & Murphy (1991) pointed out that habitat disturbance appears to be an important pressure acting upon the macrophyte population in Lake Nasser. The littoral zone is prone to massive disturbance, caused by water level fluctuations. Marginal beds of macrophytes may be exposed to the air (and to extreme heat and aridity), or submerged deep in the water column, at irregular intervals during the year, with potenially catastrophic impact on established plant populations. Murphy *et al.* (1990) showed that all macrophyte species ocurring in Lake Nasser show a strong element of disturbance-tolerance traits in their strategy type.

The highest amplitude of water level fluctuation in Lake Nasser was recorded in 1988, during the drought period. The mean monthly level of the Lake dropped to as low as 150.62 m above mean sea level on 20th and 21st July, 1988, about 30.68 m lower than the maximum level of the Lake in 1998 (181.30 m MSL). First, continuous low water level exposed the littoral shallow water habitats, and submerged macrophytes became exposed and desiccated. Following this, a period of continuous high water level caused low-light conditions for the same area of the littoral zone. The occurrence of these two events in a short period caused substantial mortality of the submerged aquatic plant communities during the drought period in 1988 (Ali *et al.* 1995). The initial community has *Najas horrida* A.Br.ex Magn. as the dominant species, with six other species present (Ali 1987). Following the destruction of that community, *Najas marina* L. subsp. *armata* (Lindb.) Horn became dominant, with four other taxa present (*Najas horrida, Zannichellia palustris* L., *Vallisneria spiralis* L. and *Potamogeton schweinfurthii* A. Benn.) (Ali *et al.* 1995).

Euhydrophyte species

The following represents the submerged hydrophytes (euhydrophytes - flowering and non-flowering) recorded in Lake Nasser.

1- *Najas marina* subsp. *armata* (Lindb.). Until recently this plant was restricted in Egypt, to the Nile Delta, Fayoum, the Mediterranean coastal strip, Isthmic region, and Oases of the Western Desert (CAI[*], Täckholm 1974). In 1973, it was

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[*] CAI=Cairo University Herberium

recorded in Lake Nasser by El-Hadidi (1976), and Entz (1976). This species has subsequently spread vigorously in Lake Nasser and, to a lesser extent, other waters in Egyptian Nubia (Triest 1988). *Najas marina* subsp. *armata* is currently a dominant species in Lake Nasser, showing vigorous growth throughout the Lake littoral region during 1980-86 (Belal *et al.*1992). In 1988-89, it made up about 40% of the total standing crop. *Najas marina* occurs mainly in Lake Nasser, characterized by alkaline water and high electrolyte concentration. It grows on sand, clay, silt, clay with shells and thick organic matter. In most cases *Najas marina* is observed on an organic substrate covered with a layer of sand or clay. Though the tendency to form extensive pure stands, inhibiting colonization by potential competitors is characteristic of *Najas,* most species are of local occurrence (Ali *et al.* 1995). However, with respect to their vigorous growth and individual seed production, the biotic importance of *Najas* as a source of food for many sorts of waterfowl should not be underestimated.

2- *Najas horrida* A. Br. This species was confined to Lower Egypt and the oases prior to the filling of Lake Nasser, although specimens in CAI* are confused with *Najas pectinata* (Parl.) (Täckholm 1974, Triest 1988). It has now become abundant in the shallow waters of numerous khors (inundated wadis and side-arms) of Lake Nasser, often codominant with *Najas marina* subsp. *armata* (Belal *et al.* 1992). *Najas horrida* shows considerable morphological plasticity in its general habitat which may be robust, with curved rigid leaves or slender with straight lax leaves. Concerning the plasticity of *Najas horrida,* there could be a relationship between very compact specimens and the total mineralization of the water.

3-*Vallisneria spiralis* L. This species was recorded from the Aswan High Dam (Abdallah *et al.* 1972). It was also reported in 1968 by El-Hadidi & Ghabbour (1968) from three separate locations around Aswan. It remains common in all Nubian waters, including both major impoundments, and the river north of the two Dams (Belal *et al.* 1992). Ali (1987) pointed out that this rooting hydrophyte grows in shallow waters of many khors in both sides of Lake Nasser.

4- *Zannichellia palustris* L. This species is widespread in Egypt, occurring in the Nile Valley, Mediterranean, Isthmic and Oases regions (CAI and Täckholm 1974). In Egyptian Nubia it was recorded by El-Hadidi & Ghabbour (1968) in the Aswan Dam Area (CAI) and by Täckholm (1974) from irrigation canals near Allaqi village (CAI). Other records confirm that the species was present pre-1964 in water courses in the Upper Nile Valley, subsequently inundated by Lake Nasser (Abdallah *et al.* 1972, Boulos 1966, El-Hadidi 1976, El-Hadidi & Ghabbour 1968). It remains quite widespread in Egyptian Nubia, including Lake Nasser, but does not form dense stands (Springuel 1981, 1985 a and b).

This tiny submerged hydrophyte was recorded in very shallow khors in the southern region of the Lake (Ali 1987).

5- *Potamogeton lucens* L. (= *P. schweinfurthii* A. Benn.). This species was found to be very rare in the Nile Delta, eastern Mediterranean coastal region, and Isthmic regions (Täckholm 1974). Small stands of this species were recorded by Springuel as *Potamogeton nodosus* in 1980 in Lake Nasser near Khor Kalabsha, in the northern sector of the Lake. Later, Ali (1992) proved it was an abundant growth of *P. lucens* in the same area.

6- *Potamogeton crispus* L. Records in CAI and Täckholm (1974) suggest that this species has long been widespread in Egypt: common in the lower Nile, Sinai, the Isthmic Desert, Mediterranean region, and Oases. The plant was recorded from the Nile at Edfu, Kom Ombo, Aswan, and the Aswan Reservoir (CAI). Its presence in the Nile in Egyptian Nubia prior to construction of the Aswan High Dam was reported by many authors (Abdallah *et al.* 1972, Ahti *et al*. 1973, Boulos 1966 and El-Hadidi & Ghabbour 1968). The plant remains were common in the Nile downstream of the Aswan Dam. It was not recorded during the early years of the formation of Lake Nasser (Entz 1976), but was slowly invading the impoundment, being first recorded by Imam (CAI). Beds of *P. crispus* were confirmed as present in the northern sector of the Lake in 1979 by Springuel. Ali (1987) pointed out that this submerged hydrophyte was rare in the southern region of the Lake, confined to khors with shallow water and slow current. In later surveys this species was not recorded, and it may have been lost from the Lake (Belal *et al*. 1992).

7- *Potamogeton pectinatus* L. A widespread aquatic weed of irrigation and drainage canals in the Nile Delta. *P. pectinatus* also occurs in the River Nile valley, Oases, Mediterranean and Isthmic Desert regions of Egypt (CAI, Täckholm 1974). The presence of the plant in Egyptian Nubia before the construction of the Aswan High Dam is confirmed by several reports (Abdallah *et al.* 1972, Ahti *et al*. 1973, Boulos 1966, El-Hadidi 1976 and El-Hadidi & Ghabbour 1968). Entz (1976, 1980b) pointed out that the spread of macrophytes on a large scale in Lake Nasser started in 1972-73, with the development of stands of *P. pectinatus* in shallow sandy areas of the Lake. *P. pectinatus* was more common in the southern than in the northern sectors of Lake Nasser. *Potamogeton pectinatus* shows phenotypic changes in growth, so that photosynthetic tissue production is maximized near the water surface under varying water levels. This plant was not observed in the Lake during recent years (Belal *et al*. 1992).

8- *Potamogeton trichoides* Cham. & Schlecht. The first record of this species in Egypt was in May 1962 by Täckholm and El-Hadidi, from irrigation channels near Aswan. The plant was recorded in Lake Nasser in 1978 by

Imam in Khors Tushka and El-Malki (CAI). During 1981-82 it was abundant in the northern sector of the Lake (Springuel 1985b). Between 1982-87, the major fall in water coincided with the disappearance of *P. trichoides* from the northern sector, although it remained as a rare species in the southern sector of the Lake, near the Sudanese border. However, recent surveys showed that *P. trichoides* could have disappeared from the Lake (Belal *et al*. 1992).

9- *Potamogeton perfoliatus* L. It is found in canals in the Nile near its banks. It was discovered for the first time in Egypt by Täckholm in 1951 growing in the recently constructed freshwater reservoir 'Sadd el Rauwafaa' in northern Sinai. Before inundation by Lake Nasser, it was discovered in the Nile at Abu Simbel and Ballana (Boulos 1966).

10- *Nitella hyalina* (DC) Agardh. This macroalga grows in Lake Nasser, not to any great depth, in open sunny locations (Ali 1992). It has a cosmopolitan distribution. Although it is known from many parts of the world, it is rare in Lake Nasser. This species often grows on calcareous sand at lake edges (Belal *et al*. 1992). The presence of the species was reported in 1972-73 by Entz (1980b) but misidentified as *Chara* sp.

11- *Myriophyllum spicatum* L. This species is often described as an invasive species, and it is loosely accepted that invasions are frequently followed by rapid concomitant displacement of native species (Smith & Barko 1990). *Myriophyllum spicatum* has been discovered in the Nile valley during the past decade and its rapid colonisation seems to be influenced by changes in the Nile water regimes after the building of the AHD (Fayed 1985).

Optimal growth of *Myriophyllum spicatum* occurs in alkaline (hard-water systems) with concomitantlly high concentrations of dissolved inorganic carbon (Spence 1967, Hutchinson 1957 and Stanley 1970). Smith & Barko (1990) point out that water alkalinity provides a simple, but useful measure of the growth potential of *Myriophyllum spicatum.* This species appeared in Lake Nasser in 1993, probably introduced into the Lake through fishing nets contaminated with this hydrophyte, which were previouslly used in the Nile downstream (personal communication, Ali 1998).

Belal *et al*. (1992) classify the above mentioned species into two groups:

a. Cosmopolitan species. *Potamogeton crispus, P. pectinatus, Najas marina* subsp. *armata, Zannichellia palustris* and *Nitella hyalina* are recorded worldwide, including a range of countries in North Africa and Middle East (CAI, Andrews 1965, Mouterde 1966, Dandy 1937, Quézel & Santa 1962, Triest 1988, Van Vierssen 1982). Their presence in Upper Egypt is to be expected, but became abundant in this area as a result of new or modified habitats due to the construction of the Aswan High Dam (Belal *et al*. 1992).

b. Subcosmopolitan species. *Potamogeton trichoides* has long been known from Western North Africa and East Africa (Dandy 1937, Maire 1952), as well as Turkey and Palestine (Dismore 1933), Syria and Lebanon (Mouterde 1966). *Vallisneria spiralis* is more typically a tropical/subtropical species (Lowden 1982), rare in Africa as a whole, but associated with the Nile system (El-Hadidi 1968). *Najas horrida* occurs throughout tropical Africa and Madagascar (Triest 1988).

Changes in the macrophyte flora of Egyptian Nubia over the time

Historically, Lower Egypt has been considered the hub of freshwater macrophytes distribution in Egypt as shown by the prevalence of herbarium records in CAI and literature records (e.g. Simpson 1932, Täckholm & Drar 1950, Täckholm 1974). Intensive botanical surveys of the Nile Valley in Egyptian Nubia prior to its inundation by Lake Nasser, revealed the presence of a limited number of aquatic macrophytes species (euhydrophytes) (Table 39).

In Lake Nasser, during 1963-1964, Boulos (1966) recorded *Alisma gramineum, Damasonium alisma* Mill var. *compactum* Michell, *Potamogeton crispus, Potamogeton pectinatus, Zannichellia palustris* and *Potamogeton perfoliatus* (which was a new record). In 1972, *Potamogeton pectinatus* (Entz 1976), and in 1973-1974 *Najas marina* subsp. *armata, N. horrida, Z. palustris* and *Potamogeton pectinatus* were recorded (El-Hadidi 1976, Entz 1980b). In 1981-1982 Springuel (1985b) recorded *Najas marina* subsp. *armata, Najas horrida, Potamogeton trichoides, P. crispus, Zannichellia palustris, Vallisneria spiralis* and *Potamogeton lucens* (which was identified as *P. nodosus*).

During 1980-1986 Springuel & Murphy (1991) recorded 9 species of euhydrophytes (Table 39). *Najas armata* and *N. horrida* were abundant in the shallow waters along both shorelines of the Lake, abundantly associated with *Vallisneria spiralis.* Less commonly associated with *Najas-Vallisneria* community were *Zannichellia palustris, Potamogeton trichoides* and *P. crispus.* In contrast *V. spiralis* showed pronounced increase mainly in the mid sector of the Lake during the study period. *Zannichellia palustris* and *Potamogeton* species tended to be most abundant in the southern sector of the Lake (>200 km south AHD), even raplacing *Najas* spp. as dominants at several sampling stations in this sector. One reason for this vegetation change may be that this upstream end of the Lake is close to sources of propagules inflowing from the Sudanese River Nile. The somewhat higher species diversity of sites at this end of the Lake (a mean of 3.6 taxa per station, compared with 2.7 for Lake Nasser as a whole) may be related to this factor. Springuel & Murphy (1991) emphasised that further studies are needed to further explain these observations as little is known at present about origins of euhydrophyte populations which have succeeded in colonising Lake Nasser.

In 1984-1986, Ali (1987) found 7 species: *N. marina* subsp. *armata, N. horrida, Potamogeton crispus, P. pectinatus, P. trichoides, Vallisneria spiralis* and *Zannichellia palustris.* In 1986, *Najas marina* subsp. *armata, N. horrida, Potamogeton crispus, P. trichoides, V. spiralis* and *Z. palustris* were recorded (Springuel 1987). In 1988-1990, Ali *et al.* (1995) recorded 6 species: *N. horrida, N. marina* subsp. *armata, Potamogeton lucens, V. spiralis, Zannichellia palustris* and *Nitella hyalina* (Table 39). The latter species was misidentified in the previous work as *Chara* sp. by Abdin (1949a) and Entz (1980b). Lake Nasser has shown a decrease in the number of species present, especially those which are not tolerant to extreme fluctuations in water level, *Ceratophyllum demersum* is one species that, although present downstream of the Dam, has never been recorded in Lake Nasser either before or after the Dam construction.

Subsequent to the construction of the Aswan High Dam, two euhydrophytes disappeared from the region (*Alisma gramineum* Lejeune and *Damasonium alisma* Mill. var. *compactum* (CAI). However, it seems that another four species have colonized the Lake, with varying degrees of success (Table 39). The current dominants are the macrophyte flora *Najas* spp. and these species which occurred in Nubian waters pre- 1964. *Potamogeton crispus* and *P. pectinatus* are common species in the River Nile and Aswan Reservoir, but now appear to be absent from Lake Nasser (Ali 1992). *Zannichellia palustris* remains confined to the area of the Nile Valley now filled by Lake Nasser, but *Vallisneria spiralis* is a fairly common plant in water bodies throughout Egyptian Nubia (Belal *et al*. 1992).

The construction of the Aswan high Dam, with the subsequent creation of new modified aquatic habitats for macrophyte growth in Egyptian Nubia, had a profound effect on the aquatic flora of the region. Although Lower Egypt probably retains, at present, its status as the more important area for aquatic plant growth, there is now a strong evidence for the existence of trends of increasing diversity and abundance of the freshwater macrophyte flora in Upper Egypt. (Belal *et al*. 1992).

Table 39 **Freshwater submerged macrophytes (flowering and non-flowering) species recorded in Egyptian Nubia pre- and post- completion of the Aswan High Dam (1962-1993).[Plates 1-5]**

Species	**Boulos (1966)**	**El-Hadidi (1976)**	**Abdallah *et al.* (1972)**	**Entz (1976)**	**Springuel & Murphy (1991)**	**Ali (1987)**	**Ali (1992)**	**Ali (1998)**
	1963-64	1963-64	1962-64	1972-74	1980-86	1984-86	1989-91	Personal communication
Alisma gramineum	+	+	-*	-	-	-	-	-
Damasonium alisma	+	+	-	-	-	-	-	-
Potamogeton crispus	+	+	+	-	+	+	+	+
Potamogeton pectinatus	+	+	+	+	+	+	-	-
Potamogeton perfoliatus	+	+	+	-	-	-	-	-
Potamogeton trichoides	-	-	-	-	+	+	-	-
Potamogeton lucens	-	-	-	-	-	-	+	+
Potamogeton nodosus	-	-	-	-	+**	-	-	-
Zannichellia palustris	+	+	+	-	+	+	+	+
Vallisneria spiralis	-	+	-	+	+	+	+	+
Najas minor	-	-	-	-	+	-	-	-
Najas horrida	-	-	-	-	+	+	+	+
Najas marina	-	+	-	+	+	+	+	+
Chara sp. (misidentification)	-	-	-	+	+	-	-	-
Nitella hyalina (macroalga)	-	-	-	-	-	-	+	+
Myriophyllum spicatum	-	-	-	-	-	-	-	+

* = not recorded ** absent by 1986

Succession of macrophyte species and community distribution in Lake Nasser (1988-1990)

Studies on Lake Nasser showed that it is a fairly hard-water, eutrophic lake. It seems that several of the euhydrophyte species present are associated with eutrophic conditions, including *Zannichellia palustris,* and *P. crispus.* Others, including *Vallisneria spiralis* and *Najas* spp., may be less well adapted to survival in the productive environment of Lake Nasser, where competition-tolerance strategy traits will be an advantage (Springuel & Murphy 1991).

Springuel & Murphy (1991) studied the seasonal growth and distribution of euhydrophytes in Lake Nasser and River Nile, and pointed out that *Najas horrida, N. armata* and *Potamogeton pectinatus* displayed a spring/summer decline in abundance with autumn and winter peaks of production. Furthermore the depth distribution in the Lake showed differential colonisation of different zones by individual species. The shallow zone in the Lake (0-0.5 m) was preferentially occupied by *Zannichellia palustris,* in the areas where this species was present (approximately 27% of the Lake shoreline). The less common *Potamogeton pectinatus* and *P. trichoides* occurred preferentially at intermediate depths (0.51-1.00 m). However, these species also occurred within this zone with *P. trichoides* penetrating, at a few sites, as deep as 1.5 m. The remaining species which include the principal dominants of the Lake macrophyte community, occur in all depths from the surface to 3.00 m. No species preferentially occurred in water deeper than 1.00 m in Lake Nasser.

Records of the euhydrophytes at 16 sites along the Lake (Fig. 66 and Table 40) between 1988 and 1990 indicated the dominance of *Najas marina* subsp. *armata* and *Najas horrida. Potamogeton lucens,* found in Lake Nasser only at Kalabsha, was previously incorrectly identified as *P. nodosus* (Springuel 1985b, Springuel & Murphy 1991).

Effect of water level on aquatic macrophytes of Lake Nasser

Habitat disturbance appears to be an important factor influencing the macrophytes of Lake Nasser with the fluctuations of the water level being the most important factor. Springuel *et al.* (1991) carried out a comparative study on the species composition and growth of aquatic macrophytes in Lake Nasser, Aswan Reservoir and the River Nile itself, downstream of the old Dam, as they have major differences in physical conditions, notably in water level and fluctuation regime. In Lake Nasser there is an annual cycle of water level change related to the seasonal flood pattern of the River Nile. In Aswan Reservoir, mean monthly water levels are relatively constant, although there is a diurnal range of about 3 m related to the daily pattern of inflow through the High Dam turbines.

Table 40 **Dry weight standing crop (g/m^2) of euhydrophytes in shallow and deep water zones during 1989 at 16 sites in Lake Nasser at various sampling times (Ali 1992).** [For localities refer to Fig. 66].

Zones & Species	Soliman	Mariya	Kalabsha (b)	El-Birba West	El-Birba East		Mirwaw West	Mirwaw East	Amada	Abu Hor		Kalabsha (a)	El-Madiq	Turgumi			
	16 Feb.	**17 Feb.**	**1 Oct.**	**11 May**	**11 May**	**2 Oct.**	**14 Feb.**	**14 Feb.**	**7 Sept.**	**12 Feb.**	**11 Feb.**	**6 Sept.**	**6 Sept.**	**4 April**	**1 Jan.**	**10 Oct.**	**3 Mar.**
Shallow Zone																	
N. marina	0.4	0.114	-	3.242	-	-	-	-	-	0.2	0.49	-	-	4.288	16.36	-	-
N. horrida	-*	-	-	-	-	-	1.127	10.86	-	-	-	-	0.005	-	-	-	-
Z. palustris	-	0.252	-	-	-	-	0.34	0.29	-	0.005	0.027	-	-	-	-	-	-
Deep Zone																	
N. marina	1.55	3.51	16.263	12.53		0.011	1.171	3.94	-	2.801	0.81	0.04	0.331	1.0	13.46	7.192	31.591
N. horrida	-	-	0.094	4.41		28.11	-	-	0.963	-	-	4.563	0.045	-	-	-	-
Z. palustris	-	-	-	-		-	0.199	-	-	0.373	-	-	-	-	-	-	-
V. spiralis	-	-	0.008	-		-	-	-	5.423	-	-	-	0.803	-	-	-	-
P. lucens	-	-	3.899	-		-	-	-			-	-	-	-	-	-	-

***(-)=not recorded**

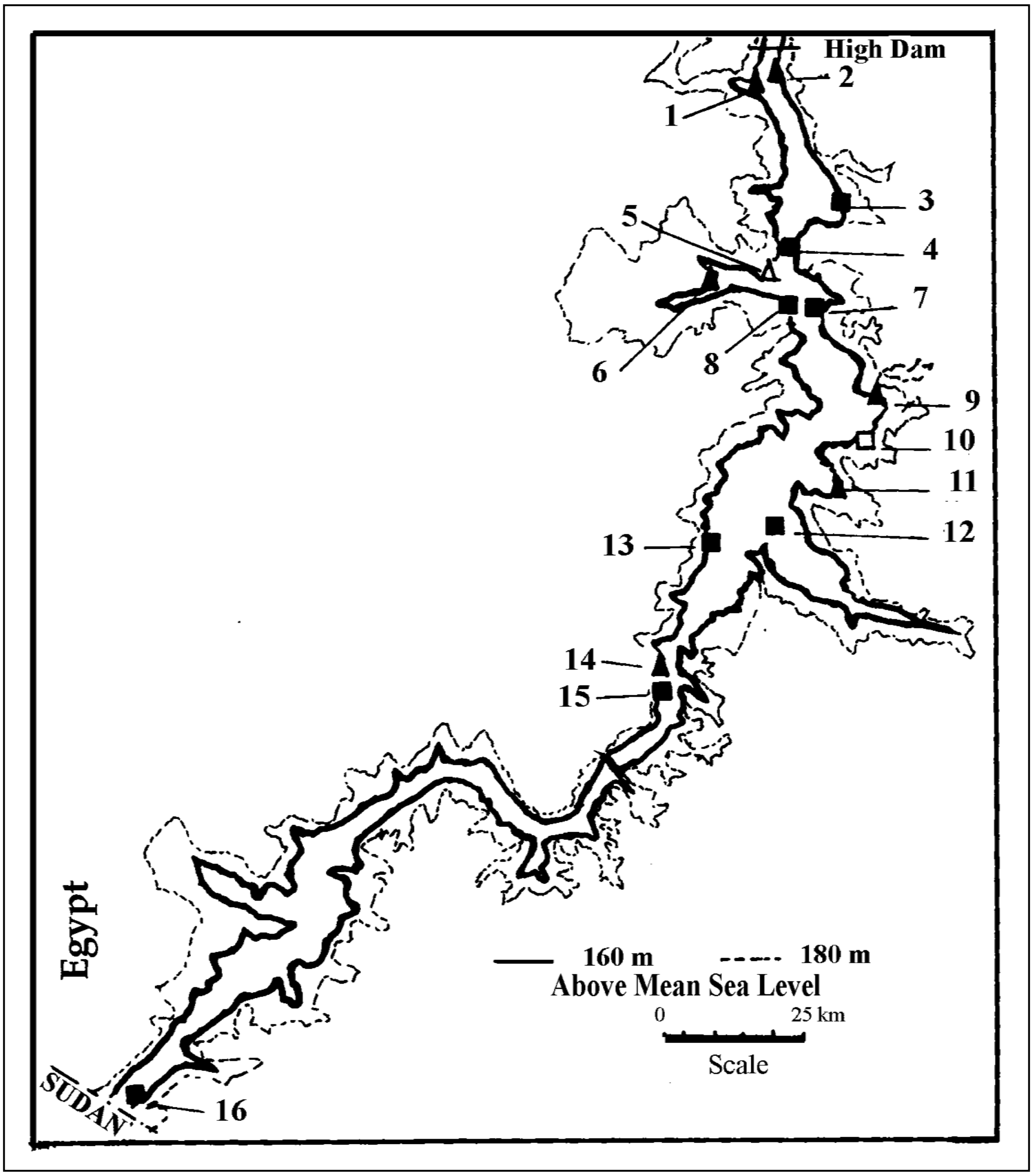

Fig. 66 **Outline map of Lake Nasser showing sampling sites (▪) and selected sites used (▲), 1: El-Birba West, 2: El-Birba East, 3: Abisco, 4: Abu Hor, 5: Kalabsha (a), 6:Kalabsha (b), 7:Mirwaw East, 8:Mirwaw West, 9: Soliman, 10:Mariya, 11:Turgumi, 12: Allaqi, 13:Kourta II, 14:Amada, 15:El-Madiq, 16:Adindan (Ali 1992).**

There were major differences in community dominance between the three systems. *Najas marina* subsp. *armata* dominated the highly disturbed littoral zone of Lake Nasser, making up nearly 40% of the total standing crop. Other species present were *Najas horrida, Vallisneria spiralis* and Charophyta. However, in both Aswan Reservoir and River Nile, the dominant species were *Ceratophyllum demersum* (comprising 59-78% of total standing crop) and *Potamogeton crispus* (15-20% of total crop). In terms of relative standing crop these species virtually excluded all others from the reservoir, but in the river approximately 25% of the total submerged standing crop was made up of other species, notably *Potamogeton perfoliatus* and *Myriophyllum spicatum*. It is suggested that the High Dam represents a major vegetation boundary in the River Nile ecosystem.

Ali *et al.* (1995) found that peak growth in the shallow water zone tended to occur following inundation or reinundation of sites by rising water levels, following exposure of sites. This produced a discontinuous distribution, over the time, of short established-phase submerged macrophytes, with a long period when no plants are present. In contrast macrophytes are always present in the deeper zone. There are geographical differences in distribution. *Najas horrida* was dominant in the northern section of the Lake (El-Birba - Fig. 66). Further south, *Najas marina* dominated the aquatic community at Turgumi and Kalabsha (in the middle section of Lake Nasser). At the southernmost site, Amada (west bank) *Najas* spp. were largely replaced by *Vallisneria spiralis,* as a dominant species, occurring at the only site with a fine sand hydrosoil. In May 1989 *N. marina* subsp. a*rmata* became more abundant and reached its highest biomass of 507.44 g/m^2 (Table 41).

Table 41 **Dry biomass (g/m^2) of euhydrophytes and macroalgae in the shallow water zone at Turgumi, Lake Nasser (Ali 1992).**

Species	April 1989	May 1989	July 1989	May 1990
Najas marina	114.87	507.44	120.94	47.93
Najas horrida	---	---	---	50.37
Nitella hyalina	103.12	54.30	---	37.55
Zanichellia palustris	---	---	---	1.25

ALGAE

PHYTOPLANKTON

The formation of Lake Nasser was accompanied by structural and physico-chemical changes which consequently affected the river biota. These changes lead to corresponding qualitative and quantitative alterations in the composition of the phytoplankton community.

Species Diversity

The community of planktonic algae in Lake Nasser is fairly diverse, belonging mainly to four divisions: Chlorophyta, Bacillariophyta, Cyanophyta and Pyrrophyta. Samaan (1971) recorded 27 species, while Latif (1974b) mentioned only 20 species. Zaghloul (1985) recorded 43 species, while Mohamed, *et al.* (1989) recorded 50 species belonging to the four divisions (Table 42).

Table 42 **Inventory of phytoplankton species recorded from Lake Nasser from 1981 to 1993. [PLATES 6-12]**

Taxa & Species	1981 Zaghloul (1985)	1982/84 Mohammed, *et al* (1989)	1993 Abdel-Monem (1995)
CHLOROPHYCEAE			
Palmellaceae			
Asterococcus limneticus (Cienkowski) Scherffel	-	-	+
Chlamydocapsa planctonica W. & G.S.West (=*Gloeocystis planctonica* G.gigass Kütz. Lage)	-	+	+
Coelastraceae			
Chlorococcum aegyptiacum **Archibald** **(=*Cholorella* Beijerinck)**	-	-	+
Coelastrum microsporum **(Nägeli) var. *microsporum*** **(=*C. robustum* Haz. 1964, *Chlorella regularis* Oltm 1904)**	-	+	+
C. reticulatum (Dangeard) seen var. *reticulatum* (= *C. distans* Turn. 1982)	-	-	+
Desmidiaceae			
Cosmarium contractum **(Kirchner)**	-	-	+
C. depressum **Lundell**	-	+	-
C. subtumidum **Nadst.**	+	-	-
Staurastrum paradoxum **Meyen**	+	-	+
S. tetracerum **Ralfs**	-	-	+
S. uniseriatum **Nyg.**	-	+	-
Closterium venus **Kütz.**	-	+	-
Dictyosphaeriaceae			
Dictyosphaerium elegans **Bachmann**	-	-	+
D. ehrenbergianum **Nägeli**	-	-	+
D. pulchellum **Wood**	+	+	+
D. subsalitarium **Van Goor** **(=*Dictyosphaerium primarium* = *D. simplex* Skuja)**	-	-	+
Micractinaceae			
Golenkinia radiata Chodat	-	+	+
Oocystaceae			
Ankistrodesmus falcatus (Corda) Ralfs	+	+	+
A. fusiformis Corda	-	-	+
Lagerheimia citriformis (Snow) G.M.Smith (=*Chodatella citriformis* Snow)	-	-	+
L. ciliata (Lager.) Chodat. (= *Chodatella ciliata* Lagerh. Lemm.)	-	+	+
L. longiseta (Lemm.) Wille (=*Chodatella longiseta* Lemm.)	-	-	+
L. quadriseta (Lemm.) G.M. Smith	-	-	+

(=*Chodatella quadriseta* Lemm.)			
***L. subsalsa* Lemm.**			
(=*Chodatella susbsalsa* Lemm.)	-	-	+
***Monoraphidium minutum (*Nägeli) Komm. Leg.**			
(= *Selenastrum minutum* Nag. Collins)	-	-	+
***M. contortum* (Thuret) Komm.**			
(=*Ankistrodesmus falcatus* var. *duplex* Kütz.	-	-	+
=*A. f.* var *spirilformis* G.S. West)			
***M. convolutum (*Cord*)* Komm**.			
(=Ankistrodesmus convulutus C*orda)*	-	-	+
***M. griffithii* Berk. Komm.**			
(=*Ankistrodesmus acicularis A*. Braun.	-	-	+
Korsh. = *A. f.* var *acicularis* Braun)			
M. komarkovae Nygaard	-	-	+
(=*Ankistrodesmus facatus.* var *setiformis* **Nyg.)**			
***Oocystis* sp.**	+	-	-
***Oocystis lacustris* Chodat**	-	-	+
***O. borgei* Snow**	-	+	+
***O. elliptica* W. West**	-	-	+
***O. parva* W. & G. S. West**	-	-	+
***Closteriopsis longissima* Lemm.**	-	+	+
***Franceia* sp.**	-	+	-
***Kirchneriella microscopica* Nyg.**	-	+	-
***Tetraedron minimum* (A. Br.) Hansg.**	-	+	-
Hydrodictyaceae			
***Pediastrum duplex* Meyen**	-	+	-
***Pediastrum duplex* var. *gracillium* W. & G. S. West**	-	-	+
***P. simplex* Meyen**	+	+	+
(= *P. clathratum* Sch. Lemm.)			
***P. simplex* var. *biwaense* Fukush.**	-	-	+
***P. simplex* var. *radians* Lemm.**	+	-	-
***P. boryanum* (Turipn) Menegh.**	+	-	-
***Planktosphaeria gelatinosa* G.M.Smith**	-	-	+
Characiaceae			
***Schroederia setigera* (Schroed.) Lemm.**	-	+	-
Scenedesmaceae			
***Crucigenia quadrata* Morren**	-	+	-
***Scenedesmus arcuatus* Lemm.**	-	+	-
***S. bijugatus* (Turp.) Kütz.**	+	-	-
***S. diamorphus* Turp.**	+	-	-
***S. quadricauda* (Turp.) Brèb.**	+	+	-
***S. obliquus* (Turp.) Kütz.**	-	+	-
***Actinastrum hantzschii* Lagerh**	+	-	-
Zygnemataceae			
***Spirogyra* Link.**	+	-	-
--			
	-	+	+
	-	+	-
	+	-	+
	+	+	-
	-	+	-
Chroococcaceae			
***Chroococcus minutus* (Kütz.) Näegeli**	-	-	+

C. dispersus (Keissler) Lemmermann	+	-	+
C. limnetica Lemm.	-	+	+
C. turgidus (Kütz.) Nägeli	-	-	+
Dactylococcopsis sp.	-	+	-
D. acicularis Lemm.	+	-	-
Gomphosphaeria lacustris Chodat (=*G. littoralis* Hayren)	+	+	+
G. lacustris var. *compacta* Lemm. (= *G. compacta* Lemm.Strom.)	-	-	+
Merismopedia warmingiana Legerheim (=*M. tenuissima* Lemm.)	-	-	+
M. minima Beck.	-	-	+
M. punctata Meyen.	+	-	+
M. tenuissima Lemm.	-	+	-
Microcystis aeruginosa Kütz (= *M. flos-aquae* Witt. Kir.)	+	-	+
M. wesenbergii (Komarek) Starmach	-	+	-
M. elachista W. & G. S. West Starmach (=*Aphanocapsa elachista* W. & G. S. West)	+	-	+
M. grevillei Hassal Elenkin (=*Aphanocapsa gravillii* Hass Kabenhorst)	-	-	+
M. rainbaldii Richter Forti (=*M. holsatica* Lemm. = *M. pulverea* Wood Forti = *M. p.* var. *incerta* Lemm. Crow = *Aphanocapsa delicatissima* W. & G. S. West)	-	-	+

Oscillatoriaceae

Lyngbya limnetica Lemm.	+	+	+
Lyngbya sp.	-	-	+
Oscillatoria limnetica Lemm.	+	-	+
O. planctonica Wolosz.	+	-	+
Oscillatoria. sp.	-	+	+
Phormidium africanum Lemm.	-	-	+
P. mucicola Naum. & Huber.	-	-	+
P. tenue (Menegh.) Gom.	-	-	+
P. corium (Ag.) Gom.	-	-	+
Phormidium sp.	-	+	-
Spirulina laxissima G.S. West	+	-	-
Spirulina sp.	-	+	-

BACILLARIOPHYCEAE

Coscinodiscinaceae

Aulacoseria muzzanensis Meister Krammer (=*Melosira muzzanensis* Meister = *M. granulata* var *muzzanensis* Bethge)	-	-	+
A. granulata Ehre. Simonsen. (=*M. granulata* (Ehr.) Ralf = *M. lineolata* Gru.)	+	-	+
A. g. var. *angustissima* O. Müller Simonsen (=*M. g.* var. *angustissima* O. Müller)	+	-	+
A granulata. var. *valida* Hust.	-	-	+
Cyclotella ocellatus Pantocsek	-	-	+
C. glomerata Bachmann	-	-	+
C. kützingiana Thwaites	-	+	+
C. meneghiniana Kütz.	+	+	+
Melosira agassizii Ostef var. *malayensis* Hust.	-	-	+

M. nyassensis **O. Müller**	-	-	+
M. nyassensis **var** ***victoriae*** **O. Müller**	-	-	-
M. distans **var.** ***distans*** **(Ehr.)**	-	-	+
M. granulata **(Ehrbg.) Ralfs**	+	+	-
Stephanodiscus aegyptiacum **Ehr. (*S. nana* Meister)**	-	-	+
Fragilariaceae			
Synedra ulna **Ehrbg.**	+	+	+
S. tabulata **(Ag.) Kütz.**	+	-	-
Naviculaceae			
Diploneis sp.	-	+	-
Gyrosigma attenuatum **(Kütz) Rabenh.**	-	+	-
Navicula pupula **Kütz.**	-	+	-
N. radiosa **Kütz.**	-	+	-
Navicula sp.	+	+	-
Pleurosigma elongatum **Sm.**	+	-	-
Achnanthineae			
Cocconeis placentula **Ehrbg.**	+	-	-
Gomphonemataceae			
Gomphonema lanceolatum **Ehrbg.**	-	+	-
Amphora ovalis **Kütz.**	+	+	-
Cymbellaceae			
Cymbella tumidae (Bréb) **van Heurk**	+	+	-
Epithemia sorex **Kütz.**	-	+	-
Epithemia gibbrula **Ehrbg.**	+	-	-
Rhopalodia sp.	-	+	-
Nitzschiaceae			
Nitzschia microcephala **(Grun.)**	+	-	-
N. palea **(Kütz.) W. Sm.**	+	-	-
N. apiculata **Greg.**	+	-	-
Surirellaceae			
Surirella ovalis **Bréb.**	+	-	-
DINOPHYCEAE (PYRRHOPHYTA)			
Ceratiaceae			
Ceratium furcoides (Levander) **Langhans** (= ***C. hirudinella*** var. ***furcoides*** **Levander**)	-	-	+
C. hirundinella **Bergh.**	+	+	+
C. cornutum (Ehr.)	-	-	+
Gymnodiniaceae			
Gymnodinum lantzchii **Ütermöhl.**	-	-	+
Peridiniaceae			
Peridinium africanum **Lemm. Lif.** (=***P. intermedium*** **Thompson** = ***P. cinctum*** **O.F. Müller**)	-	-	+
P. inconspicüm **Lemm. F. Armatum**	-	-	+
P. pigmeum (Lin.) **Baurrelly**	-	-	+
P. wierejskii **Woloszynska**	-	-	+
P. willei **Huitfeld-Kass**	-	-	+
Peridinium. sp.	-	+	-
Peridiniopsis pygmaium (Lin.) **Bourrelly**	-	-	+
Glenodiniaceae			
Glenodinium sp.	+	-	-
EUGLENOPHYCEAE			
Euglena acus **Ehr.**	+	-	-

Note: Mohamed, I. (1993g) recorded also the genus *Microcystis* sp. (Cyanophyceae).

In 1993 Abdel-Monem (1995) recorded 84 planktonic algal species including 35, 23, 15 and 11 species of Cyanophyceae, Chlorophyceae, Bacillariophyceae and Dinophyceae, most of these were not recorded by previous investigators (Table 42). Although the number of species is high, only a limited number formed the main bulk of phytoplankton communities. Green algae contributed more genera to the phytoplankton than any other group. However, diatoms and blue-green algae were found to be alternatively the dominant groups. These two dominant groups exhibited seasonal, local and vertical variations along the main body of the Lake.

The total number of phytoplankton species recorded from Lake Nasser during the period 1981-1993 (Table 42) is 135 species belonging to five classes: 54 spp. of Chlorophyceae, 34 spp. of Cyanophyceae, 33 spp. of Bacillariophyceae, 13 spp. of Dinophyceae and 1 sp. of Euglenophyceae.

The components of the plankton community are comparable to those in the White Nile between Khartoum and Gebel Aulia Dam (Brook & Rzóska 1954, Talling 1957a, Abu-Gideiri 1969, Talling 1976b), the Blue Nile (Talling & Rzóska 1967), some Central East African waters such as Lake Kyoga (Evans 1962), Lake Victoria (Talling 1957b and 1976b) and Lake Belwood (Duthie 1968).

Phytoplankton Standing Crop

The phytoplankton community in Lake Nasser is rich both in numerical density and biomass.

Density. Numerically, Bacillariophyceae and Cyanophyceae are the main components, while Dinophyceae, Chlorophyceae and Euglenophyceae persisted as frequent or rare forms. Thus, in 1993 Abdel-Monem (1995) found that the annual averages of Cyanophyceae ranged from a maximum of 83.7% forming a major peak in autumn and a minimum of 21.8 %, in winter. Following the Cyanophyceae, Bacillariophyceae constituted 76.7 % of the total crop in winter, and a minimum (13.3 %) in autumn. Chlorophyceae occupied the third predominant group with population densities ranging from 20.6 % in spring to a minimum of 2.1 % in winter. Dinophyceae being the least represented in number of species and density, they ranged from 1.4 % in spring to nil in winter.

Samaan & Gaber (1977) mentioned that because the flood-affected regions of the Lake exhibit different characteristics from the areas beyond the reach of the flood, the phytoplankton was different in terms of number and types at different periods of the year. Gaber (1982) pointed out that in October

1979 Cyanophyceae constituted 81.23 % of the total phytoplankton community (average $2.52x10^6$ algal units/l), while Bacillariophyceae formed 13.86% by number (average $0.43x10^6$ algal units/l). The percentage of Cyanophyceae increased from the High Dam to Amada (91.72 %), and reached its maximum value (95.57 %) in Khor Singari. Then it decreased gradually from Tushka to Adindan where it reached 31.05%. The average number of diatoms remained low between the High Dam and Amada, but showed a rapid increase from Tushka to Adindan (Gaber 1982). Chlorophyceae in the Lake remained low, as they constituted only about 4.9 % by number of the total phytoplankton (average $0.152x10^6$ units/l). Generally, Chlorophyceae were concentrated in the northern part of the Lake. The highest percentage was observed in Khor Kalabsha and decreased in the southern part and reached the least percentage in Tushka ($0.054x10^6$ algal units/l) and in Khor Or ($0.016x10^6$ algal units/l) (Gaber 1982). The Dinophyceae were rarely represented in the Lake by *Peridinium* sp. and in average numbers of 500 unit/l, contributing only about 0.01% of the total community (Gaber 1982).

Latif (1984b) showed that in March and August 1976, the phytoplankton in Lake Nasser, was in the range of 3.2 to 11.5 $x10^6$ algal units/l and 4.7 to $9.5x10^6$ algal units/l respectively (Fig. 67). Variations in the number and percentage of phytoplankton at different stations along the main channel of Lake Nasser (1976) show that the northern 100 km had a higher number of phytoplankton in August than in March (Latif, 1984b -Fig. 67). At the same time, the central part of Lake Nasser, extending from El-Madiq to Amada, did not show great changes in the number of phytoplankton cells. The region from Tushka to Adindan showed the widest difference. The latter author pointed out that during flood time (August) flood waters push ahead great amounts of phytoplankton to the northern part of the Lake, thus resulting in the highest figures recorded throughout the year. Nevertheless, due to riverine conditions, Adindan presented lower values in August than in March.

Latif (1984b) pointed out that in August 1976, cyanophytes were the most common, as their percentage ranged from 87.4 to 96.4% (average 94.3%); while diatoms formed only 2.7% (range 1.1 to 9.0%). From the High Dam to Amada, cyanophytes were more common than diatoms and their percentage varied from 71.2 to 89.0%. However, at Tushka and Adindan, cyanophytes comprised a very small percentage, i.e. only 7.0 and 0.9%, respectively, and in contrast diatoms constituted the major part of phytoplankton forming 92.3 and 98.6%, respectively (Latif 1984b). Chlorophytes did not show wide differences and were of low magnitude, i.e. 0.5 to 3.0% of the total numbers in March, and 2.2 to 3.6% in August. Thus, in the post-flood season, diatoms form the most common phytoplankton in the areas affected by the flood (Fig. 67-Latif 1984b).

Based on the observations of Zaghloul (1985) and Abdel-Monem (1995) the specific variations of phytoplankton in Lake Nasser may be summarized as follows:

1- The standing crop of phytoplankton tended to increase southwards from $3.405\text{x}10^6$ algal units/l at El-Birba to $15.272\text{x}\ 10^6$ algal units/l at Adindan.

2- The density of the phytoplankton standing crop was $6.258\text{x}10^6$ algal units/l in the surface water. This value decreased to $2.08\text{x}10^6$ algal units/l at 20 m depth (Zaghloul 1985). These values coincide with those obtained in 1993 by Abdel-Monem (1995) who showed that the average seasonal annual density at subsurface waters was of $1.017\text{x}10^6$ and $0.918\ \text{x}10^6$ algal units/l at 15m depth and $0.984\ \text{x}10^6$ near the bottom at 6 sites in the main channel. It seems that the difference in density in different years may be attributed to the limited number of samples collected at different localities.

3- Bacillariophyceae contributed 50.06% by number to the total phytoplankton. They were represented mainly by *Melosira* sp., which constituted numerically over 99% of the total diatoms. Other genera of frequent distribution included *Synedra* and *Nitzschia* spp. Seven species were of rare occurrence (Zaghloul 1985). Abdel-Monem (1995), however, pointed out that diatoms in the main channel were mainly represented by *Aulacoseria granulata, Aulacoseria granulata* var. *angustissima, Melosira nyassensis* var. *victoriae* and *Cyclotella ocellatus.* Other species of infrequent occurrence were: *Aulacoseria muzzanensis, Melosira agassizii, Cyclotella meneghiniana* and *C. glomerata.* Most of these species were not recorded by earlier authors.

4- The seasonal variations of Bacillariophyceae varied between the northern and southern sectors as well as in the khors. Generally, their maximum frequency was recorded in the southern region of the Lake in summer.

5- Cyanophyceae contributed numerically 47.45% of the total phytoplankton, with annual averages of $3.146\text{x}10^6$ algal units/l in the surface water and $0.813\text{x}10^6$ algal units/l at 20 m depth. *Anabaenopsis* was the dominant genus constituting about 93.41% of the total cyanophytes. Other genera with frequent occurrence comprised *Dactylococcopsis, Microcystis* and *Merismopedia* spp. In 1993 the main species recorded by Abdel-Monem (1995) were *Microcystis aeruginosa, Chroococcus limnetica, Lyngbya limnetica, Oscillatoria limnetica* and *Phormidium africanum.* The less abundant species were *Chroococcus minutus, Merismopedia punctata, Microcystis grevillei, Oscillatoria planctonica* and *Phormidium tenue.*

Glenodinium sp. was the main representative of Dinophyceae. Its main occurrence was confined to Khor Kalabsha in spring. Abdel-Monem (1995) reported that Dinophyceae were very rare in 1993 and contributed about

0.6×10^4 algal units/l representing 1.08% of the total phytoplankton crop. Their maximum occurrence was recorded in spring and summer while they were not recorded in winter.

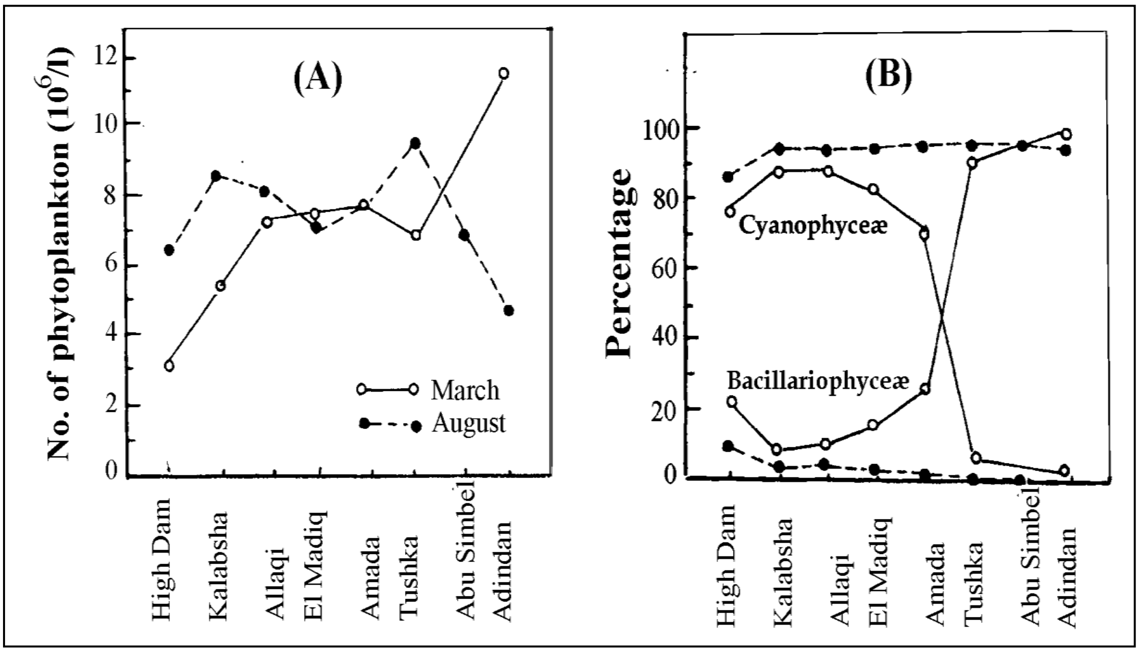

Fig. 67 **Phytoplankton at different stations along the main channel of Lake Nasser in March and August 1976. A: number of phytoplankton (10^6/l), B: percentage of Cyanophyceae and Bacillariophyceae (Latif 1984a).**

7- Chlorophyceae contributed 0.43% of the total phytoplankton crop in the Lake and consisted mainly of *Pediastrum* and *Staurastrum* spp. In 1993 Abdel-Monem (1995) showed that green algae formed numerically about 6.4×10^4 algal units/l representing 7.88% of the total phytoplankton crop. Their highest density was recorded in spring (16.9×10^4 algal units/l, 20% of the total count), and the lowest density in winter (1.9×10^4 algal units/l, 2.1% of total count).

Mohamed, I. (1993j) investigated the seasonal changes of vertical distribution of phytoplankton in the main channel of Lake Nasser and found that diatoms of genus *Melosira* contribute the highest number of cells in February, May, August and November 1990 (Fig. 69). This agrees with the observations of Zaghloul (1985).

Habib (1992b) found that in Khor El Ramla, the highest number of phytoplankton cells was recorded in August 1988 (5.13×10^4 units/l) and the lowest (0.32×10^4 units/l) in November 1986. Generally, all the stations in Khor El Ramla showed a slow increase from February to September and November (Fig. 72).

Biomass. Zaghloul (1985) summarized the biomass of phytoplankton collected from Lake Nasser as follows:

1- The phytoplankton biomass reached annual averages of 22.913 and 4.088 mg/l in the surface water and at 20 m depth, respectively. Results indicate that the biomasses of the different phytoplankton divisions were altered when compared with their numerical distribution.

2- The phytoplankton biomass increases southwards to the highest value of 45.065 mg/l at Adindan due to the increased numbers of Chlorophyceae and Bacillariophyceae. It showed also a different seasonal periodicity within the northern and southern sectors and khors, but reached its peak at most stations in spring and also at Adindan in winter.

3- Although numerous species were recorded in the Lake, yet few of them formed the main bulk of phytoplankton biomass with a specific distribution at the different localities. Thus, *Glenodinium* sp. was confined to Khor Kalabsha where it formed 95% of the total phytoplankton by weight . On the other hand, *Melosira granulata* and *Pediastrum* spp. were the main biomass components at Adindan.

Horizontal, vertical and seasonal distribution

The horizontal distribution of the total phytoplankton in the upper 10 m showed a marked increase from the High Dam (average $2.708x10^6$ algal units/l) to Kalabsha (average $3.440x10^6$ algal units/l). A slight drop was recorded at Allaqi (average $2.994x10^6$ algal units/l) (Table 43 and Fig. 68 - Gaber, 1982). Another gradual increase was recorded at El-Madiq, and this was succeeded by a rapid decrease in the total number of phytoplankton southwards, reaching the lowest value at Adindan ($0.948x10^6$ algal units/l). In 1993, Abdel-Monem (1995) studied the horizontal, vertical and seasonal variations of the phytoplankton standing crop in the main channel and found that the highest seasonal average was attained in winter ($1.327x10^6$ algal units/l), followed by autumn ($1.085x10^6$ algal units/l) and spring ($0.93x\ 10^6$ algal units/l). The lowest average value was recorded in summer being $0.729x\ 10^6$ algal units/l. The maximum standing crop ($5.92x\ 10^6$algal units/l) was recorded at Dihmit near the bottom, while the lowest was found in summer ($4x\ 10^6$ algal units/l) near the bottom at Tushka.

Khors sustained higher density of phytoplankton than the main stream; their numbers increased to $3.622x10^6$ algal units/l at Khor Kalabsha and $5.234x10^6$ algal units/l at Khor Singari (Table 43 and Fig. 68 - Gaber 1982).

Gaber (1982) recorded the vertical distribution of the total phytoplankton at the different stations in October 1979 as shown in Table 43. It appears that the phytoplankton profile remained, more or less, constant at the northern section of the Lake i.e. from High Dam to Kalabsha. The distribution of phytoplankton at Amada showed relatively higher values at 3 m depth, mainly due to

Cyanophyceae. The number of phytoplankton at El-Madiq and Abu Simbel showed higher values at the surface when compared with that of the subsurface water. The maximum distribution of phytoplankton was recorded in Khor Singari at 1 m depth being 7.62×10^6 algal units/l (Gaber 1982 - Table 44).

Mohamed, I (1993j) carried out studies on the seasonal, vertical and horizontal distribution of the dominant phytoplankton species in the main channel of Lake Nasser (Figs. 69 and 70) at six stations. It was obvious that the highest number of diatoms (mainly *Melosira* sp.) was found during February and May 1990. In February 1990, *Melosira* spp. contributed the highest number of cells at all stations (Fig. 69), followed by *Oscillatoria* sp. (Cyanophyta) (Fig. 70), while *Navicula* spp. (Bacillariophyta) were found in the lowest number of cells and was recorded only at station 1 at depths 5, 10, 15 m (Fig. 70). *Staurastrum* sp. and *Ankistrodesmus* spp. (Chlorophyta) appeared at stations 2, 3 and 4 for both genera, and stations 5 and 6 for *Staurastrum* sp. (Fig. 70).

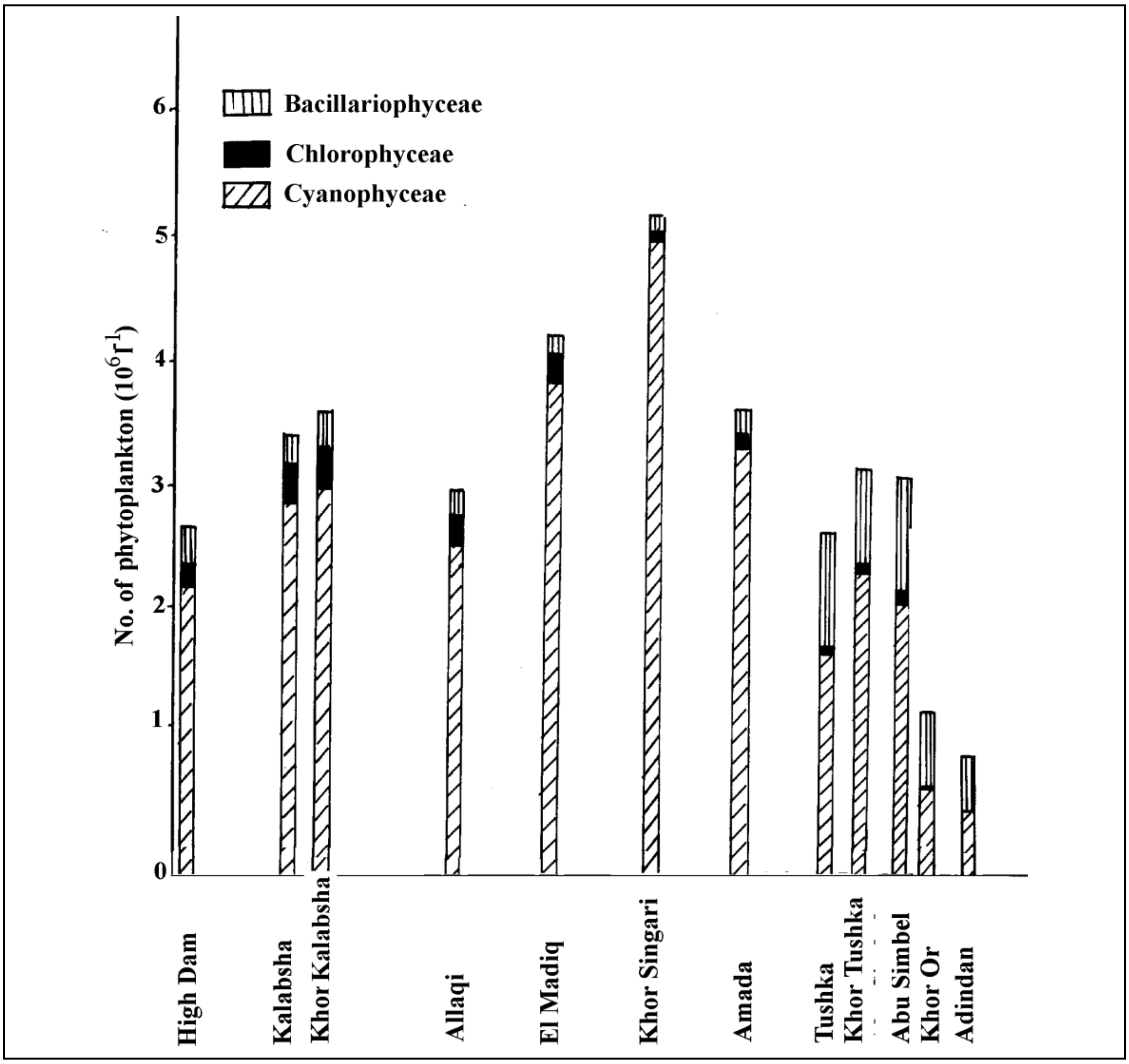

Fig. 68 **Distribution of phytoplankton density in Lake Nasser in October 1979 (Gaber 1982).**

Table 43 **Distribution of the different groups of phytoplankton (10^6 unit/l) in Lake Nasser and their percentage density to total population during October 1979 (Gaber 1982).**

Site	Cyanophyceae		Chlorophyceae		Bacillariophyceae		Dinophyceae		Total
	No.	%	No.	%	No.	%	No.	%	
High Dam	2.192	80.95	0.222	8.33	0.294	10.86	---*	---	2.708
Kalabsha	2.878	83.66	0.312	9.07	0.244	7.09	0.006	0.17	3.440
Khor Kalabsha	3.008	83.05	0.328	9.06	0.286	7.90	---	---	3.622
Allaqi	2.558	85.44	0.242	8.08	0.194	6.48	---	---	2.994
El-Madiq	3.872	90.84	0.228	5.40	0.160	3.76	---	---	4.260
Khor Singari	5.002	95.57	0.100	2.10	0.122	2.33	---	---	5.234
Amada	3.368	91.72	0.144	3.92	0.160	4.36	---	---	3.672
Tushka	1.716	62.67	0.054	1.97	0.968	35.35	---	---	2.738
Khor Tushka	4.404	74.50	0.078	2.47	0.746	23.08	---	---	3.232
Abu Simbel	2.148	67.84	0.092	2.91	0.926	29.25	---	---	3.166
Khor Or	0.652	51.34	0.016	1.26	0.602	47.40	---	---	1.270
Adindan	0.484	51.05	---	---	0.464	48.95	--	--	0.948
Average	2.523	81.23	0.152	4.90	0.430	13.86	500/1	0.01	3.107

* (--) not recorded.

In May 1990, *Melosira* sp. was recorded with the highest number of cells (Fig. 69). *Microcystis* sp. (Cyanophyta), *Cyclotella* sp. (Bacillariophyta) (Fig. 69) were represented by a high number of cells; while *Coelastrum, Staurastrum* and *Merismopedia* spp. (Figs. 69 and 70), *Peridinium* sp. and *Ceratium* sp. (Fig. 70) were recorded in the lowest number.

In August 1990, *Melosira* sp. was found in the highest number of cells and appeared at all stations except station 4 (Fig. 69). *Microcystis* sp. was recorded in all stations (Fig. 69) and *Scenedesmus* sp. only in station 1 (Fig. 70) and were present in high number of cells.

In November 1990, *Melosira* spp. and *Microcystis* spp. were recorded with the highest number of cells at all stations except station 1 (Fig. 69), while *Coelastrum* sp. was observed in high number (Fig. 70). The other genera except *Pediastrum* were found in lower number of cells (Figs. 69 and 70).

It is worth mentioning that phytoplankton in Lake Nasser revealed vertical variations during the periods of thermal stratification (late spring, summer and early autumn months). Diatoms and blue-green algae (Cyanobacteria) remained the dominant groups also in the lower layers. Moreover, *Cyclotella* sp. and *Anabaenopsis* spp. were the dominant genera in diatoms and blue-greens. Habib (1998a) pointed out that the percentage composition of blue-greens in 1991 dominated the community during spring and summer, being more tolerant to relatively high temperatures. Diatoms dominated the community once in winter (December).

Although oxygen concentration was always under the saturation level, the phytoplankton abundance in spring and summer was accompanied by high oxygen saturation levels, pH values and chlorophyll *a* concentrations (Belal *et al*. 1992). The latter authors found that the temporal course of algal development showed, more or less, the opposite trend to that of the dissolved nitrate-nitrogen (Table 45). Variations in time of the nitrate-nitrogen concentration, chlorophyll *a* and total phytoplankton populations are presented in Fig. 71.

Habib (1995c) in her investigation on the seasonal variation of phytoplankton at four stations in Khor El Ramla from September 1986 to December 1988 recorded three peaks in the total number of the population in November 1986, November 1987 and August 1988 (Fig. 72). The highest peak was recorded in August 1988 (5.13×10^4 algal units/l), and the lowest (0.32×10^4 algal units/l) in November 1986. Generally, all the stations showed a slow increase from February to September and November 1987 recording a second peak. The four stations showed the same trend of seasonal variation, recording a gradual decrease through autumn and winter. Generally, chlorophyll *a* peak always preceded or coincided with the peak of plankton numbers.

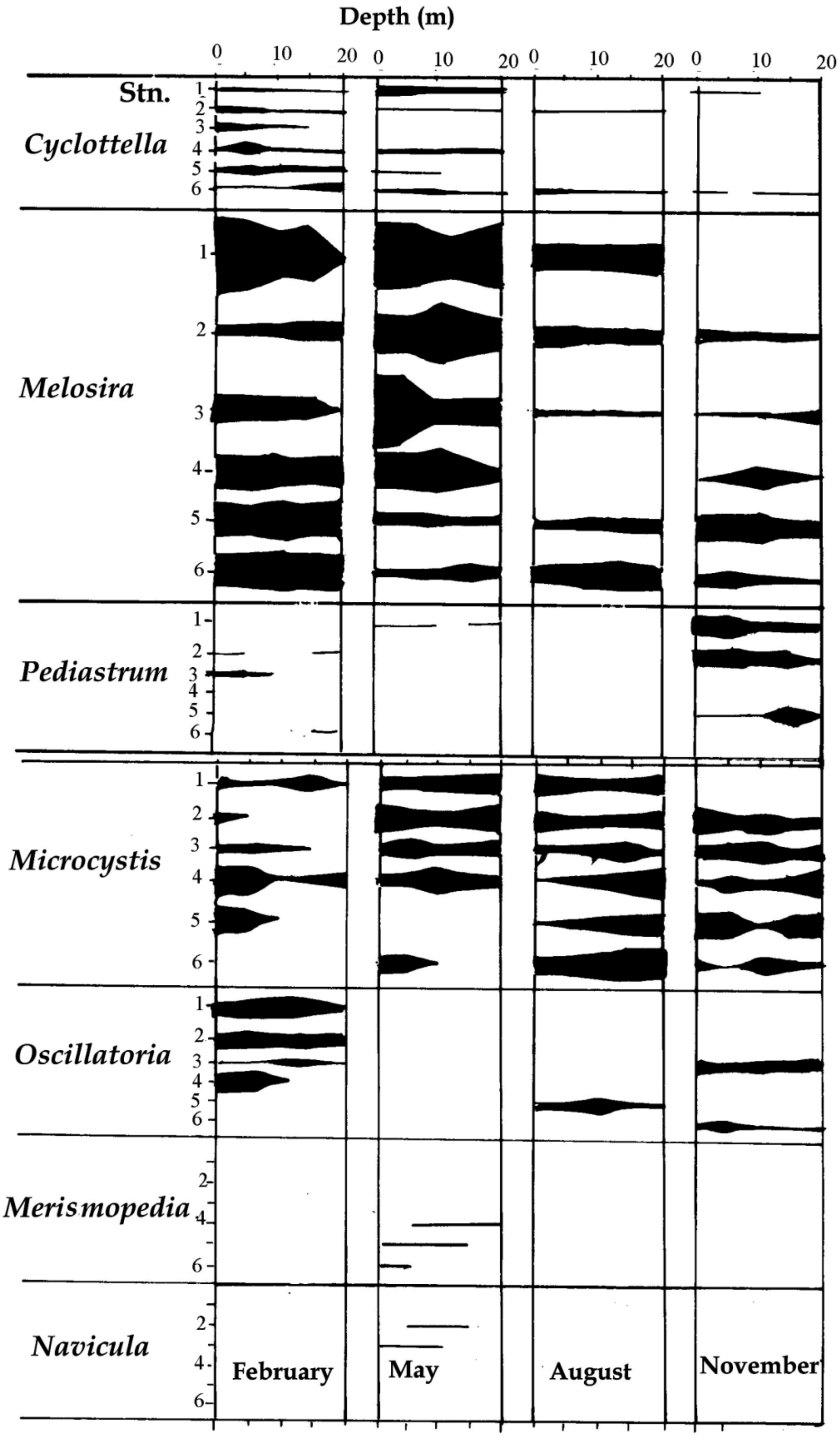

Fig. 69 **Seasonal changes of vertical distribution of phytoplankton in the main channel in 1990 (Mohamed, I. 1993j). Scale bar = 1000 cells/ml. [**For stations refer to Fig. 4**].**

Table 44 **Vertical distribution of the total number of phytoplankton (10^6 algal units/l) recorded at different stations during October 1979 (Gaber 1982).**

Site	Surface	1m	2m	3m	4m	5m	10m
High Dam	2.945	2.954	2.660	2.828	3.010	2.604	1.946
Kalabsha	4.536	3.024	3.738	3.416	3.346	3.006	2.954
Khor Kalabsha	3.584	3.598	3.024	3.374	4.046	2.884	4.844
Allaqi	2.940	3.430	3.584	2.884	3.234	3.094	1.792
El-Madiq	5.026	3.808	4.186	4.920	3.920	3.962	4.550
Khor Singari	6.132	7.602	6.622	4.884	3.990	3.374	4.634
Amada	4.088	4.410	4.284	4.970	2.618	3.024	2.310
Tushka	3.220	3.654	9.898	2.338	2.100	2.352	2.604
Khor Tushka	2.380	4.690	2.772	3.374	3.556	3.570	2.282
Abu Simbel	5.432	3.038	2.632	3.360	2.884	3.108	1.708
Khor Or	0.812	2.044	1.792	1.372	1.288	0.882	0.700
Adindan	0.658	9.980	1.008	1.120	1.008	1.134	0.728

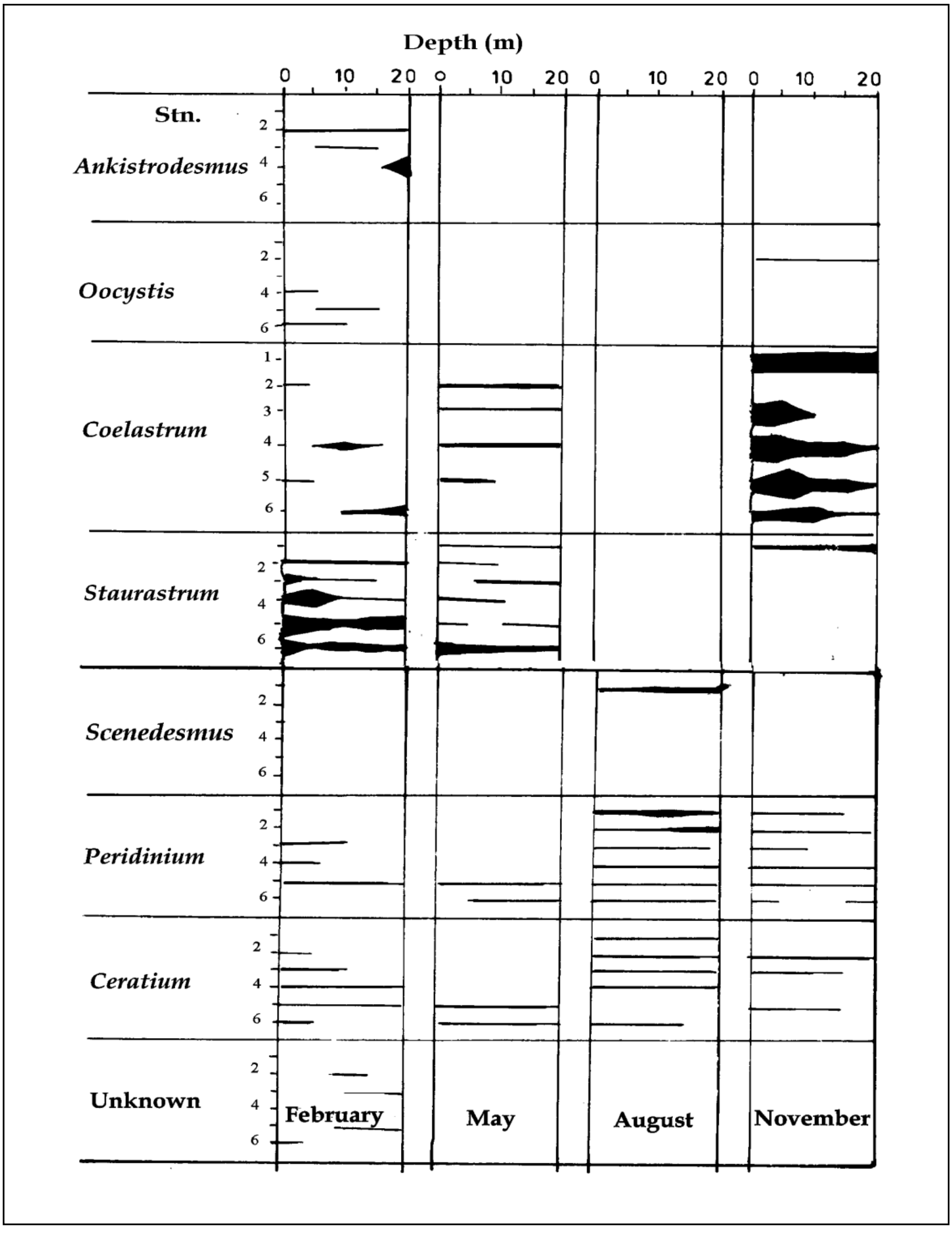

Fig. 70 **Seasonal changes of vertical distribution of phytoplankton in the main channel in 1990 (Mohamed, I. 1993j). Scale bar = 1000 cells/ml. [**For stations refer to Fig. 4**].**

Needless to mention that phytoplankton in Lake Nasser, at present, diatoms and cyanophytes (Cyanobacteria) preponderate along the main channel and even at all sites because both groups are well adapted to the new environmental conditions. All phytoplankton groups are responsible for primary production, which is the basis of food webs in Lake Nasser. Therefore, the phytoplankton could intensively influence the economy of such a man-made Lake. Hence, the recorded planktonic algae are considered as the major source of food for the plankton feeding fishes, which are the dominant species in the Lake.

WATER BLOOMS

Sometimes serious problems of unbalanced biological conditions arise in sluggish areas of Lake Nasser. Overgrowth of Cyanophyceae species causes floating crusts and scums, where plants die quickly and disintegrate in the intense sunlight. This causes depletion of oxygen below the point required for fish and other aquatic animals. Mohamed, I. (1993k) recorded the occurrence of water blooms in Lake Nasser eight times during six years (from 1987 to 1992) and pointed out that water blooms occurred only in very limited areas of the southern part of the Lake. Cyanophyceae species were found in all samples of blooms. *Microcystis aeruginosa* was the dominant species in all the samples of water blooms (Mohamed, I. 1993k) (Table 46). The latter author pointed out that *Oscillatoria* spp. were observed in extreme values at Korosko, while *Aphanocapsa* sp. was present in high quantities at Abu Simbel.

Recently, water blooms have been recorded in the central area of the Lake. Occassionally they were seen at Korosko in the northern area. Formerly *M. aeruginosa* water blooms occurred annually for several months before the flood water period, but now they may occur intermittently all the year round (Mohamed, I. & Ioriya, 1998).

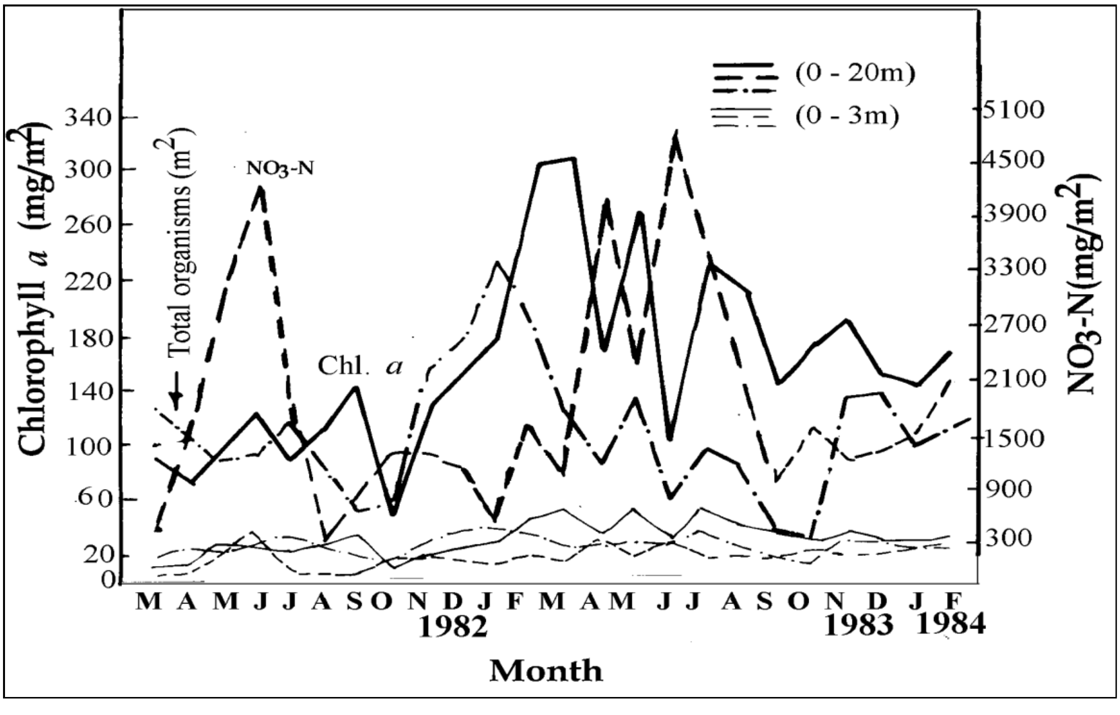

Fig. 71 **Depth-time distribution of NO$_3$-N ; chlorophyll *a* concentration and of total phytoplankton units under 1 m^2 down to a depth of 3 and 20 m in the Lake at site 1 (10 km south of AHD) [Mohamed *et al.* 1989].**

***Table** 45* **Temporal course of algal development and nitrate concentration by representation of higher, middle, and lower values from March 1982 to February 1984. (Belal *et al.* 1992).**

					1982											1983							1984	
	M	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**
Total algal count	●	•	•	•	●	•	·	·	●	●	●	●	•	•	●	-	●	•	·	·	●	●	•	●
Chlorophyll *a*	•	•	·	•	·	•	•	·	•	●	●	●	●	●	●	·	●	●	•	●	●	•	•	●
O_2 (% Sat.)	●	●	•	·	•	·	·	•	·	•	●	●	●	●	●	·	•	·	·	●	●	●	●	●
pH	--	●	•	•	●	•	•	·	·	·	•	•	•	•	●	·	●	•	·	•	•	·	·	·
NO_3.N	•	•	●	●	•	·	·	•	•	•	·	•	·	●	•	●	●	•	·	•	•	•	•	•

● maximum, •moderate, · minimum values, -- not measured.

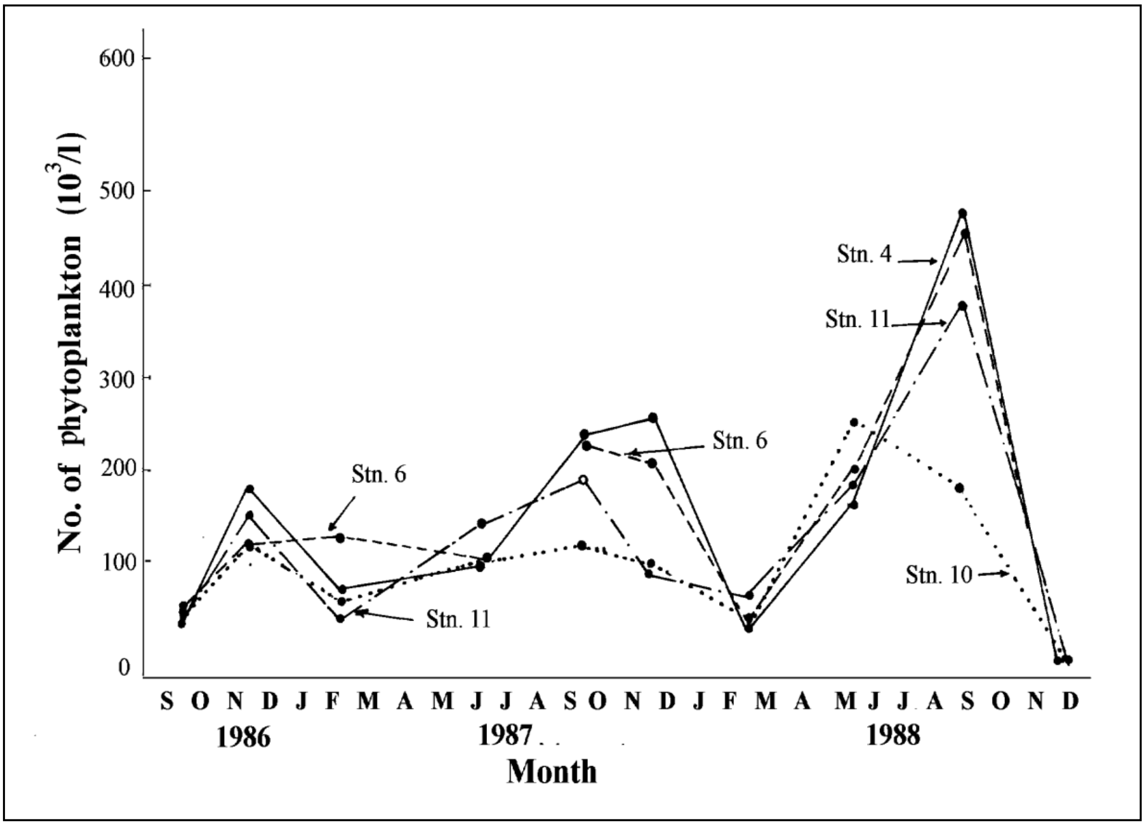

***Fig.** 72* **Seasonal variations of the total number of phytoplankton (algal units) at Khor El Ramla at four stations (Habib 1995c) [For stations refer to Fig. 4].**

CHLOROPHYLL *a*

The amount of chlorophyll *a* in water is an index of phytoplankton productivity and has been used to estimate the primary productivity in combination with data on photosynthetic activity on chlorophyll *a* basis and light conditions in freshwater lakes as well as in marine environments (Ichimura *et al.* 1962, Aruga & Monsi 1963). It will be possible to calculate primary productivity by phytoplankton in a lake on the basis of enough information on the photosynthetic and respiratory activities of phytoplankton and the diurnal and seasonal changes of light conditions.

Table 46 **Cell number of water blooms in Lake Nasser (Mohamed, I. 1993k) unit: cell/10 ml.**

		Genera								
Date	**Site**	*Micr.*	*Nost.*	*Anab.*	*Osci.*	*Phor.*	*Melo.*	*Apha.*	*Cycl.*	**Phot. Bac.**
Aug. 19, 1987	**Tushka**	4710	462	54	--	--	--	--	--	372
Aug. 19, 1987	**Abu Simbel**	5760	480	315	--	--	--	--	--	462
Aug. 16, 1988	**Korosko**	1322	129	--	196	--	---	--	--	654
Sep. 9, 1989	**Tushka**	2601	96	--	3957	105	--	--	--	261
Dec. 11, 1989	**El Seboui**	2337	--	--	--	324	156	--	--	--
Aug. 14, 1991	**Abu Simbel**	5661	216	165	129	54	--	--	--	309
Oct. 16, 1992	**Abu Simbel**	1017	--	--	215	--	189	109	9	--
Oct. 16, 1992	**Wadi El Arab**	2799	--	--	410	--	111	1110	24	--

Micr. : ***Microcystis aeruginosa*** *Nost.* : ***Nostoc* sp.**
Anab : ***Anabaena* sp.** *Osci.* : ***Oscillatoria* sp.**
Phor. : ***Phormidium* sp.** *Apha.* : ***Aphanocapsa* sp.**
Cycl. : ***Cyclotella* sp.** *Melo.* : ***Melosira* spp.**
Phot. Bact. : **Photosynthetic bacteria**

Many investigators studied the seasonal, horizontal, vertical and regional concentrations of chlorophyll *a* along the main channel of Lake Nasser as well as in some of the khors since the early stages of Lake Nasser filling (Fead 1980; Habib 1984, 1992a and b, 1996a, 1997; Habib *et al.* 1987; Mohamed, I. 1993a-c and 1996a and b; Abdel-Monem 1995). The results indicate that chlorophyll *a* concentration in the upper 8 m layer is high at the southern region compared with that at the northern region of the Lake. High chlorophyll *a* concentrations are recorded in the upper 8 m layer from March or April to October or November.

Usually, a stratified vertical distribution of chlorophyll *a* was observed in April-September, and a homogeneous vertical distribution in November-February. In the stratified distribution the subsurface chlorophyll *a* maximum was found at 2 m depth. The highest chlorophyll *a* concentration (42.4 mg/m^3) was recorded at the surface layer in January 1984 at stn. 4 (Koroska) (Habib & Aruga, 1996), while the lowest concentration (0.0 mg/m^3) was recorded at stns. 1 (El Ramla) and 3 (Allaqi) at 30 m depth in July and September 1992 (Mohamed, I. 1996b).

It seems that chlorophyll *a* shows seasonal changes with high values during the high temperature period and low values during the low temperature period. Furthermore, Secchi disk depth from 0.3 to 5.5 m, being high during low temperature period and low chlorophyll *a* concentration; and low during high temperature period and high chlorophyll *a* concentration. A summary of the results of some investigators is shown in Tables 47, 48, and 50 -52.

The relationship between chlorophyll *a* concentration and Secchi disk depth obtained by various investigators in Lake Nasser and its khors (Habib 1996a, Habib *et al.* 1992 & 1996; Mohamed, I. 1993a-c, 1995a & b, 1996a & b) seems to be similar to those reported in other freshwater lakes (Ichimura 1961) and in marine waters (Ichimura & Saijo 1959, Saijo & Ichimura 1960, Shibata & Aruga 1982, Brandini & Aruga 1983).

I. The Main Channel

(a) Regional variations. The southern region of Lake Nasser (stations 4, 5 and 6 - Fig. 4) showed higher mean annual values of chlorophyll *a* concentration (about 12 mg/m^3) than the northern region (stations 1, 2 and 3) (about 8-11 mg/m^3). Fead (1980) recorded the highest concentration of chlorophyll *a* at Abu Simbel directly preceding the annual flood. This may be partly due to the supply of sufficient nutrient salts from upper stream of the Nile to the southern part of the Lake and to the flood waters which push ahead multitudes of phytoplankton to the southern part of Lake Nasser, thus resulting in the highest figures of chlorophyll *a* recorded through the year. Mohamed, I. (1992a, 1993a, 1995b and 1996b) studied the regional variation of chlorophyll *a* concentration along the main channel and its relation with the temperature and his results are shown in Table 47 and Figs. 73-75.

(b) Seasonal variations. No distinct seasonal variations of chlorophyll *a* concentration were observed in the northern stations (1-3), while stations 4-6 in the southern region of the Lake showed distinct seasonal variations. The highest chlorophyll *a* concentrations were recorded during summer and spring, while low chlorophyll *a* concentrations were found in autumn and winter (Table 48). The highest seasonal variations of chlorophyll *a* were recorded at the southern three stations, less at the northern three stations. Levels of chlorophyll *a* concentrations were generally high during the period of high water temperature (Table 47 and Figs. 73 - 75).

The seasonal changes of the average chlorophyll *a* concentration in the upper 8 m layer are illustrated in Fig. 76 (Habib & Aruga 1996). The results of the latter authors indicate that the levels of chlorophyll *a* concentration were generally high (1.0-24.0 mg/m^3) at stns. 4-6 at the southern region, and low (1.0-16.5 mg/m^3) at stns. 1-3 in the northern region of the Lake. The patterns of seasonal changes of chlorophyll *a* were similar among stns. 1-3 and among stns. 4-6, but the patterns at the latter stations were clearly different from those at the former stations (Fig. 76 C and D). The range of chlorophyll *a* variations was quite high at stns. 4-6 as compared with stns. 1-3. A rapid increase in chlorophyll *a* concentration was observed in July or August at stns. 4-6 in 1984, and stns. 4 and 5 in 1985 (Fig. 76-D). The same trends were also observed in spring-early summer at stns. 1-3 in 1984 and 1985, even though the increase was much less (Fig. 76-C). Chlorophyll *a* concentration was high during the period of high water temperature and low during the period of low water temperature at stns. 4-6 in 1984 and 1985.

Table 47 **Seasonal, vertical and regional variations of chlorophyll *a* concentration (mg/m^3) along the main channel of Lake Nasser.**

		Year of Investigation and Author						
		1982-83 Habib (1992a)	**1983-84 Habib (1992b)**	**1986-87 Mohamed I. (1993a)**	**1988 Mohamed I. (1993b)**	**1989 Mohamed I. (1993c)**	**1990 Mohamed I. (1995b)**	**1992 Mohamed,I. (1996b)**
Maximum Conc.	**Value**	27-24	26.8	28.2	27.2	26	22	17.2
	Stn.	4	5	3	6	5	6	5
	Depth (m)	0-10	--	--	10	30	10	0
	Date	Sept. 82	Aug. 84	Nov. 86	Jan.	Jan.	Aug.	Aug.
Minimum Conc.	**Value**	1.2	3.0	2.8	0.5	0.1	0.1	0.0
	Stn.	4,5,6	1	5	6	4	6	1.3
	Depth (m)	0-10	--	--	30	30	30	30
	Date	Nov. Dec. 82	Jan. 84	Feb. 87	Feb.	Aug.	July, Aug.	July, Sept.
Temp. (°C)	**From**	15.0	16.5	16.6	16.2	14.9	-	15.2
	Stn.	1	6	6	6	6	-	6
	Depth(m)	4	20	--	30	4	-	30
	Date	Feb. 83	Feb. 84	Jan. 87	Jan.	Feb.	-	--
	To	29.7	31.5	31.7	31.9	32.4	-	31.3
	Stn.	5	2	4	6	5	-	2
	Depth (m)	0.0	0	--	0	0	-	0
	Date	Sep. 83	July 84	Aug. 87	Aug.	Aug.	-	--
Transparency (range m)	**From**	-	-	0.3	0.4	0.4	0.6	0.3
	Stn.	-	-	6	6	6	6	6
	Date	-	-	Aug. 87	Sept.	Sept.	Sept.	Aug.
	To	-	-	5.8	5.3	5.4	6.1	5.8
	Stn.	-	-	1	1	1	6	1
	Date	-	-	Dec.	Dec.	March	Dec.	March)

For stations refer to Fig. 4. Stn. 1 (El Ramla), Stn. 2 (Kalabsha), Stn. 3 (Allaqi), Stn. 4 (Korosko), Stn. 5 (Tushka), Stn. 6 (Abu Simbel).

Figure 77 illustrates the seasonal changes of chlorophyll *a* concentration in the surface water and 2 m layer at stns. 1-6 along the main channel of Lake Nasser from September 1986 to December 1988 (Habib *et al*. 1996). The results show that the averages of chlorophyll *a* concentrations were slightly higher at stns. 4-6 (1-26 mg/m^3) than at stns. 1-3 (1-21 mg/m^3). The seasonal patterns of chlorophyll *a* concentration were similar among stns. 1-3 and among stns. 4-6, even though the patterns at stns. 1 and 6 were rather obscure as compared with those of other stations. The patterns at stns. 1-3 were different from those at stns. 4-6. The range of seasonal variations of chlorophyll *a* concentration was high at stns. 4-6 as compared with that at stns. 1-3.

Table 48 **Seasonal average of chlorophyll *a* concentration (mg/m^3) at various stations in the main channel from October 1983 to August 1984 (Habib 1992a).**

Season	**1**	**2**	**3**	**4**	**5**	**6**
Autumn	7.9	6.8	9.7	19.1	15.2	14.4
Winter	5.1	8.5	13.0	7.0	7.2	9.1
Spring	7.1	11.0	10.0	10.3	8.3	10.0
Summer	10.2	10.3	11.7	14.6	17.4	15.3

[For stations refer to Fig. 4].

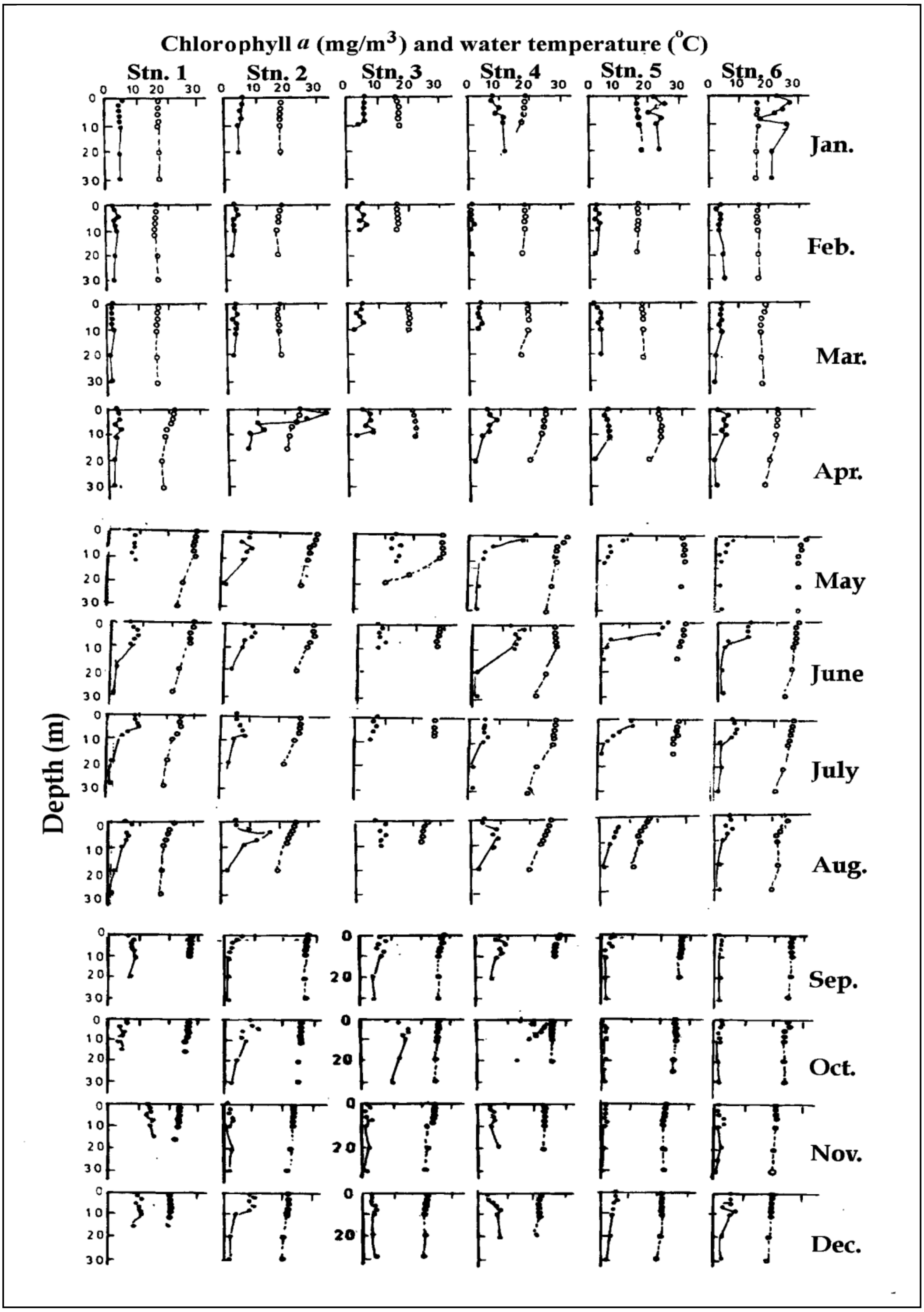

Fig. 73 **Vertical distribution of chlorophyll *a* concentration (•——•) and water temperature (o.......o) in the main channel of Lake Nasser during 1988 (Mohamed, I. 1993e). [**For stations refer to Fig. 4**].**

Chlorophyll *a* (mg/m^3) and water temperature (°C)

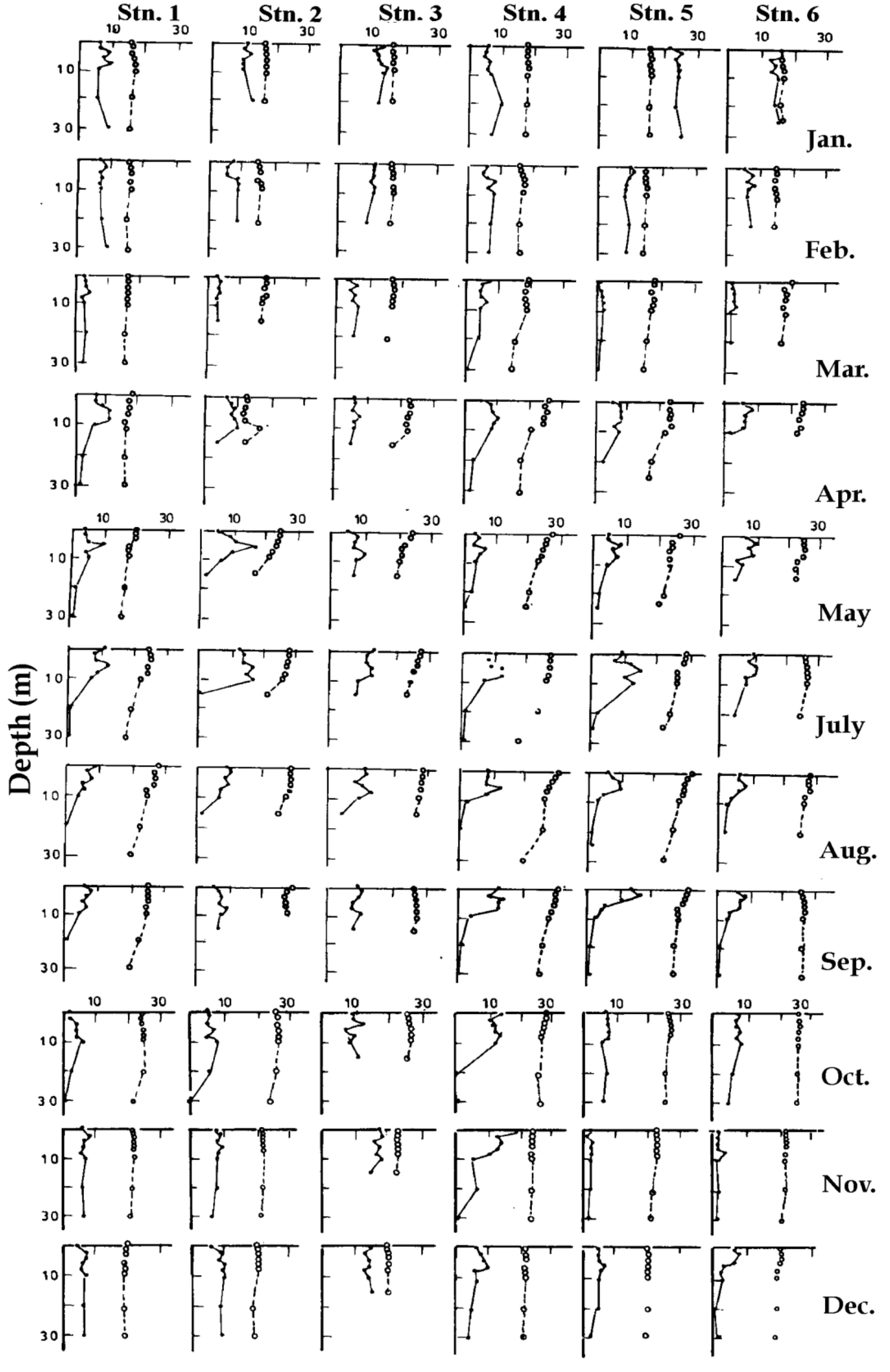

***Fig. 74* Vertical distribution of chlorophyll *a* concentration (•—•) and water temperature (o.......o) in the main channel during 1989 (Mohamed, I. 1993 g)** [For stations refer to Fig. 4**].**

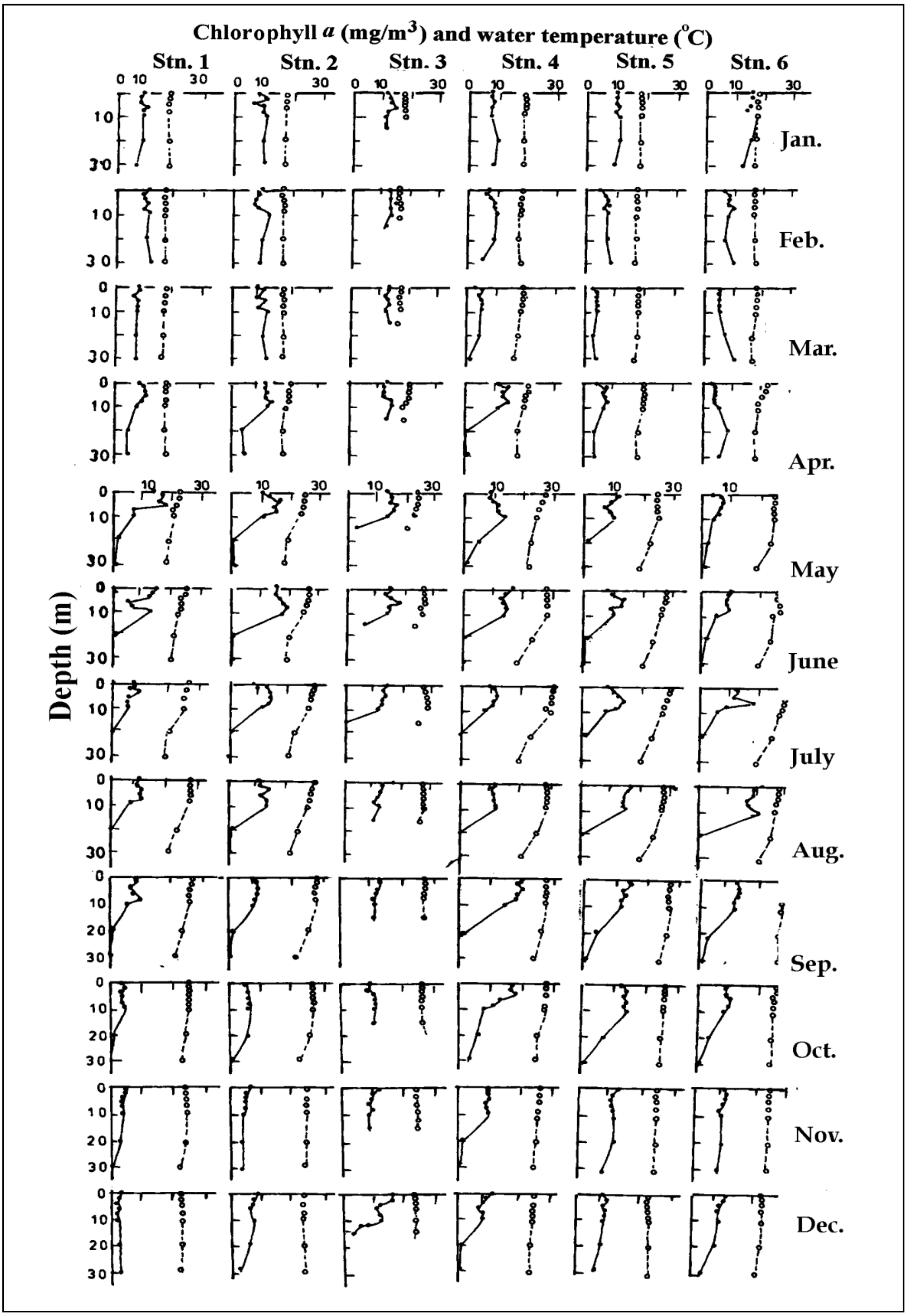

Fig. 75 **Monthly variations of chlorophyll *a* concentration (mg/m^3) and water temperature (°C) at six stations in the main channel during 1990 (Mohamed, I. 1995b). (Temperature: (o.......o) chlorophyll *a* : •—•)** [For stations refer to Fig. 4]**.**

(c) Vertical variations. High and homogenous values of chlorophyll *a* concentrations were recorded in the upper layers of the water column till 8 m depth. The highest values were recorded at 2 and 4 m depth because the photosynthetic activities of phytoplankton at the surface were inhibited by high light intensity of solar radiation. Thus, the highest production was obtained at about 2 m depth and gradually decreased with depth (Latif, 1974b); low values in deep layers up to 30 m were due to the depletion of light. This supports the previous conclusion of Fead (1980) that the concentration of chlorophyll *a* in Lake Nasser correlates with the depth of the euphotic zone suggesting that chlorophyll *a* is the main variable controlling light penetration into the non-flood waters of the reservoir.

In their study in October 1982 through December 1985, Habib *et al*. (1996) showed that the upper layer of the water column from the surface to a depth of 8 m showed high chlorophyll *a* concentrations; deeper layers usually contain less chlorophyll *a*. However, similar high chlorophyll *a* concentrations as in the upper layer were recorded in deeper layers at several stations in some months. Usually the homogenous type of vertical distribution was found in November through February coinciding with the low water temperature, while the stratified type in April through September coinciding with a clear thermocline which was observed during March to October (Ichimura 1961). The subsurface maxima of chlorophyll *a* were obtained mostly at depths 2-6 m during the period April-July. The observed maximum concentration of chlorophyll *a* was 57.6 mg/m^3 at 2 m in November 1984 at stn. 1.

The vertical distribution of chlorophyll *a* concentration along the main channel of the Lake during 1988 was studied by Mohamed, I. (1993e - Fig. 73 and Table 47). The highest concentration (27.2 mg/m^3) was recorded at 10 m depth of stn. 6 in January, and a high value (26.7 mg/m^3) was found at 30 m depth at stn. 6 in February. Mohamed, I. (1993g) recorded the highest concentration of chlorophyll *a* (26.0 mg/m^3) at stn. 5 at 30 m depth in January 1989, while the lowest concentration (0.1 mg/m^3) was recorded at stn. 4 at 30 m depth in August 1989 (Fig. 74 and Table 47). In 1996 (SECSF) the maximum value of chlorophyll *a* concentration in the main channel (23.95 mg/m^3) was recorded in summer at surface waters at Abu Simbel, and the minimum value (1.06 mg/m^3) was found at Kalabsha at 6 m depth. During winter there was an increase of chlorophyll *a* concentration in deeper water (5-7 m) as compared with surface water. At Kalabsha and Allaqi high concentrations were recorded compared with other localities during the same season.

Relationship between chlorophyll *a* concentration and Secchi disk depths. The relationships between chlorophyll *a* concentration and Secchi disk depth in the surface water and 2 m-layer at stns. 1-6 in the main channel of Lake Nasser during the period from October 1983 to December 1985 are shown in

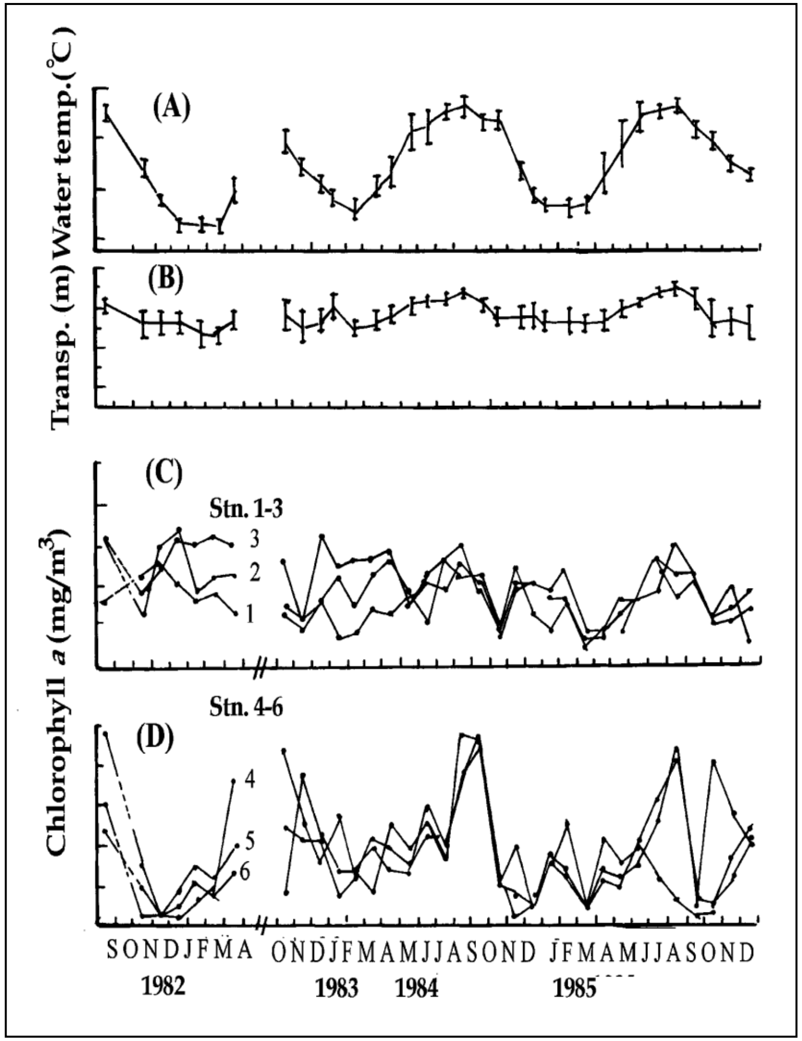

Fig 76 **Seasonal changes of A: average water temperature in the upper 8 m layer, B: transparency, and C and D : average chlorophyll *a* concentrations in the upper 8m layer at stns. 1-6 in the main channel of the Lake Nasser. Vertical bars in A and B indicate the standard deviation (Habib & Aruga 1996).**

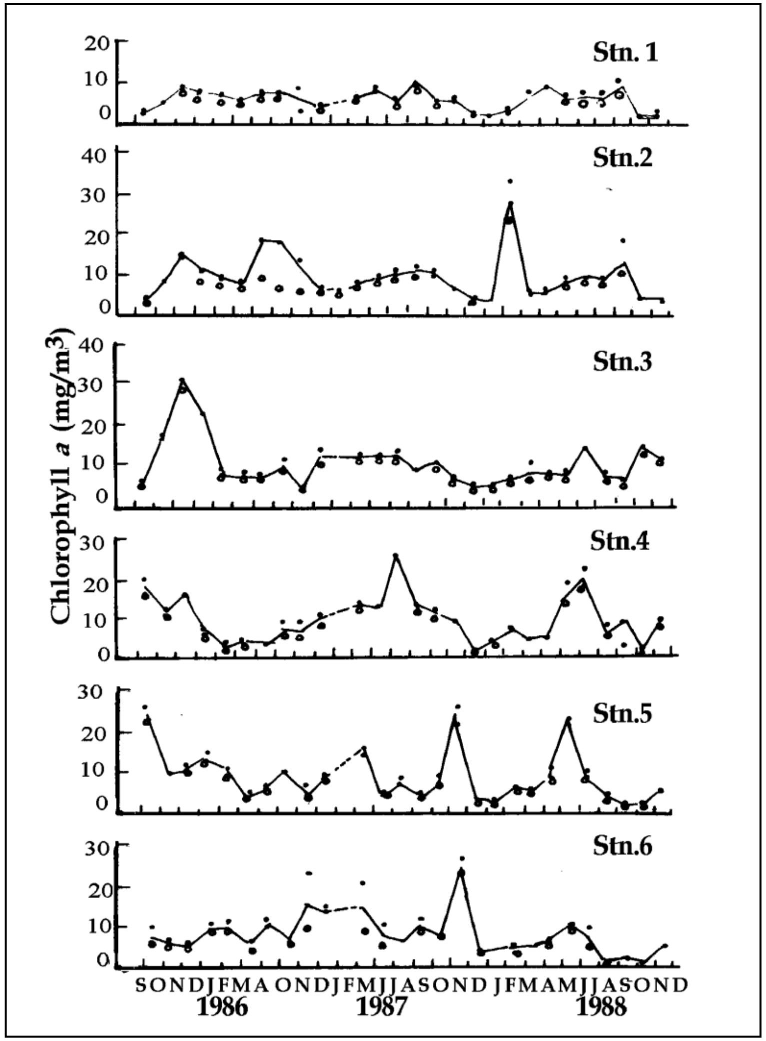

Fig. 77 **Seasonal changes of chlorophyll *a* at stns. 1-6 in the main channel of Lake Nasser (Habib *et al.* 1996). Lines are for average of the surface (◦) and 2 m (·) samples [**For stations refer to Fig. 4**].**

Fig. 78 (Habib & Aruga 1996). Data are greatly scattered possibly due to greater variability of the proportion of inorganic solids in suspended matter in the Lake water. If the upper levels of chlorophyll *a* concentration at respective Secchi disk depth are taken into consideration by assuming relative contribution of inorganic suspended solids to attenuation of light in water, the relationship seems to be exponential on a semilogarithmic plot as reported by several investigators (Ichimura 1956, Ichimura & Saijo 1959 and Ichimura 1960, Schibata & Aruga 1982, Brandini & Aruga 1983, Habib *et al*. 1987) in various waters.

Relationship between chlorophyll *a* concentration and suspended solids. The relationship between chlorophyll *a* concentration and suspended solids was studied for the surface water and the 2-m layer at stns. 1-6 along the main channel of Lake Nasser (Fig. 79 - Habib *et al*. 1996). The results indicate positive correlation between the two parameters. However, the data points were very much scattered. There is no significant difference between the relationships in the two layers.

Relationship between chlorophyll *a* concentration and particulate organic matter. The relationship between chlorophyll *a* concentration and particulate organic matter for the surface water and 2-m layer was studied at stns. 1-6 along the main channel of Lake Nasser (Fig. 80 - Habib *et al*. 1996). The results show that there were positive correlations with considerable scattered data points between the two parameters and no significant difference was observed between the two layers.

II. The Khors

Lake Nasser has side branches known as khors. There are 85 khors; 48 of which lie on the eastern side and 37 on the western side. Some of these khors are deep, narrow and with rocky bottom as Singari and Korosko. On the other hand, other khor bottoms are relatively wide with sandy or sandy loam as Kalabsha, Tushka and El Ramla. Some of these khors are very rich in the fish production.

1. In Khor El Ramla. Khor El Ramla (Fig. 81) is situated at the western side of Lake Nasser, about 10 km south of High Dam with relatively wide sandy or sandy loam bottom. Morphology of the khor at 180 m above mean sea level (MSL) was provided by Entz (1974a) and summarized in Table 49. Thorough study of chlorophyll *a* was carried out in this khor (Habib 1992b) and the results are summarized as follows:

(a) Regional variation. Generally, the concentrations of chlorophyll *a* inside Khor El Ramla and at its entrance were higher than those outside the khor (i.e. in the main channel and eastern part of the Lake). The mean values of chlorophyll *a* concentration were about 10.8 mg/m^3 inside the khor, 9.0 mg/m^3 at the entrance of the khor and 7.8 mg/m^3 outside the khor, i.e. in the main channel (Table 50).

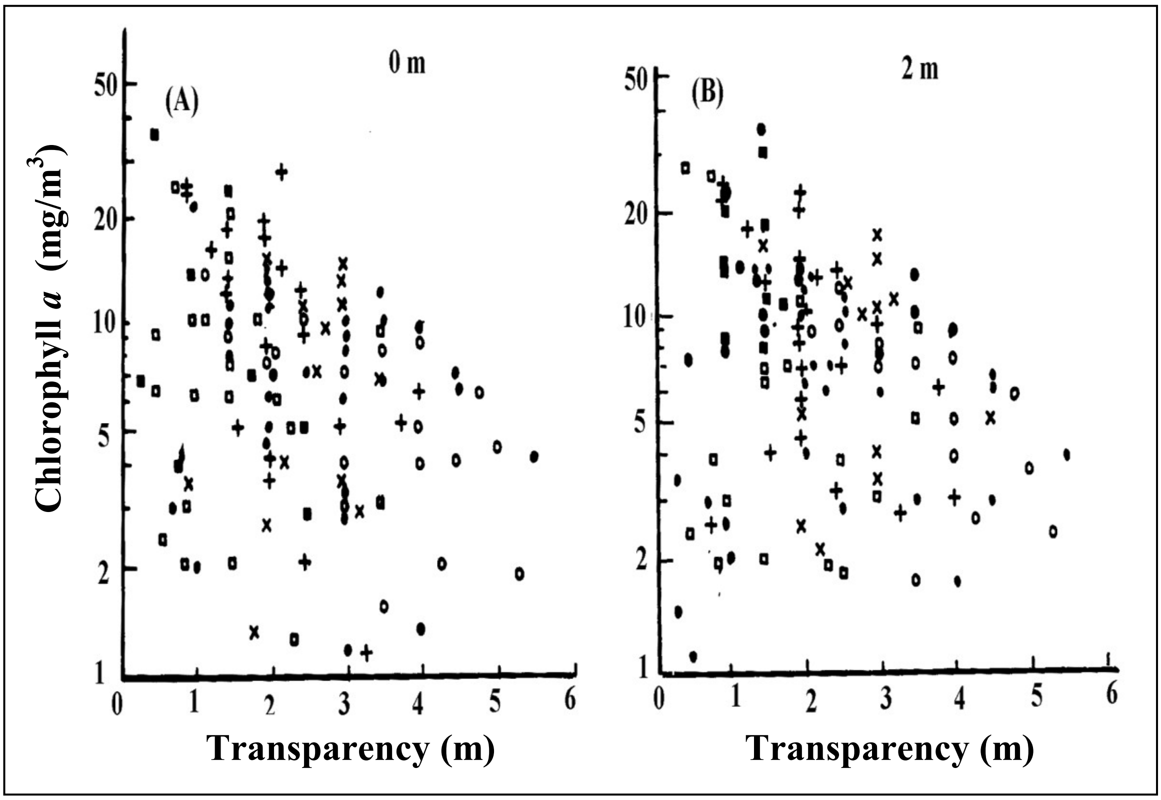

Fig. 78 **Relationships between the transparency and chlorophyll *a* concentration in the surface water (A) and the 2m layer (B) at stns. 1-6 in the main channel of Lake Nasser. Data from October to December 1985. (○) Stn.1, (•) Stn. 2, (x) Stn. 3, (+) Stn. 4, (□) Stn. 5, (▪) Stn. 6 (Habib & Aruga 1996) [**For stations refer to Fig. 4**].**

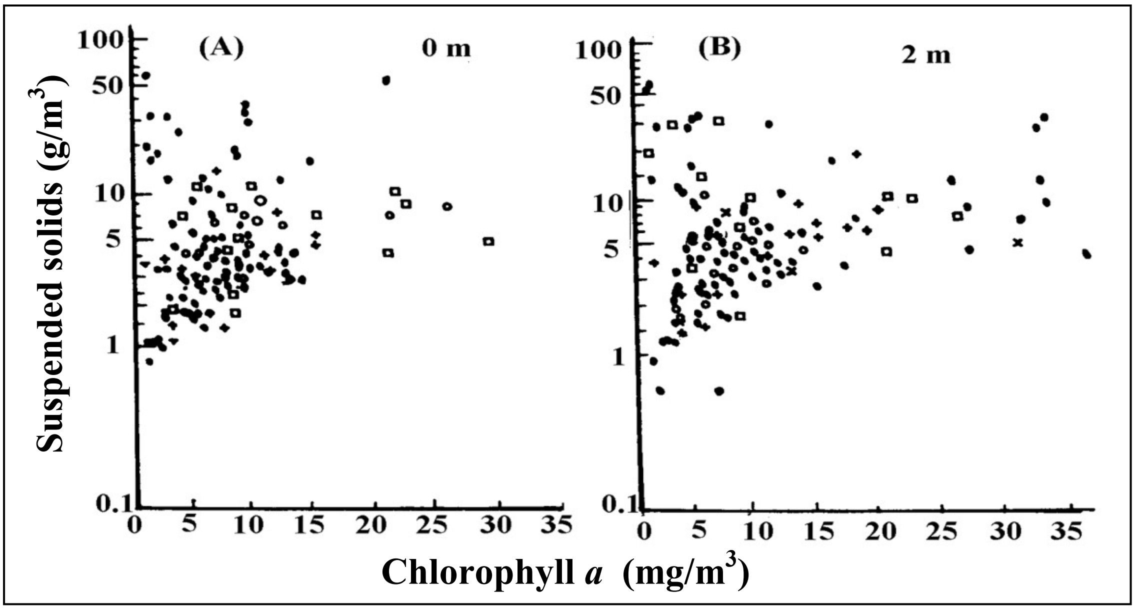

Fig. 79 **Relationships between the suspended solids and chlorophyll *a* at stns. 1-6 in the main channel of Lake Nasser. (○) Stn.1, (•) Stn. 2, (x) Stn. 3, (+) Stn. 4, (□) Stn. 5, (▪) Stn. 6 (Habib *et al.* 1996) [**For stations refer to Fig. 4**].**

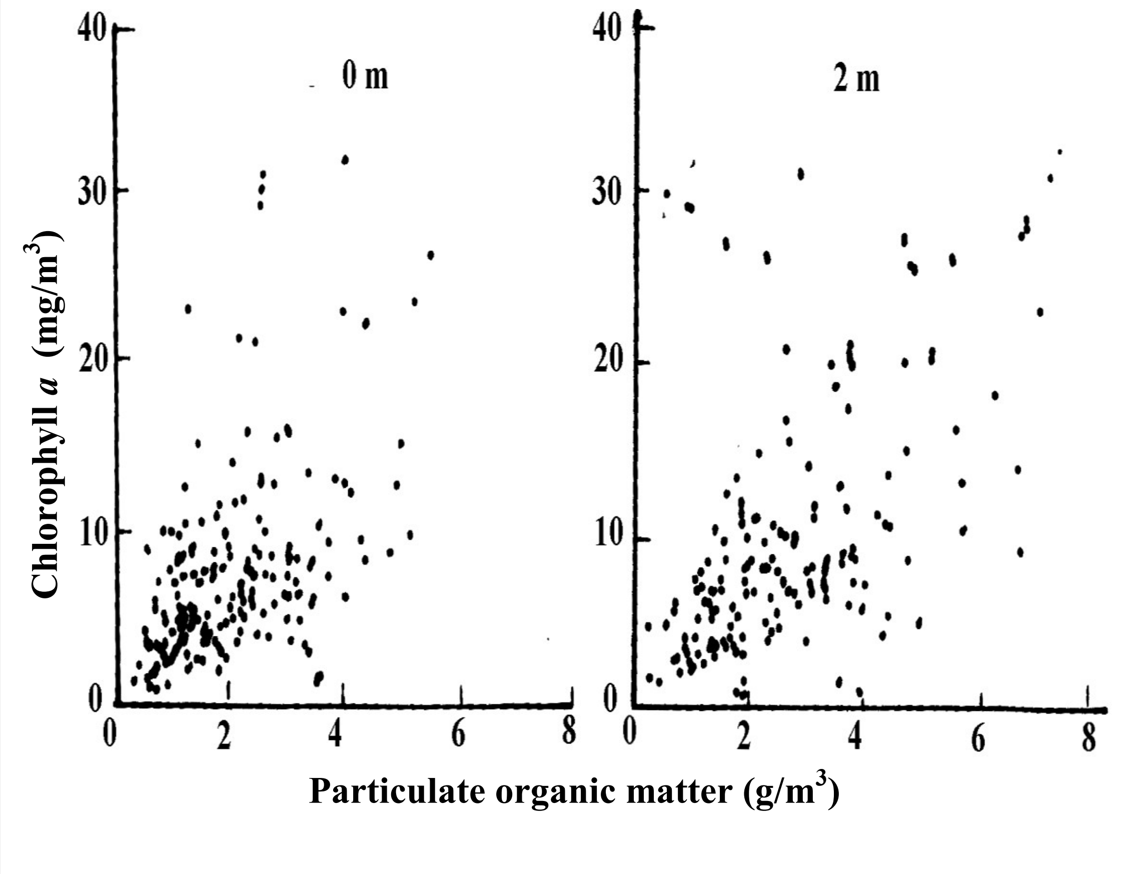

Fig.80 **Relationship between chlorophyll *a* concentration and the particulate organic matter at stns. 1-6 in the main channel (Habib *et al.* 1996).**

(b) Seasonal variation. Generally, chlorophyll *a* concentrations were high in spring (March and April), decreased in autumn (October and November) and in winter (December, January and February) in a descending order. In autumn and spring chlorophyll *a* concentration inside the khor showed the highest values compared with those at the entrance and outside the khor but in winter chlorophyll *a* concentration at the entrance of the khor showed the highest values (Table 50).

Table 49 **Morphometery of Khors El Ramla and Kalabsha at 180m above MSL (Entz 1974a).**

		Khor El Ramla	**Khor Kalabsha**
Distance from HD	(km)	10.00	44.00
Shoreline	(km)	232.00	464.00
Length	(km)	23.6	47.20
Mean width	(km)	1.2	--
Mean depth	(m)	21.00	9.88
Surface area	(km^2)	95.2	620.00
Volume	(km^3)	2.15	7.16

Table 50 **The mean value of chlorophyll *a* concentration (mg/m^3) in and outside Khor El Ramla and at its entrance (Habib 1992b).**

Month	Inside the khor Stns. (1-4)	At the entrance of the khor-Stns. (5-7)	Outside the khor Stns. (8-13)
Oct. 1982	11.1	5.8	4.7
Nov.	11.6	11.5	7.7
Dec.	11.9	9.7	5.8
Jan. 1983	6.7	11.7	10.5
Feb.	7.2	7.6	8.1
Mar.	10.6	7.6	9.6
April	16.4	9.0	8.5
Mean	10.8	9.0	7.8

For stations refer to Fig. 81.

Chlorophyll *a* concentration and water temperature at 4 stations in Khor El Ramla for the surface water layer from September 1986 to December 1988 are shown in Fig. 82 (Habib 1995a). The results indicate that maximum chlorophyll *a* concentration (i.e. 32.1 mg/m^3) was recorded in March 1987 at stn. 4, while the minimum value (i.e. 2.0 mg/m^3) was in December 1988. Generally, spring and summer showed high chlorophyll *a* concentrations, while low concentrations were recorded in winter.

Habib *et al.* (1996) investigated the distribution of chlorophyll *a* at 13 stations inside and outside Khor El Ramla (Fig. 81) from October 1982 through December 1985. The seasonal changes of the average chlorophyll *a* concentration in the upper layer of 0-8 m at stns. 1-13 are illustrated in Fig. 83. It is obvious that the levels of chlorophyll *a* concentration were generally higher at stns. 1-3 in the khor than at other stations in the main channel. The range of variations of chlorophyll *a* concentration was also higher at stns. 1-3 (1-46 mg/m^3) in the khor than at other stations (1-20 mg/m^3) in the main channel. Trends of seasonal changes at stns. 1-3 (Fig. 83 A) in the khor were different from those at other stations (Fig. 83 B-D) outside the khor, although the changes at stn. 4 were rather similar to those at stn. 3. Trends of the change were rather similar at stns. 5-13 (Fig. 83 B-D) even though the detailed variations were different from one another. A rapid increase of chlorophyll *a* concentration was observed in March, April and May at stns. 1 and 3 in the khor to attain the highest levels especially at stns. 1 and 2. An exceptionally high value of chlorophyll *a* (106.8 mg/m^3 at 4 m depth) was recorded in April 1984 at stn. 2. The levels of chlorophyll *a* were very high during the low temperature in November 1984 - February 1985 at stns. 1-3 (Fig. 83 A). At stations outside the khor, the levels of chlorophyll *a* concentrations were generally higher during the period of high water temperature and low during the period of low water temperature (Fig. 83 B-D). Chlorophyll *a* concentrations distinctly decreased in November and December 1985 at stns 4, 6, 10 and 11 (Fig. 83 C).

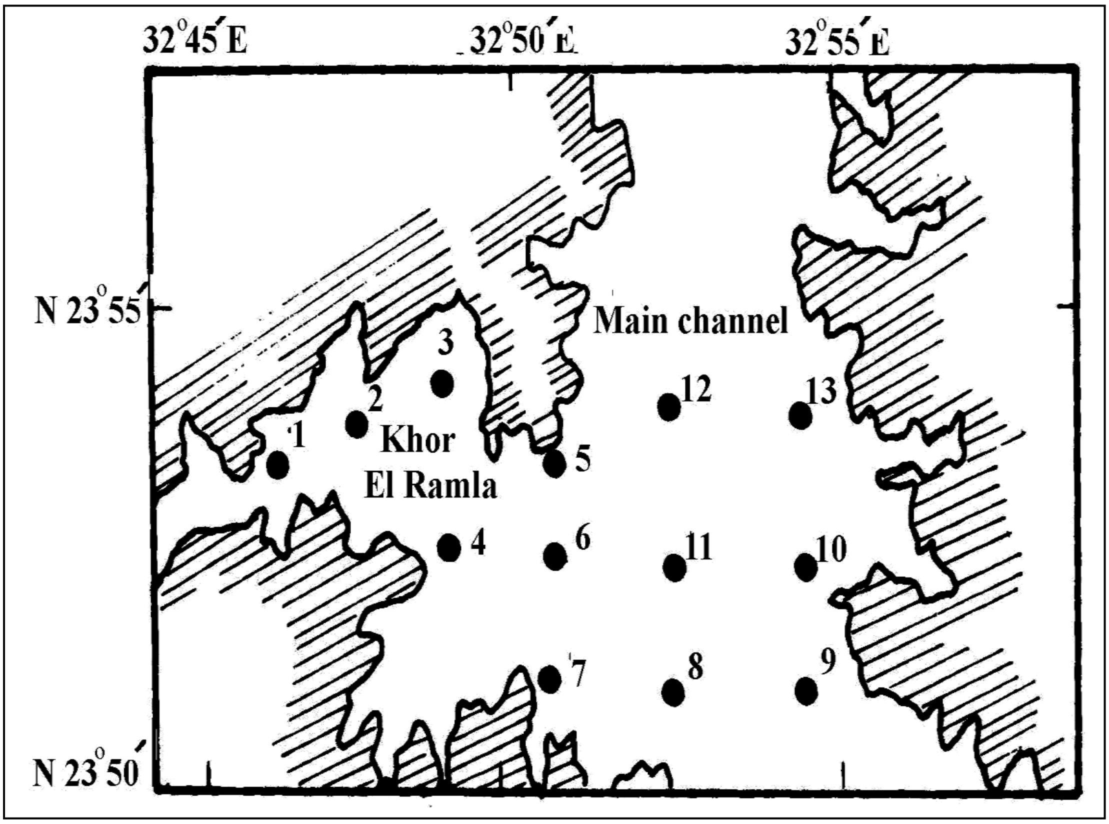

Fig. 81 **Location map of Lake Nasser and Khor El Ramla showing sampling stations. Figures indicate station numbers (Habib 1992b).**

(c) Vertical distribution. Generally, there were no wide variations in the vertical distribution of chlorophyll *a* inside, at the entrance and outside Khor El Ramla during any month except in March and April 1983 when there were wide variations of chlorophyll *a* distribution along the water column, e.g. 14 mg/m^3 at stn. 1 in March, 39 mg/m^3 at stn. 1 in April, and 18 mg/m^3 at stn. 2 in April (Table 51 - Habib 1992b).

Habib *et al.* (1996) studied the vertical distribution of chlorophyll *a* concentration at 13 stations inside and outside Khor El Ramla (Fig. 81) from October 1982 through December 1985. The results show that chlorophyll *a* concentration was usually high in the upper layer from the surface to 8 m depth. The subsurface chlorophyll *a* maxima were obtained mostly at 2-6 m depth during April to August, while in other months the surface maxima or the homogenous type of distribution was observed. The patterns of vertical distribution at stations inside the khor were generally different from those at stations outside the khor. The observed subsurface maxima of chlorophyll *a* may be related to the photoinhibition of phytoplankton

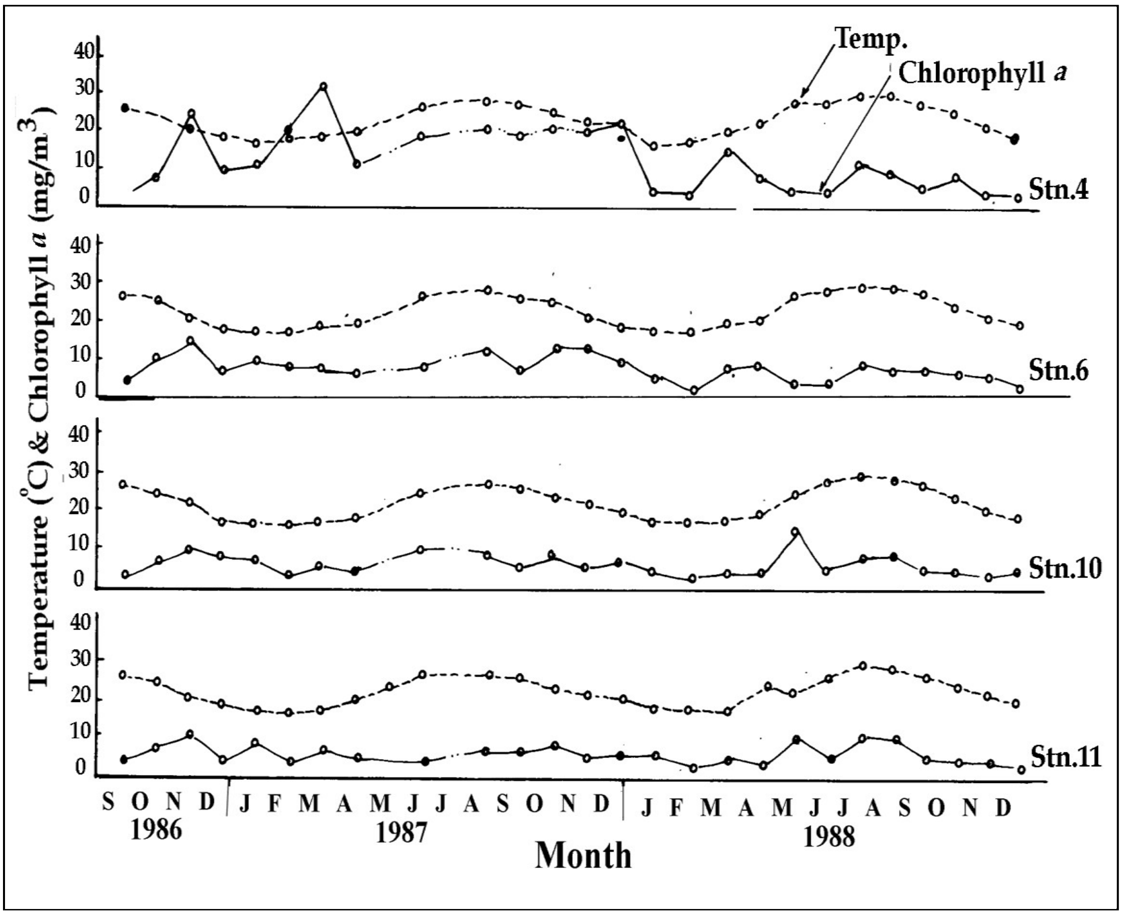

Fig. 82 **Seasonal variations of chlorophyll *a* (○—○) and water temperature (○- - -○) at 4 stations in Khor El Ramla (Habib 1995a) [**For stations refer to Fig. 81**].**

Table 51 **The vertical variation of chlorophyll *a* concentration (mg/m^3) in and outside Khor El Ramla (Habib 1992b).**

Month	**Inside the khor Stns. (1-4)**	**At the entrance of the khor-Stns. (5-7)**	**Outside the khor Stns. (8-13)**
Oct., 1982	3-6	1-3	1-3
Nov.	2-5	1-6	1-3
Dec.	2-6	1-4	1-2
Jan., 1983	1-3	1	1
Feb.	1-6	1-2	1-2
Mar.	4-14	5-7	2-6

April	4-39	3-6	2-7

For stations refer to Fig. 81.

photosynthesis at the surface layer due to high solar radiation (Latif 1974b). According to Raymont (1980), it is common in tropical marine waters to find out a maximum of algal growth near the base of the euphotic zone with generally abundant light and also with high nutrient concentrations. Low values in deeper layers down to 30 m might be due to the depletion of light.

(d) Variation in different years. The highest concentration of chlorophyll *a* inside Khor El Ramla was 57.6 mg/m^3 recorded in November 1984 at Stn. 1 (Habib *et al.* 1996). Yearly variations of chlorophyll *a* were recorded during different years as follows (Table 52):

1986/1987: The highest concentration of chlorophyll *a* (24.0 mg/m^3) was recorded at stn. 4 in November 1986, and high values of 20.5, 20.1 and 19.9 mg/m^3 were recorded at the same station in February, June and March 1987 respectively. The lowest value for chlorophyll *a* concentration (3.1 mg/m^3) was recorded at stn. 10 in March 1986 and stn. 11 in February 1987 (Table 52). The high value of Secchi disk extinction depth showed low chlorophyll *a* concentrations during winter, and the low value of Secchi disk extinction depth was paralleled by high chlorophyll *a* concentration.

1988: The highest value of chlorophyll *a* recorded was 26.2 mg/m^3 at stn. 4 inside Khor El Ramla at 4 m depth in April, and the lowest value was 0.8 mg/m^3 at stn. 11 outside Khor El Ramla at a depth of 30 m in September (Table 52). Transparency was high at areas where chlorophyll *a* concentration was low and vice versa.

1989: The maximum concentration of chlorophyll *a* (20.5 mg/m^3) was recorded at stn. 4 inside Khor El Ramla at 8 m-depth in December, and the minimum concentration of 0.2 mg/m^3 was recorded at stn. 11 outside Khor El Ramla at 30 m-depth in August. A correlation was observed between transparency and chlorophyll *a* concentration. When the value of transparency was high, chlorophyll *a* concentration was also low (Table 52, Mohamed, I. 1993f).

1990: The maximum value of chlorophyll *a* concentration (29.2 mg/m^3) was recorded at stn. 4 (4 m depth) in June, and the minimum value (0.1 mg/m^3) was recorded at stn. 11 (30 m-depth) in June. The transparency was usually low during the period of high chlorophyll *a* concentration and high during the period of low chlorophyll *a* concentration.

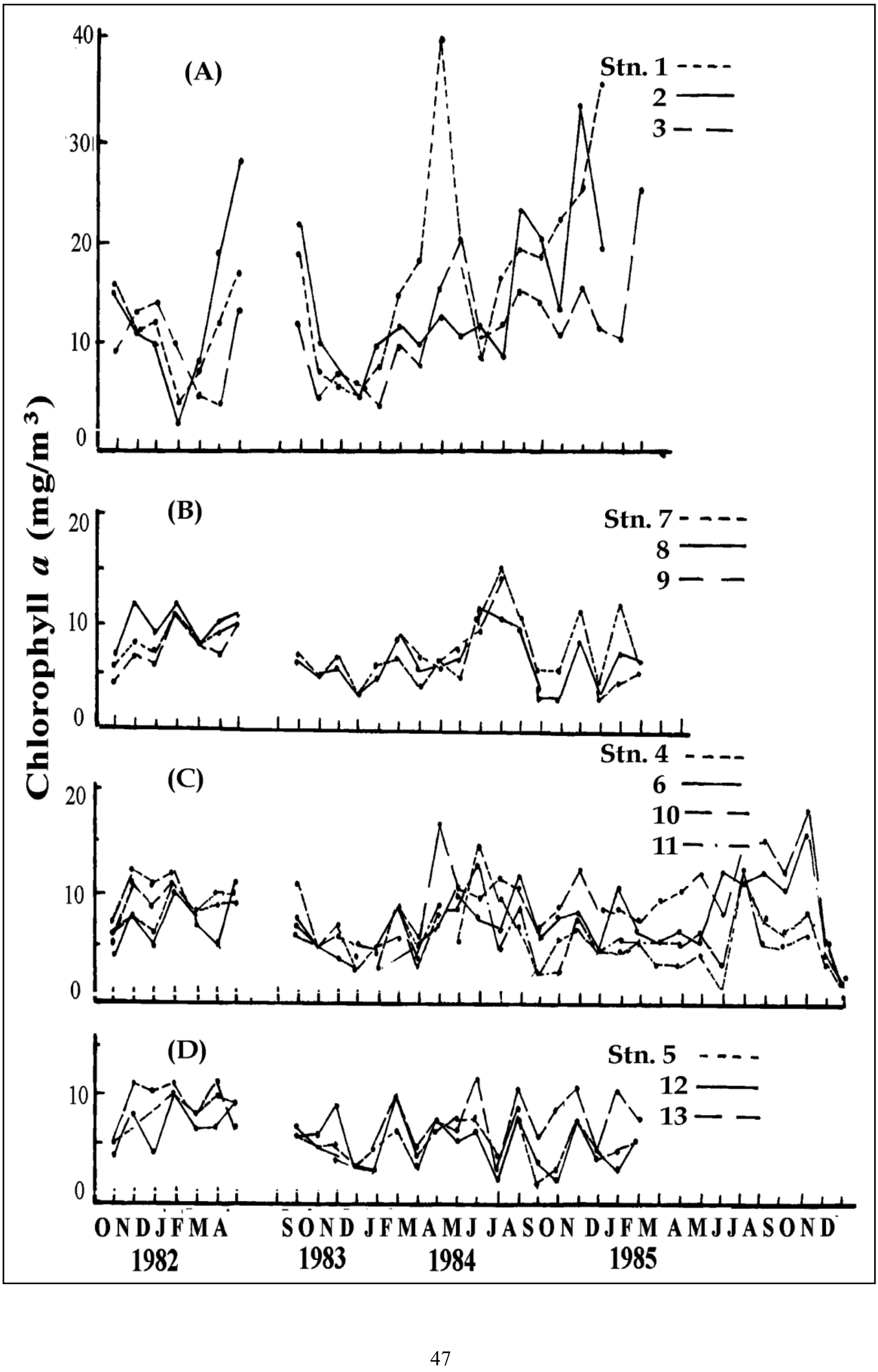

Fig. 83 **Seasonal changes of the average chlorophyll *a* concentration from the surface to 8 m depth at 13 stations in Khor El Ramla and in the main channel (Habib *et al.* 1996) [**For stations refer to Fig. 81**].**

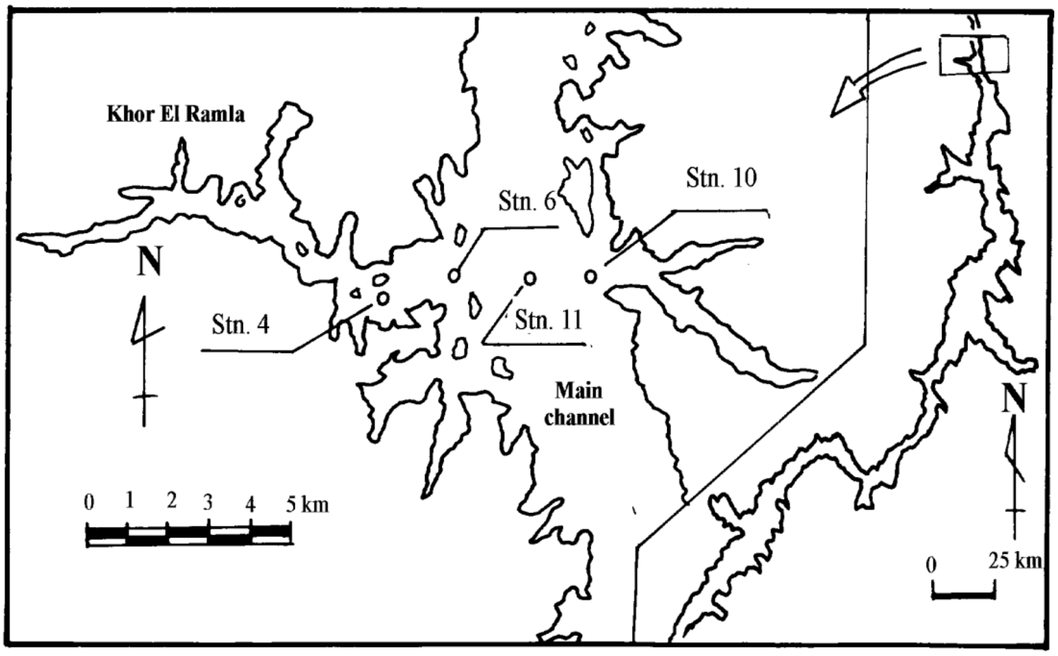

Fig. 84 **Location of stations in Khor El Ramla (Mohamed, I. 1993f).**

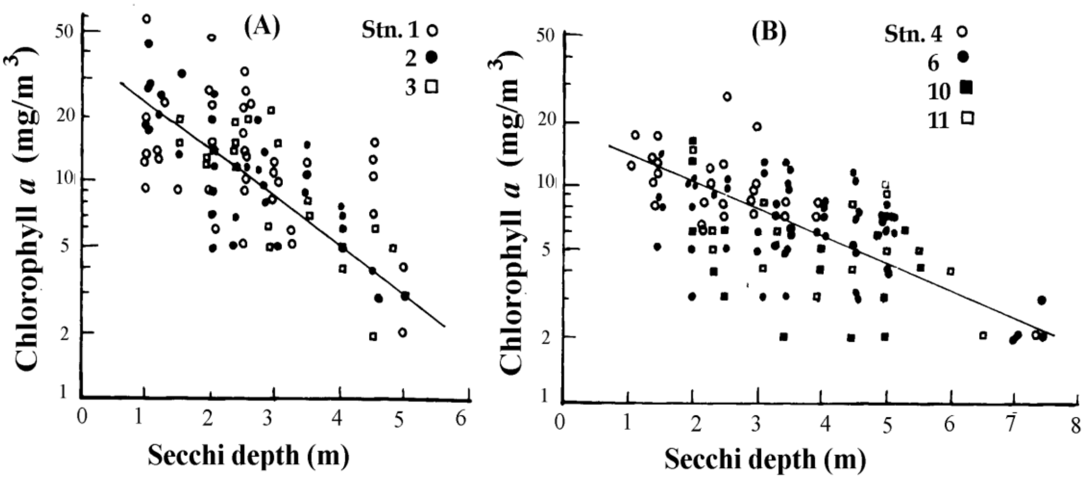

Fig. 85 **Relationships between the Secchi disk depth and chlorophyll *a* concentrations in the surface water and at 2 m depth for stns. 1-3 (A) and stns. 4, 6, 10 and 11 at Khor El Ramla (B) (Habib *et al.* 1996) [**For stations refer to Fig. 81**].**

At station 4 in Khor El Ramla the highest values of chlorophyll *a* are recorded during 1986 to 1990, while minimum values were found at stations 10 and 11 in the main channel.

Relationships between chlorophyll *a* concentration and the Secchi disk depths. Habib *et al.* (1996) studied the relationships of chlorophyll *a* concentration to the Secchi disk depth inside Khor El Ramla (stns. 1-3, Fig. 85). Both relationships are exponential when plotted on a semilogarithmic diagram, or hyperbolic when plotted on a normal diagram in a similar manner as reported in freshwater lakes (Ichimura 1956) and in marine waters (Ichimura & Saijo 1959, Saijo & Ichimura 1960, Schibata & Aruga 1982, Brandini & Aruga 1983). The relationships (Fig. 85) are almost similar, but the gradient of the regression line is slightly different from one to another. This difference might have been dependent on the different composition of suspended matter in the water of the khor and in the main channel (outside the khor), suspended matter should have contained more particles other than living phytoplankton in the main channel than in the khor.

Table 52 **Variation of chlorophyll *a* concentration (mg/m^3) in Khor El Ramla during 1986-1990 (Mohamed, I. 1993 b, f and 1996a).**

		Year of Investigation and Author			
		1986/87 Mohamed, I. (1993b)	**1988 Mohamed, I. (1993f)**	**1989 Mohamed, I. (1993h)**	**1990 Mohamed, I. (1996a)**
Maximum Conc.	**Value**	24.0	26.2	20.2	29.2
	Stn.	4	4	4	4
	Depth (m)	within euphotic zone	4	8	4
	Date	Nov. 86	April.	Dec.	June
Minimum Conc.	**Value**	3.1	0.8	0.2	0.1
	Stn.	10, 11	11	11	11
	Depth (m)	within euphotic zone	30	30	30
	Date	March 86 & Feb.87	Sept.	Aug.	June
Temp. (°C)	**From**	16	17.1	15.5	16.8
	Stn.	4	6	6	4
	Depth (m)	within euphotic zone	30	10	15
	Date	June 86	Feb.	Feb.	May
	To	28.9	30.2	29.0	30.2
	Stn.	10	10	6	10
	Depth (m)	within euphotic zone	---	0.0	0.0
	Date	July, 86	July	July	June
Transparency (range, m)	**From**	1.2	1.3	1.2	1.1
	Stn.	6	10	10	10

Date	Aug. 87	July	July	May
To	6.0	7.3	6.4	5.3
Stn.	4	11	4 & 6	10
Date	Feb. 86	Nov.	Feb.	May

[For stations refer to Fig. 84].

2. Khor Kalabsha. Khor Kalabsha (Fig. 86) is located in the northern part of Lake Nasser, about 44 km south of the High Dam. It covers an area of about 620 km^2 and its length is about 47.2 km (Table 49). Mohamed, I. (1993c) studied the regional and seasonal variations of chlorophyll *a* concentration in Khor Kalabsha; his results are given below:

Regional variation. The highest values of chlorophyll *a* were recorded at the central part of the khor (stns. 3 and 4) in May 1986 (Tables 53 and 54). Lower values of chlorophyll *a* were observed at stns. 8 and 9, i.e. at the entrance of the khor. The lowest value (2.6 mg/m^3) was recorded at station 9 in August 1986 (Tables 53 and 54).

Generally, in both khors (El Ramla and Kalabsha) the concentrations of chlorophyll *a* are higher inside the khors than outside. Therefore, khors of Lake Nasser are more productive than the main channel. Moreover, southern khors are more productive than the northern. Thus, in Khor Kalabsha (44 km south of the H D) the highest concentration of chlorophyll *a* was recorded (32 mg/m^3) compared with only 24.5 mg/m^3 at Khor El Ramla (10 km south of the HD) (Table 54).

Table 53 **Average chlorophyll *a* concentration (mg/m^3) at the euphotic zone at 9 stations in Khor Kalabsha in 1986/1987 (Mohamed, I. 1993c).**

Month and Date	Stations								
	1	2	3	4	5	6	7	8	9
May 6-8, 86	16.6	9.7	31.5	32.1	26.7	4.4	5.8	16.9	13.9
Aug. 7-8, 86	7.5	4.4	8.3	8.2	7.3	7.0	--	5.0	2.6
Nov. 20-22, 86	8.4	14.5	25.0	21.1	25.3	18.1	8.5	22.2	17.2
Dec. 28-30, 86	14.9	26.2	17.1	16.1	20.5	16.6	15.3	13.8	10.5
June 29-30, 87	---	---	12.2	15.1	4.8	---	--	6.0	5.4

[For stations refer to Fig. 86].

Chlorophyll *a* for Net and Nanoplankton

Abdel-Monem (1995) studied chlorophyll *a* of net and nanoplankton and his results show that the nanoplankton (<20 µm) constituted the major component of chlorophyll *a* in the main channel of Lake Nasser in 1993 with few exceptions where net plankton (>20 µm) was dominant (Table 55). The highest average values for net and nanoplankton chlorophyll *a* were recorded in spring and the lowest in winter. The seasonal variations of chlorophyll *a* were as follows:

Winter: Chlorophyll *a* concentrations were higher at the northern region than at the southern. Nanoplankton chlorophyll *a* constituted the major component of total chlorophyll *a* at all sites except at the bottom waters of Adindan. The highest value of chlorophyll *a* for net and nanoplankton (8.3 µg/l) was recorded at El-Madiq at 3 m depth, while the minimum value was found at Adindan at 15 m depth.

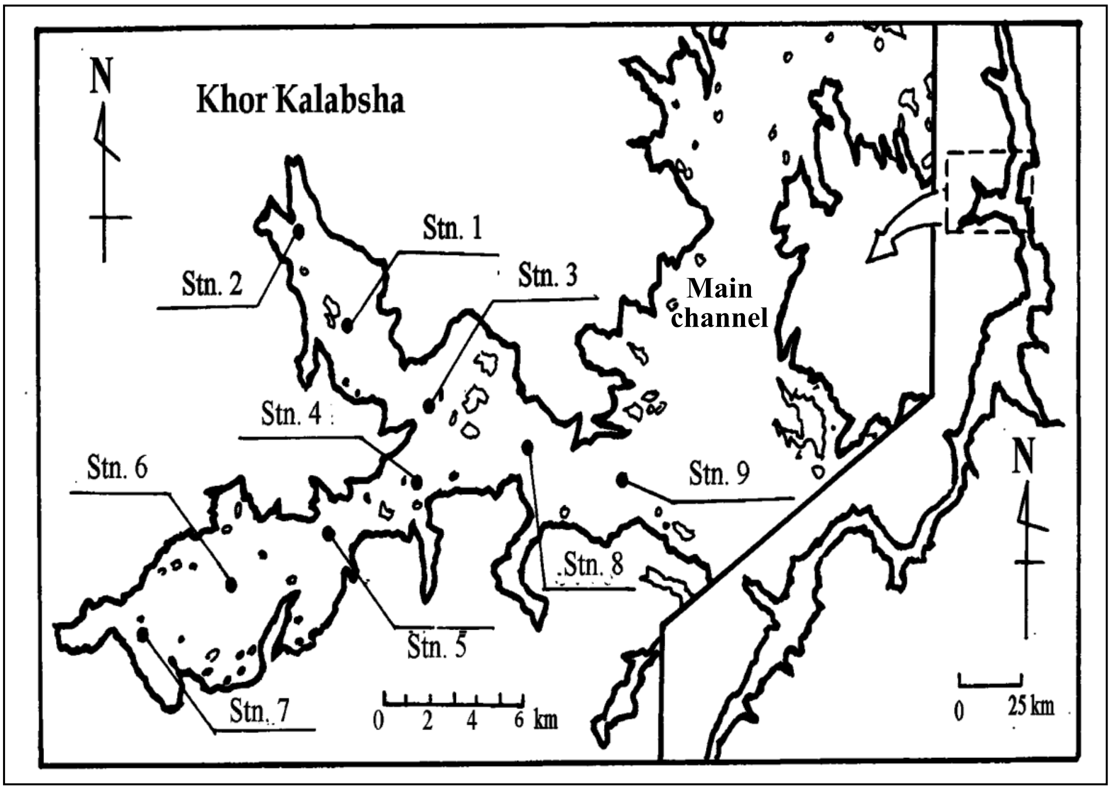

Fig. 86 **Location of stations in Khor Kalabsha (Mohamed, I. 1993c).**

Table 54 **Variations of chlorophyll *a* concentration (mg/m^3) in two khors during 1986 and 1987.**

		El Ramla*	Kalabsha**
Maximum	**Value**	24.5	32.1
Conc.	**Stn.**	4	4
	Date	Nov. 86	May 86
Minimum	**Value**	3.1	2.6
Conc.	**Stn.**	10, 11	9
	Date	March 86, Feb. 87	Aug. 86
Temp. (°C)	**From**	16.0 °C	15.8 °C
	Stn.	4	6
	Date	Jan. 86	Dec. 86
	To	28.9	28.7

	Stn.	10	8
	Date	July 86	June 87
Transparency			
(range,m)	**From**	1.2	0.8
	Stn.	6	2
	Date	Aug. 87	Aug.86
	To	6.0	3.3
	Stn.	4	9
	Date	Feb. 86	Dec. 86

* For stations refer to Fig. 84 (Mohamed, I. 1993f) . ** For stations refer to Fig. 86 (Mohamed, I. 1993c).

Table 55 **Chlorophyll *a* for net and nanoplankton (µg/l) [Abdel-Monem 1995].**

Site	Depth	Winter		Spring		Summer		Autumn	
		net	nan.	net	nan.	net	nan.	net	nan.
High Dam	**3 m**	1.71	4.13	3.56	14.19	4.18	1.98	1.86	2.74
	15 m	1.30	5.02	1.18	2.59	1.28	2.93	1.32	3.86
	Bott.	1.68	4.22	0.85	1.62	0.06	0.36	1.22	0.37
Dihmit	**3 m**	0.89	3.88	1.07	4.11	4.21	2.64	0.09	6.02
	15 m	1.08	4.05	10.63	3.68	0.78	2.64	1.67	6.11
	Bott.	1.29	3.41	0.41	2.06	0.47	1.17	1.33	1.02
Kalabsha	**3 m**	1.05	2.85	5.84	15.16	1.27	3.67	0.53	6.41
	15 m	0.46	2.21	1.23	6.06	0.27	2.66	2.10	6.02
	Bott.	0.54	3.68	0.32	1.91	0.01	0.45	0.38	1.68
Maryia	**3 m**	0.95	2.66	1.47	7.63	0.54	3.86	0.10	7.48
	15 m	0.90	3.72	12.56	6.94	2.00	3.23	2.16	6.06
	Bott.	0.61	3.58	0.34	3.21	0.05	0.36	0.20	2.05
El Madiq	**3 m**	1.98	6.32	2.68	5.14	3.5	15.25	4.75	14.50
	15 m	0.57	2.97	1.32	7.19	1.67	5.18	3.50	15.50
	Bott.	2.08	6.22	2.61	2.38	0.02	0.52	0.17	1.57
Singari	**3 m**	0.93	3.11	19.00	16.75	0.29	8.02	6.25	20.00
	15 m	0.79	3.25	8.50	17.50	0.73	2.89	4.75	14.25
	Bott.	0.37	0.86	1.18	6.16	7.00	8.75	0.38	0.85
Amada	**3 m**	0.62	3.06	11.00	34.00	10.00	14.00	24.88	1.62
	15 m	1.30	5.28	15.26	7.24	1.51	3.28	2.64	2.64
	Bott.	0.53	2.36	0.49	3.23	0.12	0.55	1.66	0.39
Tushka	**3 m**	1.33	1.52	8.98	8.02	0.59	8.41	4.28	2.76
	15 m	0.63	1.25	4.94	3.86	0.83	2.23	0.66	1.49
	Bott.	0.26	0.82	1.08	2.25	0.02	0.27	0.21	0.22
Abu Simbel	**3 m**	0.46	1.85	32.51	23.00	9.00	29.75	2.97	2.02
	15 m	0.60	1.62	16.96	4.79	0.48	4.21	1.06	1.87
	Bott.	0.30	0.84	13.87	2.89	0.80	1.45	0.03	0.30
Adindan	**3 m**	0.19	1.61	12.98	16.52	7.00	13.50	2.13	1.53
	15 m	0.11	0.74	13.78	7.97	0.83	3.13	1.13	1.34
	Bott.	1.71	1.21	3.70	3.10	0.08	0.40	0.11	0.24
Average		**0.91**	**2.95**	**7.01**	**8.04**	**1.99**	**4.92**	**2.48**	**4.43**

Spring. The highest averages of chlorophyll *a* were recorded in spring as well as at most sites mostly at 3 m depth. The southern region sites attained higher chlorophyll *a* than the northern ones. The maximum value of net chlorophyll *a* (32.51 µg/l) during the year was recorded at Abu Simbel at 3 m depth.

Summer: Maximum chlorophyll *a* values were recorded in summer at most sites at 3 m depth (Table 55). The highest chlorophyll *a* values were found at Abu Simbel amounting to 9 and 29.75 μg/l for net and nanoplankton chlorophyll *a* at 3 m depth.

Autumn: Nanoplankton chlorophyll *a* was the major constituent of total chlorophyll *a* at the northern sites in autumn, while the reverse was the case at most depths at the southern region. Furthermore, higher values of chlorophyll *a* were recorded at 3 m depth except at Dihmit and Mariya. The maximum chlorophyll *a* value (26.50 μg/l) was recorded at 3 m depth at Amada composed of 24.88 and 1.62 μg/l for net and nanoplankton (Table 55).

Chlorophyll / Phaeophytin Ratio

In 1993 chlorophyll/phaeophytin ratios were calculated for net and nanoplankton (Abdel-Monem 1995) collected from ten sites in the main channel and the results indicate regional, seasonal and vertical variations. The following shows the average seasonal variations of chlorophyll / phaeophytin ratios:

	Winter		Spring		Summer		Autumn	
Average	**net**	**nano.**	**net**	**nano.**	**net**	**nano.**	**net**	**nano.**
values	0.25	0.31	0.57	0.60	0.81	0.57	0.72	0.55

The results indicate minimum values in winter and maximum in summer.

PRIMARY PRODUCTIVITY

Entz (1972) reported a value of 16 g O_2/m^2/day for Lake Nasser from a 24 h light- and dark - bottle study. Samaan (1971) estimated primary productivity at different locations of Lake Nasser by using the C_{14} method, and showed that it ranged between 0.225-2.202 g C/m^3/12 hrs. (Table 56). Fead (1980) recorded values ranging from 10.7 and 16.4 g O_2/m^2/day. During 1986/87 Habib (1998b) recorded values ranging from 1.0–27.4 and 0.7-23.8 g C/m^2/day for gross and net primary production respectively.

Table 56 **Gross primary productivity (g C/m^3/12hrs.) at different localities in Lake Nasser (Samaan 1971).**

Site	Gross primary productivity (g C/m^3/12hrs.)					
	Surface	0.3 m	1m	2m	3m	5m
El-Berba	1.198	---	1.486	1.284	0.797	0.295
El-Madiq	1.200	---	1.704	---	0.856	0.225
Singari	0.829	1.194	1.252	1.007	0.467	---
Khor Singari	1.224	1.962	2.202	1.097	0.487	---

It appears that the Lake water is highly eutrophic and sustains a dense crop of phytoplankton. The photosynthetic activities of phytoplankton at the surface water are inhibited by the high light intensity of solar radiation. Thus, the highest production rate is obtained at a depth of about 1-2 m from the surface water and it decreases gradually with increasing the depth of water.

Gross primary productivity below one square meter per day (∑ gross), is controlled by the fertility of water and the depth of the photic zone, i.e. the depth of 0.5% light illumination. The depth of the photic zone ranges between 390 cm (Khor Singari) and 485 cm (El-Birba). Results of gross primary productivity in g carbon below one square meter per day (∑ gross) is given in Table 57 which also shows the optimum photosynthetic rate (A opt.) and the relation ∑ gross/A opt. The results indicate that the primary productivity in Lake Nasser ranges between 3.21 and 5.23 g C/m^2/day. The highest primary productivity below one square metre is obtained at El-Madiq and El-Birba, while the highest fertility of the water per unit volume (A opt.) is attained at Khor Singari. The relation ∑ gross/A opt. is highest at El-Birba and then decreases gradually towards the southern region due to the gradual decrease of the depth of the photic zone. Habib & Aruga (1987) estimated the primary net production at different areas of the Lake (Fig. 149 and Table 148) and found that it ranged between 2.51-5.28 with an average of 4.01 kg/dw/m^2/year. It appears also that a gradual eutrophication of the Lake is a result of continuous sedimentation of organic matter that accumulates on the bottom and through the annual introduction of the flood water rich in nutrients which supply phytoplankton with their inorganic requirements.

***Table* 57 Gross primary productivity below one square metre per day (∑ gross) in g C/m^2/day and optimum production rate at different localities of Lake Nasser (A opt.) in g C/m^2/day (Samaan 1971).**

Site	∑ gross g C/m^2/day	A opt. g C/m^2/day	∑ gross/A opt.
El-Birba (El Ramla)	4.840	1.486	3.25
El-Madiq	5.230	1.707	3.05
Singari	3.210	1.252	2.56
Khor Singari	4.340	2.020	2.15

In 1993 Abdel-Monem (1995) measured the primary productivity (using light and dark bottle C^{14} method) and the photosynthetic capacity (assimilation number) in the main channel of the Lake at 3 and 15 m depth at ten localities and his results (Table 58) indicate the following:

1- The primary productivity ranged from 2.72 mg C/m^3/h at 3 m depth at the High Dam site in summer to 179.91 mg C/m^3/h at Dihmit in spring at the same depth. At 15 m depth the primary productivity ranged between 0.0 (at most sites) in winter to 128.15 mgC/m^3/h in summer at Mariya.

Table 58 **Primary productivity (P.p) (mg C/m^3/h) and assimilation number (As.no) (mg C/mg chl/h) at various sites of Lake Nasser along the main channel (Abd El-Monem 1995).**

Site	Winter				Spring				Summer				Autumn			
	3m		15m		3m		15m		3m		15m		3m		15m	
	P.p	As.no	P.p	As.no	P.p	As.no	P.p	As.no	P.p	As.no	P.p	As.no	P.p	As.no	P.p	As.no
High Dam	45.20	9.34	0.00	0.00	95.93	5.40	14.00	3.71	2.72	0.44	33.21	7.89	30.26	11.04	9.56	2.48
Dihmit	4.36	0.91	0.00	0.00	179.91	34.73	0.00	0.00	46.25	6.75	15.24	4.46	30.83	5.12	1.56	0.26
Kalabsha	7.93	2.03	0.00	0.00	40.65	1.94	0.00	0.00	91.27	18.48	71.54	24.42	9.45	1.47	1.52	0.25
Maryia	34.26	9.49	0.00	0.00	100.93	11.09	4.00	0.21	24.92	5.66	128.15	24.50	12.45	1.66	12.19	2.01
El-Madiq	11.90	1.43	0.00	0.00	37.20	4.76	41.21	0.00	15.02	0.80	48.96	7.15	7.62	0.53	7.45	0.48
Singari	9.48	2.35	0.00	0.00	26.22	0.73	45.03	1.73	6.16	0.74	0.00	0.00	9.35	0.47	10.67	0.75
Amada	8.25	2.24	0.00	0.00	125.13	2.78	106.13	4.72	2.87	0.12	7.44	1.55	28.69	17.71	14.90	5.64
Tushka	13.92	4.88	0.00	0.00	16.47	0.97	0.00	0.00	12.39	1.38	0.00	0.00	21.82	7.91	4.26	2.86
Abu Simbel	10.94	4.74	23.87	10.75	43.27	0.78	28.26	1.30	29.38	0.77	0.00	0.00	14.90	7.38	8.73	4.67
Adindan	4.32	2.40	0.00	0.00	22.29	0.76	29.66	1.36	11.24	0.55	47.99	12.12	30.49	19.93	42.61	31.80
Average	15.06	3.98	2.39	1.08	68.80	6.39	26.83	1.30	24.22	3.57	35.25	8.21	19.59	7.32	11.35	5.12

Comparable results were obtained in 1996 (SECSF 1996) which showed that primary productivity fluctuated between 7.5 mgC/m^3/h at 3 m depth at Abu Simbel in autumn to 249 mgC/m^3/h at the same depth at Korosko during winter. In deeper waters (6-12 m) the range was from 45 mgC/m^3/h at the High Dam site in autumn to 247.5 mgC/m^3/h at Korosko in winter.

2- The highest average annual primary productivity at 3 m depth recorded in the main channel during 1993 was 68.80 mgC/m^3/h in spring, and the lowest value (15.06 mgC/m^3/h) was recorded in winter at the same depth. At 15 m depth the average maximum primary productivity was 35.25 mgC/m^3/h recorded in summer, while the minimum (2.39 mgC/m^3/h) was found in winter.

3- The photosynthetic capacity (assimilation number) ranged from 0.76 mg C/mg Chl/h in spring at 3 m depth at Adindan, to 34.73 mgC/mg Chl/h at Dihmit in spring at the same depth. At 15 m depth the photosynthetic capacity ranged from 0.0 (at most sites) in winter to 31.80 mg C/mg Chl/h at Adindan.

4- At 3 m depth the maximum annual average of photosynthetic capacity was 7.32 mg C/mg Chl/h in autumn, and the minimum (3.57 mg C/mg Chl/h) was recorded in summer. At 15 m depth the highest value (8.2 mg C/mg Chl/h) was found in summer, and the lowest (1.08 mg C/mg Chl/h) was recorded in winter.

5- There is no parallelism between primary productivity and photosynthetic capacity. Thus, high primary productivity do not always correspond to high photosynthetic capacity.

EPIPHYTES

Epiphytic algae are among the most important food items for the tilapias which constitute the major fish species of Lake Nasser. In Lake Nasser the attached algae are Chlorophyceae, Bacillariophyceae and Dinophyceae. Mohamed, I. (1993d) studied the attached algae at nine different areas of Lake Nasser, and calculated chlorophyll *a* concentration and his results are presented in Tables 59 and 60. The results indicate the presence of 14 algal species belonging to 3 major groups (Table 59). In 1989/91 Habib (1997) recorded 28 species of attached algae at four localities in Lake Nasser.

Studying the distribution of attached algae along 9 localities indicates that Abu Simbel, Marwaw, and Eneba are richer in number of species (i.e. 4-5 spp.) than other localities (Tushka and Allaqi 2 spp.) while other localities contain only one species (Table 60 – Mohamed I. 1993d).

*Table 59 A***ttached algae recorded in Lake Nasser during 1989-1991 (Mohamed, I. 1993d).**

Chlorophyceae	**Bacillariophyceae**	**Dinophyceae**
Cladophora sp.	*Cyclotella* sp.	*Ceratium* sp.
Cosmarium sp.	*Cymbella* sp.	*Peridinium* sp.
Oedogonium sp.	*Diatoma* sp.	
Pediastrum sp.	*Melosira* sp.	
Scenedesmus sp.	*Navicula* sp.	
Spirogyra sp.	*Synedra* sp.	

Table 60 **Distribution of the common attached algae in different areas (Mohamed, I. 1993d).**

Site	**Attached Algae**
Abu Simbel	*Oedogonium* , *Pediastrum* , *Cladophora* and *Melosira* spp.
Tushka	*Oedogonium* and *Pediastrum* spp.
El-Ramla	*Oedogonium* sp.
Marwaw	*Oedogonium* , *Spirogyra* , *Cladophora* , *Melosira* and *Navicula* spp.
Eneba	*Cladophora, Spirogyra, Navicula* and *Diatoma* spp.
Wadi El-Arab	*Oedogonium* sp.
Sayala	*Melosira* sp.
Dihmit	*Spirogyra* sp.
Allaqi	*Spirogyra* and *Synedra* spp.

The maximum chlorophyll *a* concentration of the attached algae (101.4 mg/m^2) was recorded at Eneba in December 1989, while the minimum values (2.0-2.2 mg/m^2) were recorded at Allaqi in July and August 1991 (Table 61). In Tushka, the concentration of chlorophyll *a* of the attached algae was recorded as 82.2 mg/m^2 in November 1989 (Table 61).

Table 61 **Chlorophyll *a* concentration of the attached algae (Mohamed, I. 1993d).**

Value Degree	**Concentration (mg/m^2)**	**Area**	**Sampling Date**
Maximum	101.4	Eneba	December, 1989
High	82.2	Tushka	November, 1989
Minimum	2.0 and 2.2	Allaqi	July and August, 1991

FUNGI (MYCOFLORA)

Aquatic Phycomycetes from Surface Water Samples

El-Hissy *et al.* (1996) recorded 25 identified and 4 unidentified species which belong to eleven genera of aquatic fungi from water samples collected from Lake Nasser (Table 62). The occurrence of the aquatic fungal genera was in the following descending order: *Saprolegnia, Pythium, Aqualinderella, Achlya, Aphanomyces, Blastocladiopsis, Pythiopsis, Dictyuchus, Blastocladia, Allomyces* and *Leptomitus.*

The relation between the different water characteristics versus the number of aquatic fungal genera and species is highly significant (El-Hissy *et al. 1996).* The latter authors mentioned that temperature is the major factor conversely affecting the number of genera and species with a relative efficiency of 48.13% and 36.18% respectively. This observation is in agreement with Dick (1971), Föhn (1973), Tomlinson & Williams (1975), El-Hissy (1979) and Rattan *et al.* (1980).

The total soluble salts constitute the second factor affecting the number of genera and species with a relative efficiency of 13.12% and 19.15% respectively and the relation is a positive one (El-Hissy *et al.* 1996). However, these results are in contrast with those obtained by Scholz (1958), Fuller *et al.* (1984), Amon (1978) and Amon & Yei (1982).

The pH values showed a negative correlation with the number of genera and species with a relative efficiency of 3.32 % and 3.94% respectively (El-Hissy *et al.* 1996). This agrees with the results obtained by Lund (1934). However, many authors (e.g. El-Hissy *et al.* 1982, 1992, El-Hissy & El-Nagdy 1983, Paul *et al.* 1984) mentioned that pH value is not a major factor governing the distribution and occurrence of aquatic phycomycetes.

Previous studies indicate that there is no clear relationship between the occurrence of aquatic fungi and the fluctuations in the amount of dissolved oxygen (Alabi 1971, Rattan *et al*. 1980 and El-Hissy *et al*. 1996). However, Misra (1980) and El-Hissy & Khalil (1989) found a close relationship between the dissolved oxygen of water and the occurrence, seasonal changes and zoosporic production of aquatic fungi.

The organic matter content of the tested water samples showed also a limited influence on the number of aquatic fungal genera and species (0.27% and 0.76% respectively) (El-Hissy *et al.* 1996).

The richest water samples in aquatic phycomycetes species were those characterized by relatively low temperatures (15.9 - 20.3 °C), and pH ranging between 7.4-8.3, dissolved oxygen ranging from 5.2 to 9.3 mg/l and total soluble salts ranging from 208.0 to 254.0 mg/l. The poorest samples were characterized by relatively high temperatures (20.6-33.1°C), pH values fluctuating between 6.3 and 9.2, dissolved oxygen varying from 4.5 to 10.6 mg/l, total soluble salts ranging from 149 to 175 mg/l, and the organic matter content between 12.0 and 51.1 mg/l (El-Hissy *et al.* 1996). *Saprolegnia* and *Pythium* were the most frequent aquatic fungal genera recovered by El-Hissy *et al.* (1996), whereas *Aphanomyces, Dictyuchus, Pythiopsis, Leptomitus, Allomyces* and *Blastocladiopsis* were less frequent.

Vertical Fluctuations of Mycoflora

Of the mesophilic fungi Moharram *et al.* (1990) recorded a total of 60 species and one variety related to 22 genera from both water (48 species, 1 variety and 16 genera) and bottom mud samples (40 species, 1 variety and 17 genera) from Lake Nasser and pointed out that the fungal population of Lake Nasser showed marked vertical variations during the period from July 1985 to December 1986. High fungal counts were recorded at the surface waters which were mainly due to the high counts of *Aspergillus fumigatus* and *A. terreus.* Going deeper, the fungal population decreased till 30 m, then gradually increased to reach its maximum at 70 m depth (Moharram *et al.* 1990). The latter authors attributed such increase to the high population of *Penicillium funiculosum.* At each sampling time, the water temperature and the values of dissolved oxygen were always higher at the surface than near the bottom of the Lake. The temperature ranged from 15 to 26 °C and the dissolved oxygen from 1.31 to 8.98 mg/l (Moharram *et al.* 1990).

Table 62 **Frequency of occurrence of aquatic fungi of water samples and submerged mud samples collected from Lake Nasser (El-Hissy *et al.*1996 and 1997).**

Aquatic fungal genera and species	**Occurrence remarks**	
	Fungi from surface water samples (El-Hissy *et al.* 1996)	**Fungi from submerged mud samples (El-Hissy *et al.* 1997)**
Achlya	L	L
A. dubia	R	R
A. hypogyna	R	-
A. proliferoides	-	R
A. racemosa	-	R
Achlya sp.	R	R
Aphanomyces	R	R
A. laevis	R	R
A. norvegicus	R	R
A. scaber	R	-
Aphanomyces sp.	R	R
Dictyuchus	R	R
D. carpophorus	R	R
D. sterilis	R	R
D. monosporus	-	R
Leptolegnia	-	R
L. caudata	-	R
Pythiopsis	R	R
P. cymosa	R	R
P. humphreyana	R	R

Cont. *Table 62*

Saprolegnia	M	M
S. anisospora	R	R
S. diclina	R	R
S. ferax	R	R
S. hypogyna	R	R
S. parasitica	R	R
Saprolegnia sp.	L	L
Leptomitus	R	R
L. lacteus	R	R
Aqualinderella	L	L
A. fermentans	L	L
Pythium	M	M
P. debaryanum	R	-
P. irregulare	R	-
P. pulchrum	R	R
P.rostratum	R	R
P. ultimum	R	R
P. vexans	R	R
P. thalassium	-	R
P. undulatum	-	R
Pythium sp.	R	R
Allomyces	R	-
A. arbuscula	R	-
Blastocladia	R	-
B. angusta	R	-
Blastocladiopsis	R	R
B. parva	R	R
Nowakowskiella	-	R
N. elegans	-	R

H = High occurrence; more than 50%, M = Moderate occurrence, between 25-50 %, L = Low occurrence, between 12-24%, R = Rare occurrence, less than 12%, - = not recorded

Monthly Variations of Mycoflora

El-Hissy *et al.* (1990) recorded 51 species and one variety belonging to 21 genera of mesophilic fungi from the monthly samples of marginal water (44 species, 1 variety and 18 genera) and submerged mud (78 species, 1 variety and 30 genera) of Lake Nasser during the period from July 1985 to December 1986. The most common species were *Aspergillus fumigatus, A. flavus, A. terreus, A. niger* and *Penicillium funiculosum* (El-Hissy *et al.* 1990). The latter authors found that the highest fungal populations were detected either in October, December 1985 or February 1986. Of the 12 thermophilic and thermotolerant fungal species, *Aspergillus fumigatus* and *A. nidulans* were common in the bottom mud but were completely missing at the various vertical strata of the Lake. *Paecilomyces variotii, Rhizomucor pusillus, Thermomyces lanuginosus, Thermoascus thermophilus* and *Sporotrichum thermophilum* appeared in moderate or low incidences in one site or more. El-Hissy *et al.* (1990) compared the mycoflora of submerged mud with the one recorded from water samples, and found a high degree of similarity.

Aquatic Fungi from Submerged Mud

El-Hissy *et al.* (1997) recorded 25 identified and 4 unidentified aquatic fungal species belonging to 11 genera of aquatic fungi from submerged mud collected randomly from the margins at different localities of Lake Nasser banks during the period from May 1992 to October 1992 (Table 62). The richest submerged mud samples in aquatic fungi were characterised by somewhat alkaline pH ranging between 7.1 and 7.9 and by low amounts of total soluble salts (1.9-2.9 mg/100 g mud sample) and low organic matter (1.6-1.9 mg/100g) (El-Hissy *et al.* 1997). The latter authors showed that approximately 54 % of the mud samples yielded only one aquatic fungal species per sample. *Pythium* and *Saprolegnia* were the most frequent aquatic fungal genera, whereas *Leptomitus* and *Nowakowskiella* were less frequent.

BACTERIA

Total Bacterial Counts (TBC) at 22 and 37 °C

Bacteria developing at 22 °C are saprophytic and their counts afford some indication of the amount of food substances available for bacterial nutrition and the amount of soil and other extraneous materials that water gained. On the other hand, bacteria developing at 37 °C are mainly parasitic, derived from soil or excretal material (APHA 1975). The ratio of colony counts at these two temperatures helps to explain any sudden fluctuation in bacterial counts, the wider the ratio, the more probable bacteria are related to soil or water saprophytes and therefore of minor health significance. In unpolluted water this ratio ranges from 1 to 10, while in polluted waters, it is generally less than one.

Elewa and Azazy (1986) studied the seasonal variations of the total bacterial counts (TBC) at four sites in Lake Nasser (High Dam, Allaqi, Amada and Abu Simbel) during 1974 and the drought period in 1984. Their results (Table 63) indicate regional, seasonal and yearly variations in TBCs. Thus the lowest total bacterial counts at 22 and 37 °C were recorded in winter, while the maximum values were in summer, mainly due to the renewal of nutrients carried by floods and to enrichment of the Lake with organic matter as a result of dead phytoplankton and decaying submerged vegetation. Furthermore, there was a gradual decrease of TBCs from south to north, with a further increase near the HD, which may be due to decayed materials as a result of fisheries activities.

The results (Table 63) indicate that the total bacterial counts in 1984 increased in comparison to those recorded in 1974, being parallel with the values of organic carbon. This may be attributed to the activity of the phyto- and zooplankton, and/or relative concentration of bacterial densities related to decreased water flow from the south (Elewa & Azazy 1986).

In 1996 (SECSF 1996) bacteriological studies were carried out in the main channel of Lake Nasser at nine sites in winter, spring and autumn. The results of total bacterial counts (TBCs) at 22 °C showed maximum values during spring at all sites ranging from $230\text{x}10^5$/ml at Abu Simbel to $1870\text{x}10^5$/ml at Kalabsha. At 37 °C the range was $100\text{x}10^5$/ml at Allaqi to $520\text{x}10^5$/ml at El Ramla. The minimum values developed at 22 and 37 °C were found in autumn ranging from 0.04 $\text{x}10^5$/ml at El-Madiq to $0.85\text{x}10^5$/ml at Abu Simbel (Table 64) and 0.04 $\text{x}10^5$/ml at Amada to $0.47\text{x}10^5$/ml at Korosko, respectively.

At the khors the total number of bacteria developed at 22 and 37 °C at surface waters in winter were higher than those recorded in the main channel. The maximum values recorded in spring ranged from $961\text{x}10^5$/ml at Khor Allaqi to $330\text{x}10^5$/ml at Khor Kalabsha near the bottom. The least number was found in autumn, ranging from $0.06\text{x}10^5$/ml at Khor Allaqi to $0.666\text{x}10^5$/ml at Khor Tushka near the bottom (SECSF 1996).

Comparing the results obtained by Elewa & Azazy (1986) in 1974 and 1984 with those recorded in 1996 (SECSF 1996) by choosing four sites for both studies (Table, 63), the following is observed:

1. A remarkable increase of the total bacterial counts in the last two decades is observed at all sites for both bacteria developed at 22 and 37 °C, amounting to more than 1000 folds.

2. High values were recorded, usually near the High Dam.

3. In winter 1996 there was a tendency of increase of the total bacterial count at 22 and 37 °C from north to south, while the reverse was true in autumn.

4. When considering the ratio of TBCs at 22 and 37 °C it was found that in 1974, 1984 and 1996 these ratios were above one, being narrower in summer and wider in winter and spring. In 1996 the ratio was less than those estimated in 1974 and 1984, except in autumn where the ratio was much higher. Thus it seems that Lake Nasser is still unpolluted and the low ratio values in winter

and spring 1996 (summer not recorded) may be due to eutrophication of the Lake.

Table 63 **Seasonal variations of total bacterial counts (TBCs) at 22 and 37 °C during 1974, 1984 (C/ml) and 1996 ($Cx10^5$/ml) in the main channel of Lake Nasser .**

Site	Year	Winter		Spring		Summer		Autumn	
		22 °C	37 °C	22 °C	37 °C	22 °C	37 °C	22 °C	37 °C
High Dam	**1974**	187	73	414	188	3730	2520	743	673
	1984	340	290	750	360	5100	4400	1800	1200
	1996	156	13	294	298	--	--	0.22	0.15
Allaqi	**1974**	175	63	238	87	2700	2450	460	383
	1996	14	10	133	100	--	--	0.39	0.12
Amada	**1974**	168	66	322	90	2680	2400	720	705
	1996	14.2	8.5	551	372	--	--	0.44	0.04
Abu Simbel	**1974**	172	68	421	192	4820	3510	710	637
	1996	5.16	4.3	230	200	--	--	0.85	0.316

(-- = not recorded)

Counts of both asymbiotic nitrogen fixers: the aerobes *Azotobacter* and the anaerobes, N_2-fixing clostridia, tended to decrease in 1984, compared with in 1974. This was attributed to the drought and less suspended matter reaching from the south, which might carry these organisms in flood water (Elewa & Azazy 1986).

Counts of nitrifying bacteria in 1984 showed a relative increase in comparison to those previously recorded in 1974. This might be due to the increase in the nitrifying activity related to the higher activity of the total bacterial load. This is confirmed by the remarkable increase in the nitrate content in the water of the Lake after the drought period. Thus, in 1984 the nitrate concentration ranged from 0 to 290 μg/l, as compared to 64 – 72 μg/l in 1974 (Elewa & Azazy, 1986). The zero value of nitrate concentration recorded in spring 1984 was correlated with the high photosynthetic rate of phytoplankton.

Considering pH values of Lake Nasser, it is noticed that upon storage in the reservoir a remarkable increase of pH (i.e. 8.89) was recorded in spring 1984, compared to pH 7.85 in autumn 1974. This may be attributed to the increasing photosynthetic activity, consuming free CO_2 from CO_3^{-3} and HCO^{-3} buffer system. This confirms that eutrophication of Lake Nasser is taking place. Hutchinson (1957) indicated that pH of productive lakes goes parallel with oxygen mainly in spring, the decrease in oxygen is related to a decrease of pH.

Purple Non-Sulfur Bacteria (Rhodospirillaceae)

Shoreit *et al.* (1989) recorded 485 isolates from different localities of Lake Nasser in summer 1984 to spring 1985 and found that these isolates comprise 5 genera with 8 species of purple non-sulfur bacteria. *Rhodopseudomonas* was the most common genus at all sites, represented by 3 species: *R. acidophila, R. blastica* and *R. palustris. Rhodomicrobium* was next in frequency, represented by *R. vannielli* only. This species was only recorded from khor sites (Fig. 87). *Rhodocyclus* was represented by 2 species, *R. gelatinosus* and *R. tenuis. Rhodobacter* and *Rodospirillum* were represented by one species each, *Rodobacter capsulatus* and *Rodospirillum rubrum.* Khor sites were richer in the number of isolates and genera of purple non-sulfur bacteria than the main body of Lake Nasser (Fig. 87).

The superior nitrogen-fixing Rhodospirillaceae from Lake Nasser were *Rhodocyclus gelatinosus* and *Rhodomicrobium vannielii* followed by *Rhodobacter capsulatus, Rhodopseudomonas viridis* and *Rhodopseudomonas palustris* (Shoreit *et al.* 1992). High and moderate nitrogenase activities (534 to 1528 n mol ethylene produced/4 ml/h) were found in 56% of the isolates (total 32), while the remainder showed low activities (76 to 477 n/mol ethylene produced /4 ml/h).

Purple non-sulfur bacteria in Lake Nasser exhibit seasonal and regional distribution. Thus *Rhodobacter capsulatus* was recovered more often in autumn, winter and spring 1985 than in summer 1984. Furthermore, it was more common in khors than in the main channel of the Lake, while *Rhodospirillum rubrum* was more common in summer than in winter and spring (Shoreit *et al* 1989). The latter authors point out that investigations are in progress to follow changes which are expected to take place with the long storage of water and their effect on occurrence and composition of photosynthetic bacteria.

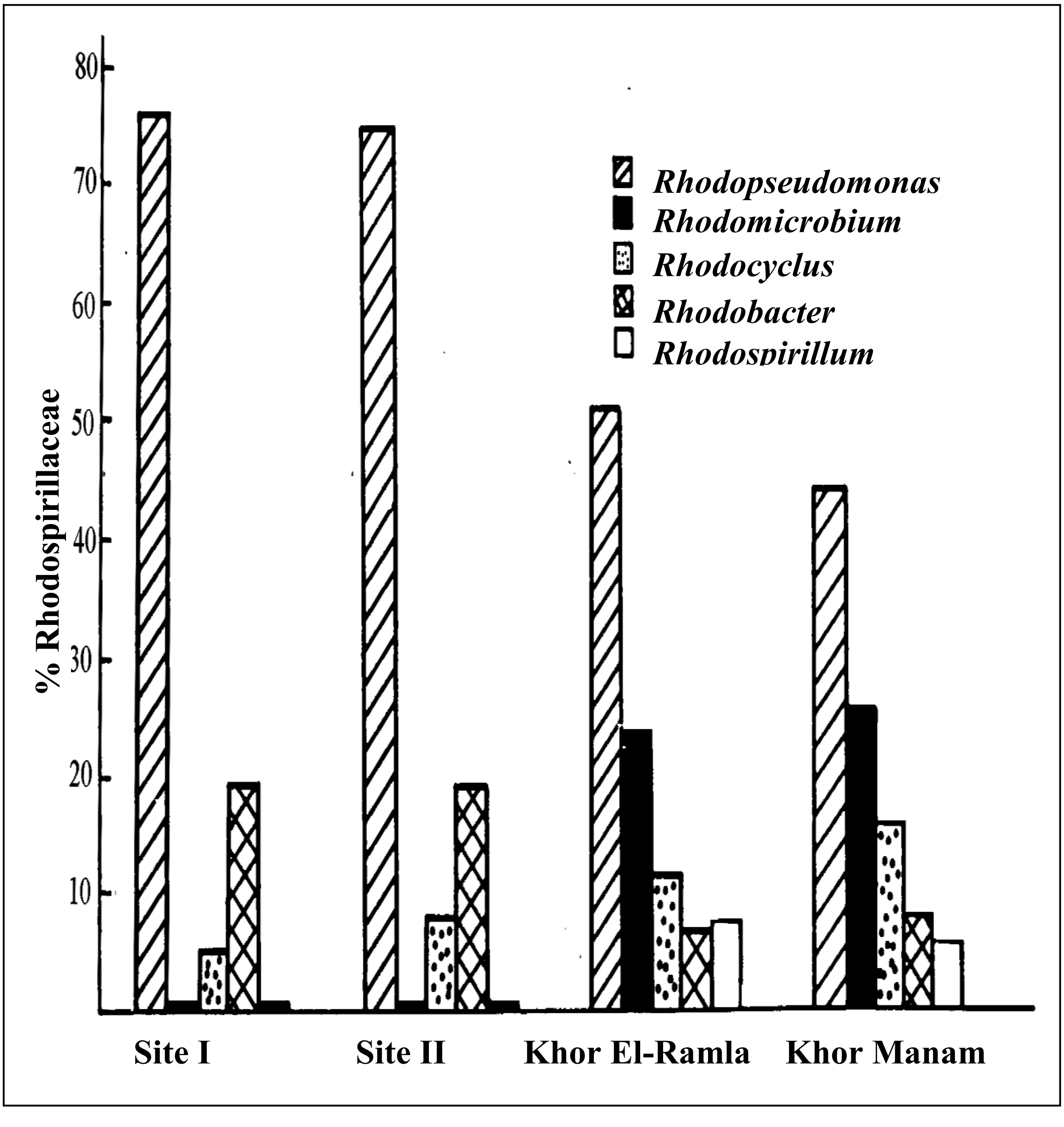

Fig. 87 **Percentage of genera of Rhodospirillaceae recovered in different localities (Sites I and II in the main channel) (Shoreit *et al.* 1989).**

Coliform and Faecal Coliform Bacteria

In 1996 (SECSF, 1996) investigations were carried out at nine sites along the main channel of Lake Nasser and five Khors (El Ramla, Kalabsha, Allaqi, Korosko and Tushka) in winter, spring and autumn, to determine the total number of coliform and faecal coliform bacteria. The results (Table, 64) indicated the following:

The main channel

(a) The highest number of faecal coliform bacteria (330x10^{3}/100 ml) was recorded near the High Dam in winter. At other sites it seems that the faecal coliform bacteria were also high in winter ranging from 0.17 to 17x10^{3}/100 ml, and low in autumn (range 0.0 to 0.035x10^{3}/100 ml).

(b) The total number of coliform bacteria was remarkably high (540x10^{3}/100 ml) near the High Dam in winter. Similar to the faecal coliform, the total number of coliform bacteria was highest in winter at other sites but with lesser values ranging from 0.22x10^{3}/100 ml at Allaqi to 46x10^{3}/100 ml at Kalabsha.

Table 64 **Total counts of bacteria (Cx10^{5}/ml) and the probable number of coliform and faecal coliform bacteria (Cx10^{3}/100 ml) in the main channel and Khors of Lake Nasser during 1996 (SECSF 1996).**

Site		Winter				Spring				Autumn			
		Coliform		Total count at		Coliform		Total count at		Coliform		Total count at	
		Faecal	Total	22 °C	37 °C	Faecal	Total	22 °C	37 °C	Faecal	Total	22 °C	37 °C
High Dam		330	540	15.6	13	0.2	0.4	294	298	0.035	0.05	0.28	0.18
El-Ramla		0.23	32	9	8.8	0.11	0.17	1850	520	00	0.002	0.3	0.12
Kalabsha		40	46	4	3.7	0.17	0.55	1870	2.7	0.11	0.014	0.12	0.06
Allaqi		0.17	0.22	14	10	0.25	0.35	133	100	0.225	0.55	0.39	0.12
El-Madiq		0.17	2.0	0.96	17.8	0.08	0.17	572	400	00	00	0.04	0.30
Korosko		0.33	0.48	15.7	2	0.002	0.005	567	393	0.002	0.005	0.26	0.47
Amada		0.23	0.54	14.2	8.5	0.002	0.008	551	372	00	0.005	0.44	0.04
Tushka		3.3	4	8.46	3.3	0.002	0.007	447	320	0.005	0.017	0.21	0.6
Abu Simbel		17	26	5.16	4.3	0.13	0.02	230	200	0.17	0.55	0.85	0.316
Khor El-Ramla	**Surface**	0.2	50	8.6	35.7	0.008	0.05	142	121	0.0	0.002	0.58	0.14
	Bottom	0.9	54	10	57	0.175	0.02	200	133	0.14	0.225	0.06	0.10
Khor Kalabsha	**Surface**	3.2	49	1.33	1	0.025	0.250	777	393	00	0.002	0.42	0.30
	Bottom	9	90	4.1	3.3	0.2	0.275	330	242	00	00	0.44	0.10
Khor Allaqi	**Surface**	0.22	40	22.1	18	0.002	0.017	933	650	0.002	0.002	0.64	0.06
	Bottom	0.46	45	8	50.6	0.045	0.200	961	680	0.002	0.004	0.08	0.16
Khor Korosko	**Surface**	0.11	11	18.2	16	0.005	0.11	550	400	00	0.002	0.12	0.35
	Bottom	0.32	20	114	90	0.035	0.20	590	480	00	0.002	0.30	0.32
Khor Tushka	**Surface**	0.2	0.7	60	35	0.025	0.14	356	349	0.017	0.050	0.53	0.65
	Bottom	0.9	5.4	182	59	0.04	0.2	378	354	0.02	0.05	0.72	0.66

Minimum values were recorded in autumn ranging from 0.0 at El-Madiq to $0.550x10^3/100$ ml at Abu Simbel.

The khors

(a) The numbers of coliform and faecal coliform bacteria were higher at the bottom than at the surface.

(b) In autumn certain Khors (Kalabsha and Korosko) were devoid of both types of bacteria, and when present in other Khors they were found in small numbers.

CONCLUSIONS

Macrophytes

Eleven macrophytic euhydrophytes (flowering and non flowering) were recorded from Egyptian Nubia pre- and post completion of the Aswan High Dam. Two euhydrophytic species have been lost after Lake Nasser formation, i.e. *Alisma gramineum* and *Damasonium alisma* Mill. var. *compactum.* Ten species were recorded from the Lake since its filling, including 5 cosmopolitan species: *Potamogeton crispus, P. pectinatus, Najas marina* subsp. *armata; Zannichellia palustris* and *Nitella hyalina* (an alga); and 4 subcosmopolitan species: *Potamogeton trichoides, P. lucens, Vallisneria spiralis* and *Najas horrida.* Recently, *Myriophyllum spicatum* was recorded from the Lake. Three species of *Potamogeton*: *P. crispus, P. trichoides* and *P. pectinatus*, recorded during the seventies and early eighties, are no longer observed in recent years.

Najas marina subsp. *armata* dominates the deep water zone at most sites and to a lesser extent in shallow water. *Vallisneria spiralis* dominates the submerged macrophytes especially at Amada. *Zannichellia palustris*, although widely spread in Lake Nasser but not forming dense stands, is found in shallow waters. *Potamogeton lucens* is found in small stands in the northern sector of the Lake. *Najas horrida* is abundant in the shallow waters of numerous khors of the Lake, often codominant with *Najas marina* subsp. *armata.* The alga *Nitella hyalina* grows in Lake Nasser not to any great depth in open sunny positions. It often grows on calcareous sand at Lake edges.

Up to the present no floating weeds are recorded in Lake Nasser although some of them, e.g. *Eichhornia crassipes* and *Pistia stratioles* are widely spread both upstream and or downstream. There is a possibility of their future appearance in the Lake and being mostly disadvantageous, so measures must be taken to prevent their spread.

Hall *et al.* (1969) listed 4 species of genus *Najas* within the Volta Basin, including the widespread weed *Najas pectinata.* The latter weed is a potentially troublesome aquatic plant. The latter authors mentioned *Eichhornia crassipes* as one of three weeds, which have caused trouble in Volta Lake (Ghana).

Therefore, in Lake Nasser, it is necessary to keep an eye against the introduction (accidental or intentional) of *Eichhornia crassipes.* It is advised to maintain a stock of dredgers and spraying equipment and a range of herbicides in case of an outbreak. Rapid total elimination from the outset will save much expense in the long run. Heinen (1965) recommended a poster campaign to acquaint local people with the appearnce of *Eichhornia.*

Algae

In the early stages of Lake Nasser (1971) 27 species of **phytoplankton** were recorded. During the period 1981-1993, 135 species belonging to 5 classes were recorded: 54 spp. Chlorophyceae; 34 spp. Cyanophyceae; 33 spp. Bacillariphyceae; 13 spp. Dinophyceae and 1 sp. Euglenophyceae. Phytoplankton community in Lake Nasser is rich both in density and biomass. Numerically, the standing crop increases southwards from $3.405\text{x}10^6$ algal units/l at El-Birba to $15.272\text{x}10^6$ algal units/l at Adindan. The average density of phytoplankton is $6.258\text{x}10^6$ algal units/l in surface water; while it is $2.081\text{x}10^6$ algal units/l at 20 m depth. The phytoplankton biomass attains annual averages of 22.913 and 4.088 mg/l in the surface water and at 20 m depth respectively.

Diatoms and blue-green algae are the dominant groups which exhibit seasonal and local distribution. Diatoms preponderate mainly over Cyanophyceae (Cyanobacteria) along the main channel and all areas as they are well adapted to the new environment.

A marked increase of phytoplankton (upper 10 m) starting from the High Dam (average $2.707\text{x}10^6$ algal units/l) to Kalabsha (average $3.44\ \text{x}10^6$ algal units/l) was recorded. Then the number of phytoplankton decreased from El-Madiq and attained minimum values at Adindan ($0.948\text{x}10^6$ algal units/l). The average highest phytoplankton density was recorded in August (1976), being $4.7\text{-}9.5\text{x}10^6$ algal units/l. During flood time, flood waters push great amounts of phytoplankton to the northern region of the Lake. At the southernmost station (Adindan) the lowest phytoplankton densities were recorded during flood and post-flood season.

Phytoplankton exhibit vertical distribution (during October 1979), where the density remains, more or less, constant at the northern stations (from the High Dam to Kalabsha). At Amada higher values were recorded at 3 m depth, mainly of Cyanophyceae. At El-Madiq and Abu Simbel phytoplankton density during summer and autumn was higher at surface waters compared with subsurface ones. At Adindan, the highest density was recorded at one m depth and the least at the surface and 10 m depth. During thermal stratification (late spring, summer and early autumn) phytoplankton in Lake Nasser exhibit vertical variations. Diatoms mainly *Cyclotella* spp. and blue-green algae mainly *Anabaenopsis* sp. are the most dominant.

There is an inverse relationship between algal development and dissolved nitrate nitrogen. During August (1976) Cyanophytes were most common (71.2-89%) in the northern stations (High Dam to Amada), while diatoms were of minor importance (2.7%). In the southern stations (Tushka and Adindan) the reverse was the case, where diatoms were dominant (92.3-98.0%) and Cyanophytes constituted low percentages (0.9-7.0%). Chlorophytes remained at low concentrations throughout the Lake.

Khors sustain higher phytoplankton densities than in the main stream. Thus, the average values were 3.622×10^6 algal units/l and 5.234×10^6 algal units/l at Khor Kalabsha and Khor Singari respectively. Furthermore southern khors are more productive than the northern.

Water blooms occur occasionally (1987 to 1992) in Lake Nasser, in limited areas of the southern region. Recently it occurs intermittently all the year round and throughout the Lake. Water blooms are caused by flourishing of Cyanophyceae species leading to the formation of crusts and scums, where plants die quickly and disintegrate in intense sunlight causing oxygen depletion. In water blooms *Microcystis aeruginosa* is the dominant species in all cases, followed by *Nostoc* spp. and *Oscillatoria* spp. The latter species was recorded in remarkable quantities in Korosko, and *Aphanocapsa* spp. at Abu Simbel. During the period of 1987-1992 only six water blooms were recorded.

The southern region of the Lake shows high mean values of **chlorophyll *a*** concentrations than in the northern region. The highest concentration is recorded at Abu Simbel in the main stream prior to the annual flood. The highest values of chlorophyll *a* concentrations are recorded at 2 to 4 m depth and gradually decrease with depth.

There is no distinct seasonal variation of chlorophyll *a* concentrations in the northern stations; while marked seasonal variations are found in the southern region. Chlorophyll *a* concentration in the main channel shows seasonal changes with high values during the high temperature period, and low values during the low temperature period. This is paralleled with Secchi disk depth being highest during the low temperature period and lowest during the high temperature period and high chlorophyll *a* concentration.

Relationships between chlorophyll *a* concentration and Secchi disk depths seem to be exponential on a semilogarithmic plot, as reported by several investigators in various waters. Positive correlation is observed between chlorophyll *a* concentration and suspended solids. Positive correlation with considerable scattered data points is noticed between chlorophyll *a* concentration and particulate organic matter.

Chlorophyll *a* concentrations are generally high inside khors than at their entrance or in the main channel, except during winter in Khor El Ramla where the reverse is true. Khor Kalabsha located in the southern region is more productive than Khor El Ramla located in the northern region. Chlorophyll *a* concentrations in khors follow the same trend as in the main channel, attaining their maximum values during spring and summer, and reaching their minimum during winter. In khors there is no wide horizontal variation of chlorophyll *a* concentrations inside, outside or at the entrance of khors, except during spring (March-April), where remarkable variations are recorded. It seems that the maximum chlorophyll *a* concentration in khors during successive years (1982-1988), is, more or less constant.

Both relationships of chlorophyll *a* to the Secchi disk depth inside and outside the khors are exponential, when plotted on a normal diagram in a similar manner as reported in both freshwater lakes and in marine waters.

Nanoplankton (<20 µm) constituted the major component of total chlorophyll *a* along the main channel with few exceptions, where chlorophyll *a* of net plankton was dominant. Maximum values for chlorophyll *a* of net and nanoplankton were recorded in spring and the minimum in winter. There were seasonal, regional and vertical variations of nanoplankton chlorophyll *a.* During winter, chlorophyll *a* concentrations were higher at the northern region than at the southern, but in spring the reverse was true.

Studies on **primary productivity** of Lake Nasser showed that it is eutrophic with highest productivity at 1-2 m depth. Gross primary productivity below 1 m^2 (∑ gross g $C/m^2/day$) ranged from 3.2 to 5.23, while optimum productivity (A opt.) ranged between 1.25 and 2.02 g $C/m^2/day$. The relation between gross primary productivity (∑ gross) and optimum production (A opt). - ∑ gross/A opt. - is highest at El-Birba then decreases gradually towards the southern region due to the gradual decrease of depth of the photic zone. Gradual eutrophication of Lake Nasser may be a result of continuous sedimentation of organic matter which accumulates annually with flood water rich in nutrients.

Studies on primary productivity of Lake Nasser – during recent years - along the main channel showed that it ranged from 179.91 in spring at Dihmit to 2.72 mg $C/m^3/h$ in summer at the High Dam at 3m depth. The highest average primary productivity (68.80 mg $C/m^3/h$) was recorded in spring, the lowest (2.39 mg $C/m^3/h$) in winter. The maximum average value of photosynthetic activity was recorded in summer at 15m depth (8.21 mg C/mg Chl/h) and the minimum in winter (1.08 mg C/mgChl/h).

Of the **epiphytic algae** - which constitute the most important food items of tilapias - 28 algal species were recorded, belonging to 4 major groups : Chlorophyta, Cyanophyta, Bacillariophyta and Pyrrophyta. The predominant genera were *Oedogonium, Stigeodonium* and *Spirogyra.* The maximum amounts of chlorophyll *a* were correlated with the dominance of filamentous forms and the low values were observed in poor samples which contained paucity of green or blue green algae. *Spirogyra* was recorded mainly in the southern part of the Lake (Abu Simbel and Tushka).

Fungi

25 identified and 4 unidentified species related to eleven genera of aquatic phycomycetes were recorded from surface water samples, collectd from Lake Nasser. The richest water samples in aquatic phycomycetes species were characterised by relatively low temperatures (15.9 - 20.3 °C) and pH range between 7.4 and 8.3. The poorest samples were characterised by relatively high temperatures (20.6 - 33.1°C), pH values fluctuating between 6.3 and 9.2, dissolved oxygen varying from 4.5 to 10.6 mg/l, total soluble salts ranging from 149 to 175 mg/l and the organic matter content between 2.0 and 51.1 mg/l. *Saprolegnia* and *Pythium* were the most frequent aquatic fungal genera; whereas *Aphanomyces, Dictyuchus, Pythiopsis, Leptomitus, Allomyces* and *Blastocladiopsis* were less frequent.

The fungal population of Lake Nasser showed marked vertical variations. High fungal counts were observed at the surface water mainly due to the high counts of *Aspergillus fumigatus* and *A. terreus.* Going deeper, the fungal population decreased till 30 m, then gradually increased to reach its maximum at 70 m depth. Such increase was basically due to the high population of *Penicillium funiculosum.*

Mesophilic fungi recoverd from the monthly samples of marginal water and submerged mud of Lake Nasser showed the highest fungal populations either in October, December 1985 or February 1986. Thermophilic and thermotolerant fungal species were common in one or more locality.

The richest submerged mud samples in aquatic fungi were characterised by somewhat alkaline pH, ranging between 7.1 and 7.9, by low amounts of total soluble salts (1.9-2.9 mg/100 g mud sample) and low organic matter (1.6-1.9 mg/100g). *Pythium* and *Saprolegnia* were the commonest aquatic fungal genera whereas *Leptomitus* and *Nowakowskiella* were less frequent.

Bacteria

Microbiological studies of Lake Nasser during 1974, 1984 and 1996 showed regional, seasonal and yearly variations. In 1974 and 1984 the lowest total bacterial counts (TBCs) at 22 and 37 °C were recorded in winter and maximum values in summer. There was a gradual decrease in TBCs from south to north with highest values near the HD. Furthermore, TBCs in 1984 were higher than in 1974, and those in 1996 were more than thousand fold those recorded in 1984. In 1996 total bacterial counts determined at 22 and 37 °C showed maximum values in spring at all sites in the main channel and khors (no data were recorded in summer), while minimum values were recorded in autumn. In khors the TBCs of surface waters recorded during winter were higher than those in the main channel. The ratio between total bacterial counts at 22 and 37 °C in Lake Nasser is more than one, with slight changes since its early filling, an indication that it is still unpolluted.

The counts of both asymbiotic-nitrogen fixers the aerobes *Azotobacter* and the anaerobes, N_2-fixing bacteria tended to decrease in 1984 compared to ten years earlier. This might be due to the drought and less suspended material reaching from the south, which carry these organisms in flood water.

The nitrifying bacteria showed a remarkable increase in 1984 compared with counts in 1974, associated with increase in nitrifying activity related to higher activity of the total bacterial load. This led to an increase in the nitrate content of the Lake water after the drought in 1984. An indication of eutrophication of Lake Nasser is the remarkable increase of pH in spring 1984 as compared to that in autumn 1974.

Four different genera with 8 species of purple non-sulfur bacteria were recorded from Lake Nasser. *Rhodopseudomonas,* the most common genus at all sites, was represented by 3 species: *R. acidophila, R. blastica* and *R. palustris. Rhodomicrobium* was the next in frequency, represented by *R. vannielli*, recorded only from khor sites. *Rhodocyclus* was represented by *R. gelatinosus* and *R. tenuis,* while *Rhodobacter,* and *Rodospirillium* each was represented by one species. It was observed that khor sites were richer in the number of isolates and genera of non-sulfur bacteria than the main body of Lake Nasser. Furthermore, purple non-sulfur bacteria in Lake Nasser exhibited seasonal and regional distribution.

Studies on the coliform and faecal coliform bacteria in the main channel showed that their number was highest in winter near the High Dam compared with other localities. In other sites the highest values were recorded also in winter (no records were undertaken in summer), while minimum values were found in autumn. The number of coliform and faecal coliform bacteria at the bottom of khors was higher than those at the surface. Furthermore certain Khors (Kalabsha and Korosko) were devoid of both types of bacteria.