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AADRAY

THE DIATOM FLORA OF A EUTROPHIC BAY, THE EASTERN HARBOUR OF ALEXANDRIA

DIJATOMEJSKA FLORA EUTROFIČNOG ZALJEVA, ISTOČNA LUKA ALEKSANDRIJE

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The plantonic and benthic diatoms — epiphytes, lithophytes and psammophytes — were investigated in relation to the pollution gradient. A distinct zonation is observed between the inner, turbid and heavily polluted bay and the outer »recovery« zone. The inner bay is characterised by a drastically improverished population, by the presence of some brackish forms, the exclusive occurence of the psammophytic species and the dominance of some planktonic diatoms. On the average, the cells were smaller in volume in the »recovery« zone than in the inner bay. The quantitative cyle, compared to eariler observations, reflects the steady change resulting from the cessation of the Nile input accompanied by intensified pollution.

The »Eastern Harbour« of Alexandria is a relatively small semicircular bay surrounded by the city, except on its northern side, where it communicates with the sea through two channels. Although the E. H. is not the main port of Alexandria, fishing docks occupy a small area in the N. W. corner of the bay. Municipal waste water is released intermittently from several outfalls on the southern embankment. This, added to the dock and ship wastes, creates eutrophic conditions in the inner bay, and primary productivity is abnormally high (Halim *et al.*, this volume). Towards the bay inlets, however, the effect of the outfalls is reduced by dilution with inflowing se water. In the inner bay, the bottom is muddy and smells of H_2S. In the center and towards the inlets, it is of muddy sand mixed with shell remains, on which grow large patches of *Caulerpa* sp. Surface circulation is anticlockwise. Surface temperature ranges from 16.5°C to 28.5°C. The average salinity is lowest at the inner station I, 37.96‰, directly affected by the discharge, increasing to 38.10‰ and 38.25‰ respectively at stations II and III (Figs. 2 to 4). The E. H. waters are turbid all the year round. The Secchi-disc depth (Fig. 5) ranged between 50 cm (Station I) and 350 cm (Station III). The lowest readings were in summer, due to the thick blooming of the dinoflagellate *Alexandrium minu-*

tum Halim. The pollution gradient from the bay inlets (Station III) to the outfalls (Station I) is accompanied by a decrease in salinity and an increase in turbidity.

The diatom flora of the E. H. bay, both planktonic and benthic, was investigated in relation to the pollution gradient during a period of 12 months. The benthic diatoms were collected from three types of substrates the infralittoral zone all round the bay; a) algae b) rocks and barnacles c) sediments.

According to their substrate of attachment therefore the benthic species obtained include three categories, epiphytes, lithophytes and psammophytes.

Table 1. Type of substrate, depth of collection and number of benthic diatom species.

	Substrate	Depth	Number of species
Epiphytes	*Ulva* sp.	0—1 m	6
	Petrocladia sp.		9
Lithophytes	Barnacles & Rocks	0—2 m	20
Psammophyetes	Mud,	4—6 m	20
	Muddy sand	10 m	46

The planktonic diatoms were collected from three stations (Fig. 1) by means of a reversing bottle and a phytoplankton net. Station I is under the direct influnce of the municipal outfalls while Station III is alternately affected both by the dilute waste waters and by the inflowing seawater. It is more or less a »recovery« zone. Station II is intermediate.

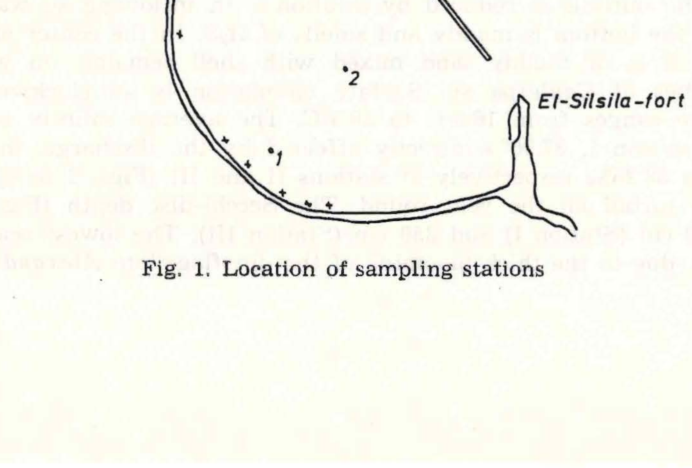


Fig. 1. Location of sampling stations

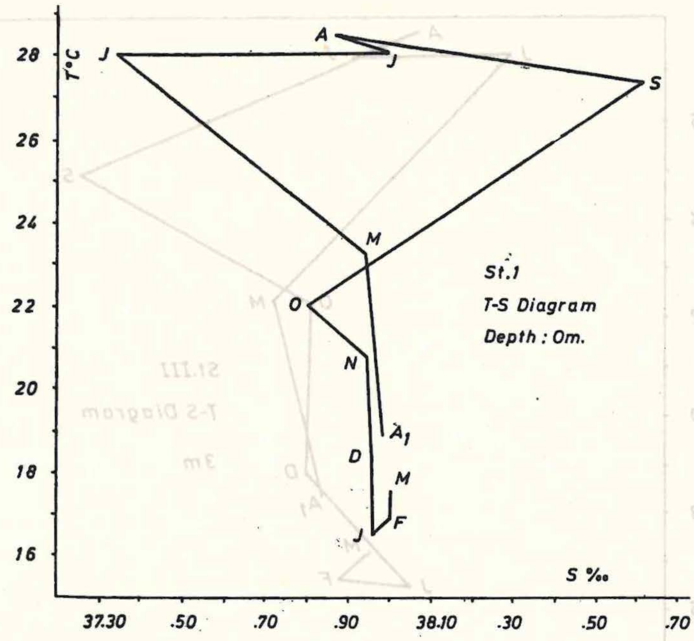
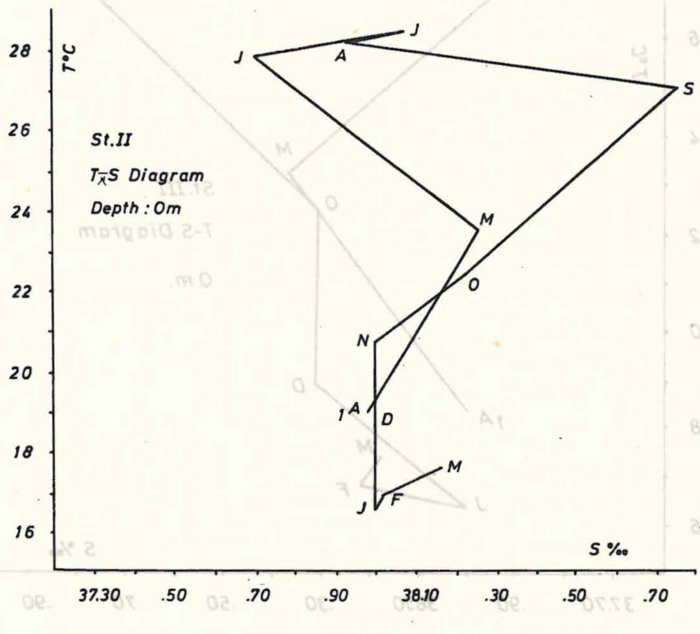

St.1
T-S Diagram
Depth : Om.
T°C
S ‰
28
26
24
22
20
18
16
37.30
.50
.70
.90
38.10
.30
.50
.70

Fig. 2.


St.II
T-S Diagram
Depth : Om
T°C
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28
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Fig. 3

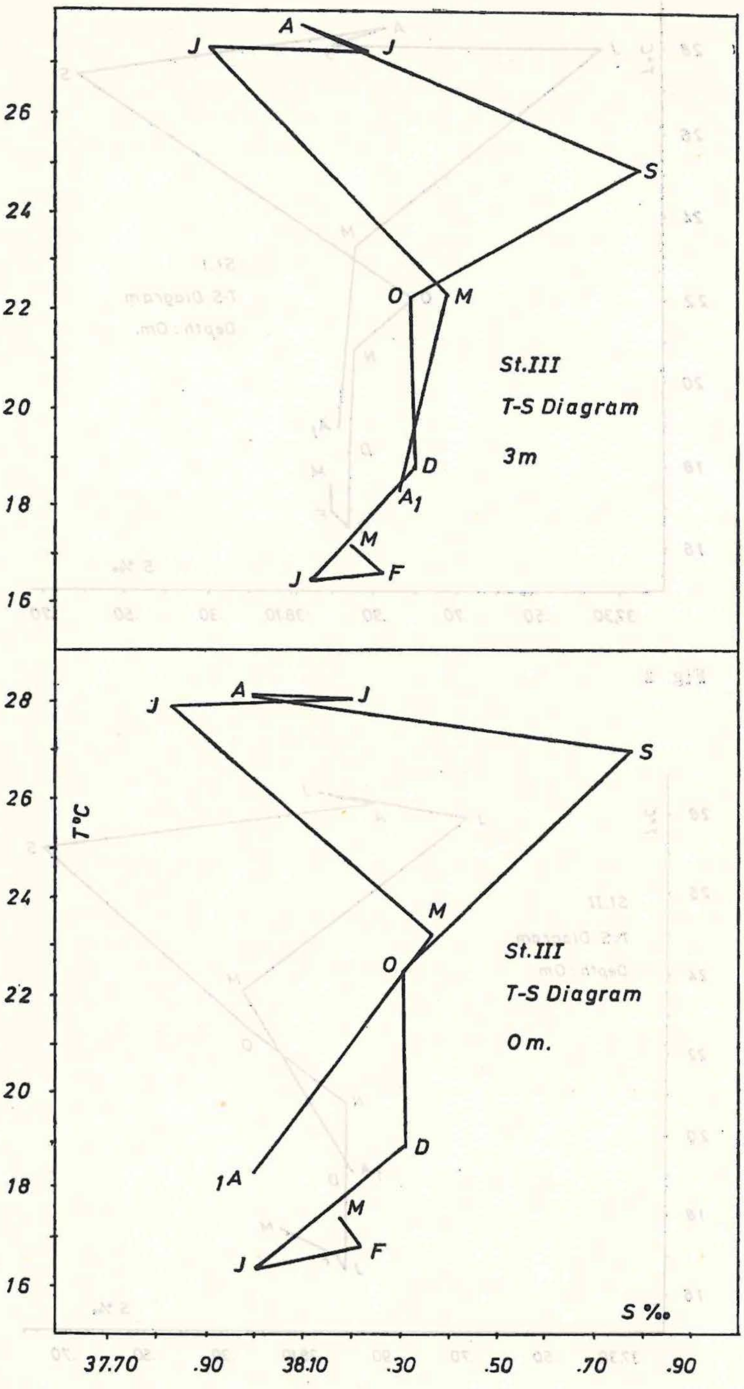
St.III
T-S Diagram
3m
St.III
T-S Diagram
0 m.
T°C
S ‰
37.70
.90
38.10
.30
.50
.70
.90

Fig. 4

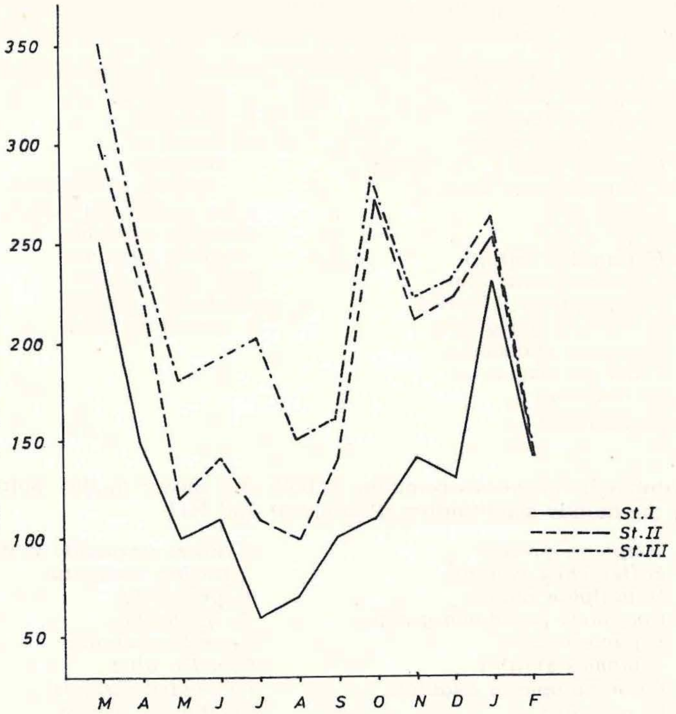

Fig. 5. The Secchi-disc readings at stations, I, II and III

SPECIES DISTRIBUTION

The total number of species and the species composition show a significant zonation reflecting the pollution gradient from the inner bay to the inlets. This is particularly obvious for the benthic psammophytic species. The distribution of the planktonic species is also affected but it is less distinct, because of mechanical transport and drifting.

Of the 49 psammophytic species obtained from the bay sediments, 29 appear to be repelled by the anoxic conditions of the muddy bottom in the inner bay and do not extend beyond stations II & III.

The species common to both the anoxic muddy bottom of the inner bay and to the muddy sand bottom were less numerous (17 species). Most of them were rare at Station I, but two appear to be more abundant at this Station: ***Diploneis fusca* & *Melosira granulata* v. *angustissima*.**

Three psammoptytic sepcies were found to be restricted to the inner bay They were ***Cymatosira belgica*, *Navicula distans*** and ***Amphora grevilleana contricta*.** The latter three species together with *Diploneis fusca* and *Melosira granulata* v. *angustissima* constitute therefore the characteristic psammophytic community of the heavily polluted inner bay.

The epiphytic and lithophytic species, collected from the upper infralittoral zone appear to be more dependent on the type of substratum. The smooth

Table 2. Psammophytic species intolerant to pollution and limited to the outer (recovery) zone of the bay (Stations II & III).

Amphora cymbifera	*Nitzchia panduriformis*
Amphora ocellata	*N. carinifera*
Amphora turgida	*N. abrupta*
Amphiprora alata	*N. plana*
Caloneis liber v. *bicuneata*	*N. punctata*
Campylodiscus decorus	*Pinnularia trevelyana*
C. echeneis	*Pleurosigma formosum*
C. fastousus	*Surirella hybrida*
Cerataulus smithii	*Surirella pandura*
Cocconeis scutellum	*Synedra baculus*
Cymatopleura elliptica	*Terpsinoe musica*
Dictyoneis marginata	*Triceratium favus*
Diploneis chersonensis	
Navicula clavata	
N. crucifera	
N. perplexa	

Table 3. Psammophytic species common to both the anoxic muddy bottom (Station I) an the muddy sand bottom (Stations II and III).

Amphora proteus	*Meloisra granulata* v. *angustissima*
Bellerochea malleus	*Nitzschia focripata*
Biddulphia obtusa	*N. preatexta*
Cocconeis pseudomarginata	*N. spathulata*
Diploneis fusca	*Surirella fastuosa*
Diploneis smithii	*Synedra ulna*
Grammatophora angulosa	*Toxonidea insignis*
G. oceanica	*Trachyneis aspera*

Ulva fronds provide poorer surface of attachement than those of *Pterocladia.* More epiphytic diatom species therefore were found on *Pterocladia* than on *Ulva*. Five epiphyte species are dominant and abundant all round the bay. By order of abundance they are: *Grammatophora marina, Licmophora lynglyei, L. flabellata, Climacosphenia moniligera* and *Nitzschia sigma v. rigida* (Table 4).

The lithophyte species were more numerous, but always found in lesser abundance.

Eighty-eight planktonic species were recorded from the bay (including the tychopelagic), 23 of which were absent from the inner polluted zone. These are mostly offshore species carried in by the inflowing sea water and unab'e to survive in the conditions of the inner bay (Table 5). The distribution of planktonic forms, however, is unlikely to present a distinct zonation in such a small bay because of mixing and mechanical transport. Two species were only met with in the inner zone, though their occurrence was occasional, *Surirella ovata* and the brackish *Synedra ulna* v. *aequalis.* The occurrence of some fresh-water Chlorophyceae should also be mentioned.

Compared to the outer zone or zone of recovery, therefore, the eutrophic inner zone is not only characterized by an impoverished population — both benthic and planktonic — and by the presence of some brackish and tolerant forms of rare occurrence but also by the permanent dominance of a small community of blooming species.

Table 4. Epiphytes and lithophytes of the infra-lottoral zone. v. r.: wery rare, r: : rare, f : frequent, c : common ab : abundant

Species	Epiphytes *Pterocladia* sp.	Epiphytes *Ulva* sp.	Lithopytes Rocks and barnacles
Melorisa granulata angust.	r	—	—
Cyclotella meneghiniana	r	—	f
Triceratium pentacrinus	—	—	r
Biddulphia aurita	—	—	f
Rhabdonema adriaticum	—	—	r
Grammatophora angulosa	—	—	r
G. marina	ab	f	f
Licmophora lyngbyei	ab	f	f
L. flabellata	f	r	r
L. paradoxa	r	—	—
Climacosphenia moniligera	c	—	r
Cocconeis scutellum	—	—	vr
C. pseudomarginata	—	vr	vr
Achnanthes longipes	—	—	vr
Navicula lyorides	r	—	r
N. atlatnica	—	—	vr
N. hennedyii	—	—	r
N. preatexta	—	—	vr
Diploneis smithii	—	—	r
Nitzchia lorenziana	—	vr	r
N .sigma var. *rigida*	f	c	f
N. spathulata	—	—	f

Table 5. Planktonic species intolerant to pollution, restricted to the recovery zone (Stations II & III).

Achnantehs longipes
Asteroalmpra grevillei
A. marylandica
Bacteriastrum varians
Biddulphia laevis
B. rhombus
Chaetoceros socialis.
Coscinodiscus centralis
C. nitidus
Donkinia recta
Hyalodiscus stelliger
Opephora schwartzii
Rhabdonema adriaticum
Rhizosolenia alata v. *indica*
R. delicatula
R. fragilissima
R. robusta
R. shrubsolei
R. stolterfothi
Stauroneis membranacea
Surirella amoricana
S. striatula
Thalassiotrix frauenfeldi

THE STANDING CROP

The quantitative variations of the standing crop in the Eastern Harbour have been studied over several complete year cycles before and after the Asswan High Dam became functional in 1965: in 1956—57 (El-Maghraby and Halim, 1964), in 1965—66 (Guerguess, 1969) and in 1972—73 (Halim *et al.*, in this volume) to which must be added the present work carried out in 1977—78. The sequence of these observations reveals a steady trend of change resulting from the absence of Nile water outflow after the High Dam, accompanied by the intensifyied pollution.

1. In 1956—57, long before the High Dam was in place, the standing crop was typical of all Egyptian neritic waters. The cycle was bimodal with an outstanding »Nile bloom« in Autumn and a small late winter bloom.

2. In 1965—66, the Nile outflow was already reduced by half. The cycle was still bimodal but the »Nile bloom« dropped to about 10% of its pre-High Dam level.

3. In 1972—73, in the absence of any »Nile bloom« the cycle was still bimodal but the relative importance of the two peaks was reversed. The spring bloom now became the major one, as happens regularly in most Mediterranean localities.

In the present observations, the quantitative cycle reflects both the absence of the Nile outflow of Autumn and of the increased eutrophication and does not follow any seasonal trend. Instead of a bimodal cycle, it is characterized by successive blooming pulses at 2 to 3 months intervals (Fig. 6 to 8). Blooms occurred in early and in late spring, in early and late summer and in mid-winter. The drop in density of the standing crop during the inter-blooming periods coincides or follows an increase in the density of the herbivorous zooplankton. Grazing appears to be the major factor causing the standing crop fluctuations. This was particularly obvious in mid-spring, mid-summer and in Autumn.

The total cell volume was found to be a more adequate measure of the standing crop as it reflects its true size. The estimation of the crop by cell numbers can sometimes be misleading as a result of the large range in cell sizes of the dominant species, and also of the seasonal size changes within the same species (Table 6).

Table 6. Range of cell size variations for the dominant species in μ^3.

Species	Cell size range
Skeletonema costatum	: 169 — 450
Rhizosolenia fragilissima	: 4850 — 6640
Chaetoceros curvisetus	: 690 — 2155
Lithodesmium undulatum	:49000 — 68000
Leptocylindrus danicus	: 650 — 4100
Biddulphia alternans	:18400 — 24800

Fig. 6 to 8, show some discrepancies between the numerical and the volumetric standing crop. The decrease in cell numbers between May and June (Stations I to III) was accompanied by an increase in the crop volume. The opposite trend was observed in July at Station I.

The total average cell size, for all observations, was significantly higher in the inner zone of the bay, respectively 1.25, 0.27 and 0.24 × 10^3 μ^3 at stations I, II and III. On the average, smaller cells are found in the »recovery« zone than in the inner, heavily polluted zone.

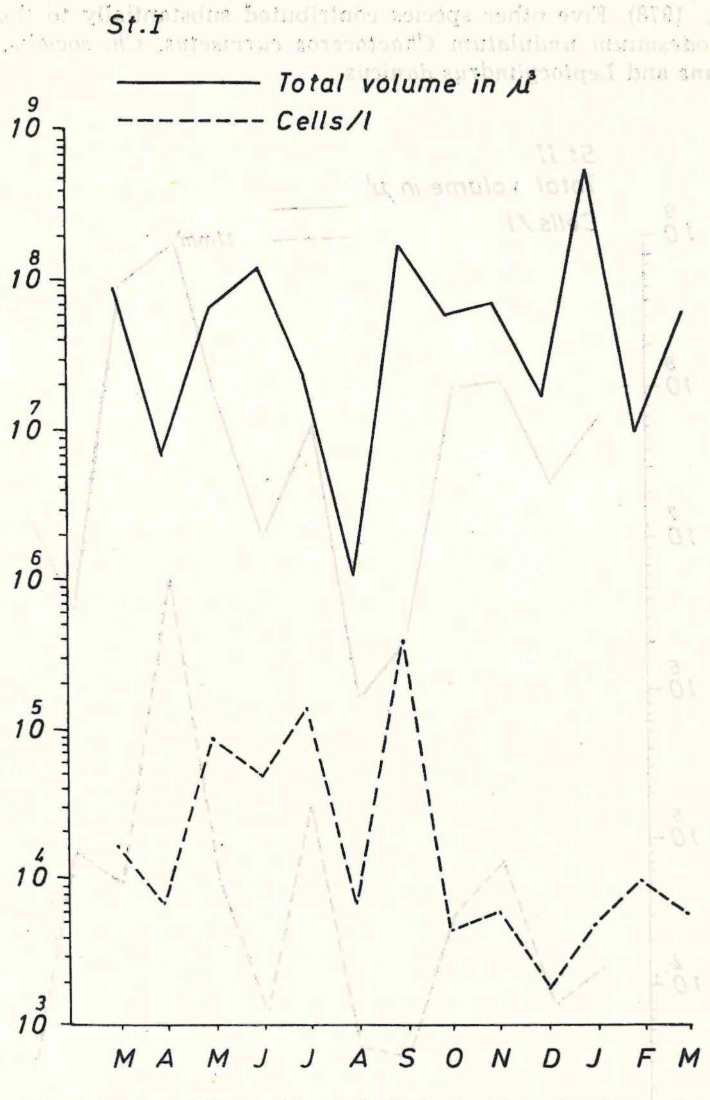

Fig. 6. Seasonal fluctuations of phytoplankton standing crop (total cell volume in μ^3/I ond cell number/1) at tion I

The standing crop was unexpectedly low, particularly in comparison with the station worked by Halim *et al.* (this volume) in the western part of the bay. The »recovery« zone (Station II and III) was more productive than the inner zone, hut this is due to the heavy bloom of *Chaetoceros socialis* in December, reaching almost 7 milion cells/1. *Skeletonema costatum* was the major species throughout the year (Fig. 9). This species is known to be dominant in the Eastern Harbour (Halim *et al.*, this volume), as well as in other dilute organically polluted waters (Pucher-Petković et Mar a s o v i ć, 1978). Five other species contributed substantially to the standing crop: *Lithodesmium undulatum Chaetoceros curvisetus, Ch. socialis, Biddulphia alternans* and *Leptocylindrus danicus.*

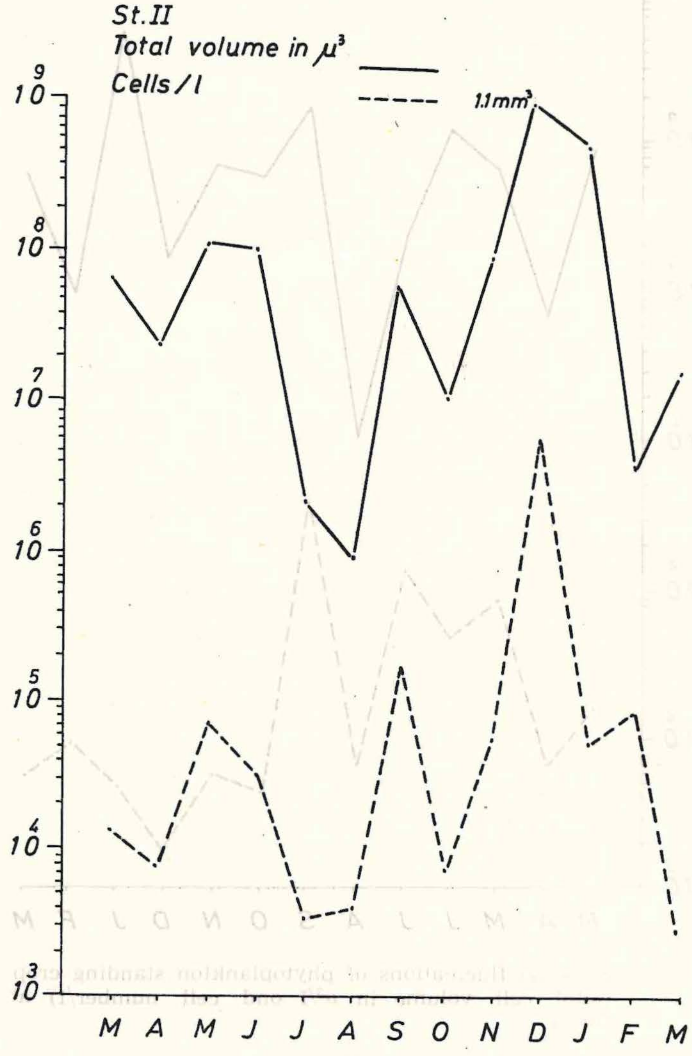

Fig. 7. Seasonal fluctuations of phytoplanktion standing corp (total cell volume in u³/l and cell number/l) at station II

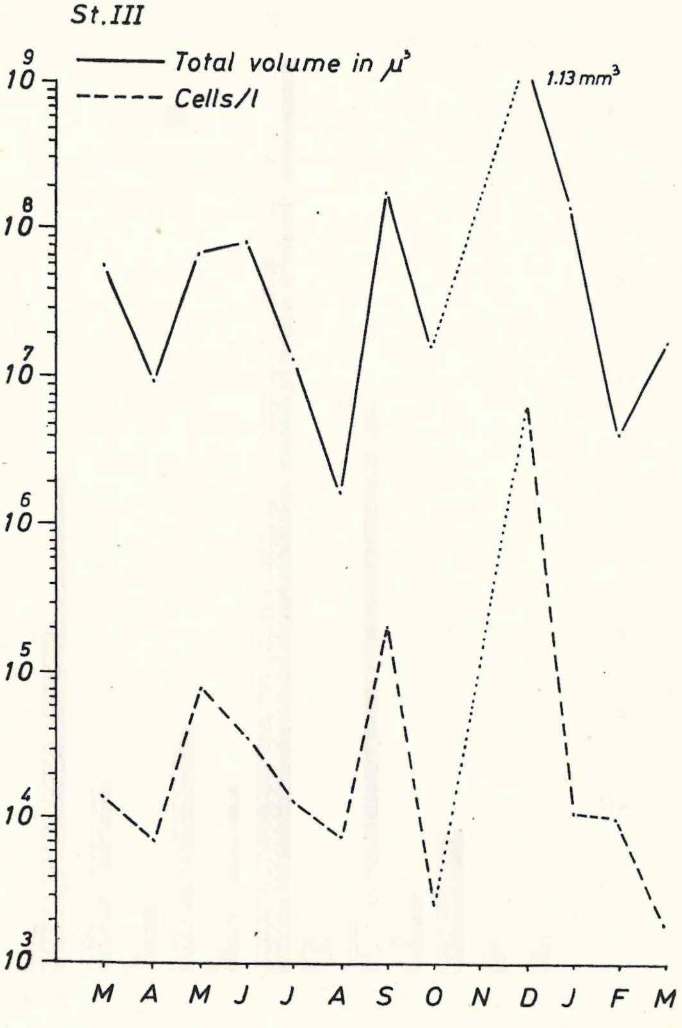

Fig. 8. Seasonal fluctuations of the phytoplankton standing crop (total cell volume in μ^3/l and cell number/l) at station III

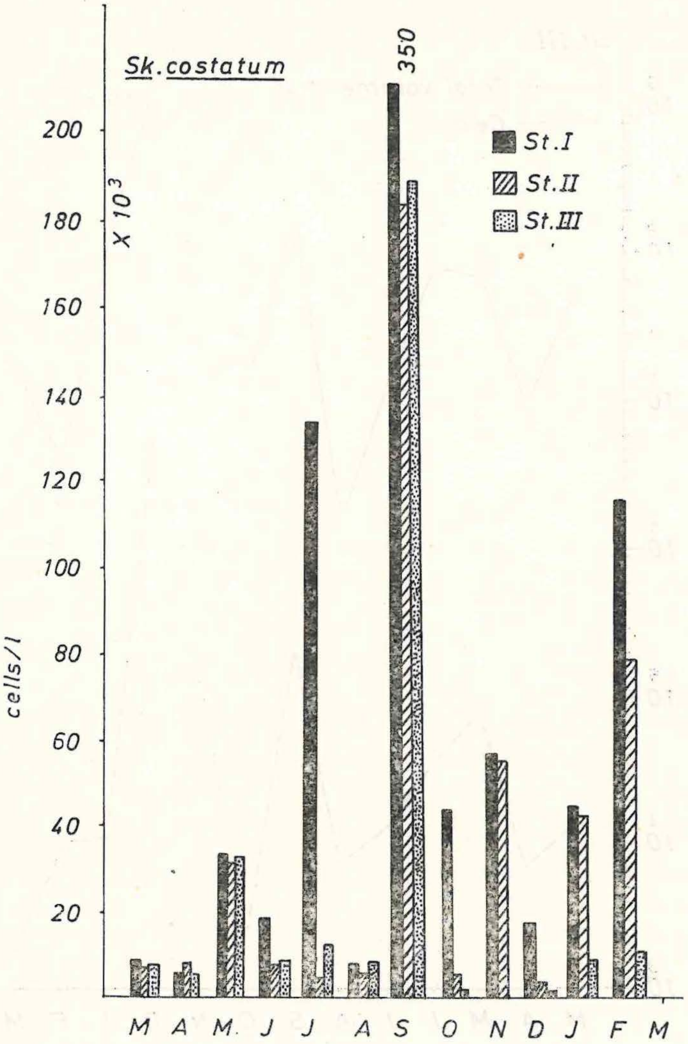

Fig. 9. Seasonal fluctuations of *Skeletonema costatum* density (No cells/1 X 10^3) at stations I, II and III

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DIJATOMEJSKA FLORA EUTROFIČNOG ZALJEVA, ISTOČNA LUKA ALEKSANDRIJE

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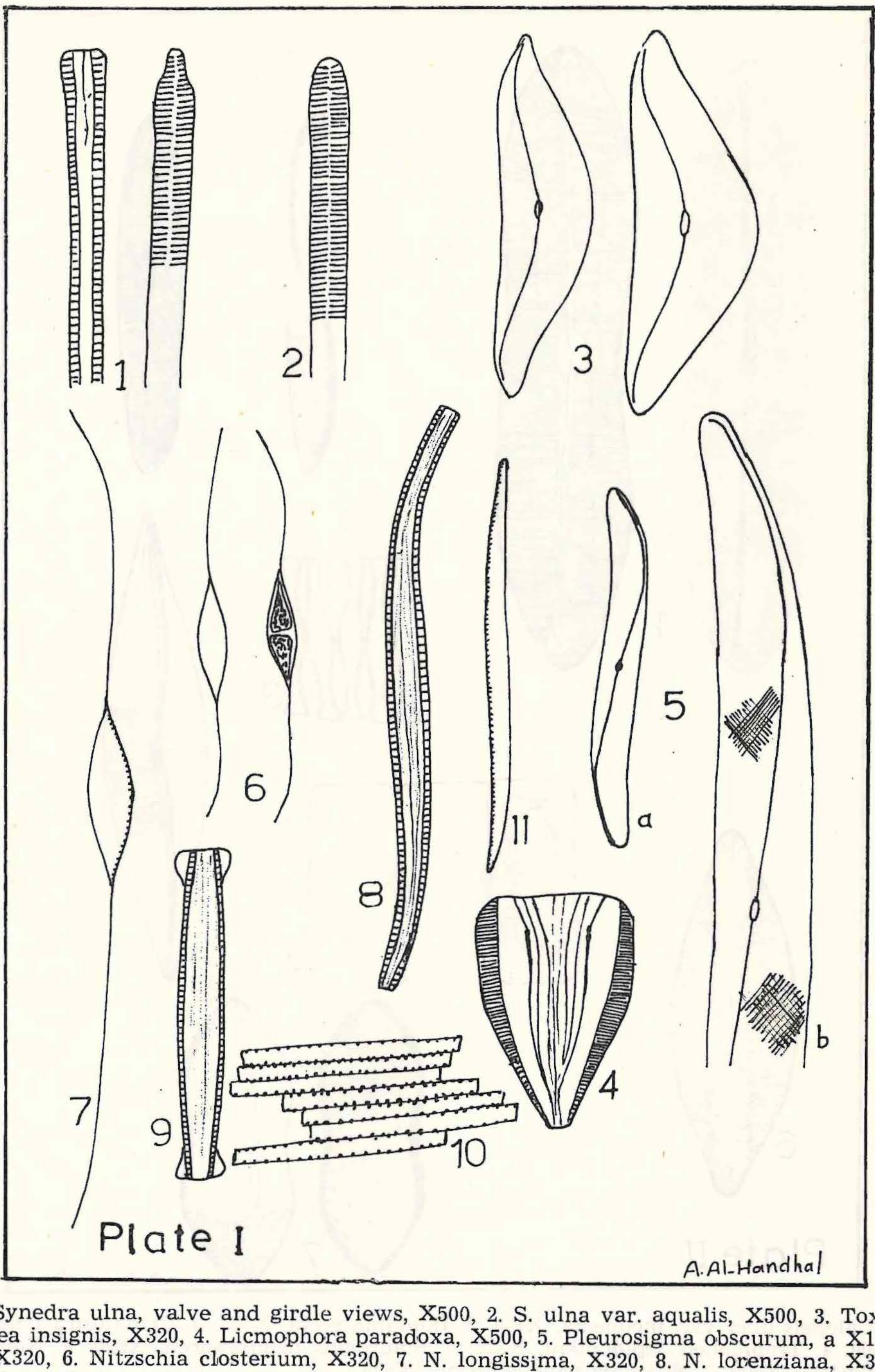
KRATAK SADRŽAJ

Izučavane su planktonske i betonske dijatomeje (epifiti, litofiti i psamofiti) u odnosu na gradient polucije. Uočena je jasna zonacija između nutarnjeg, zamućenog i jako zagađenog zaljeva te vanjske, »oporavljene« zone.

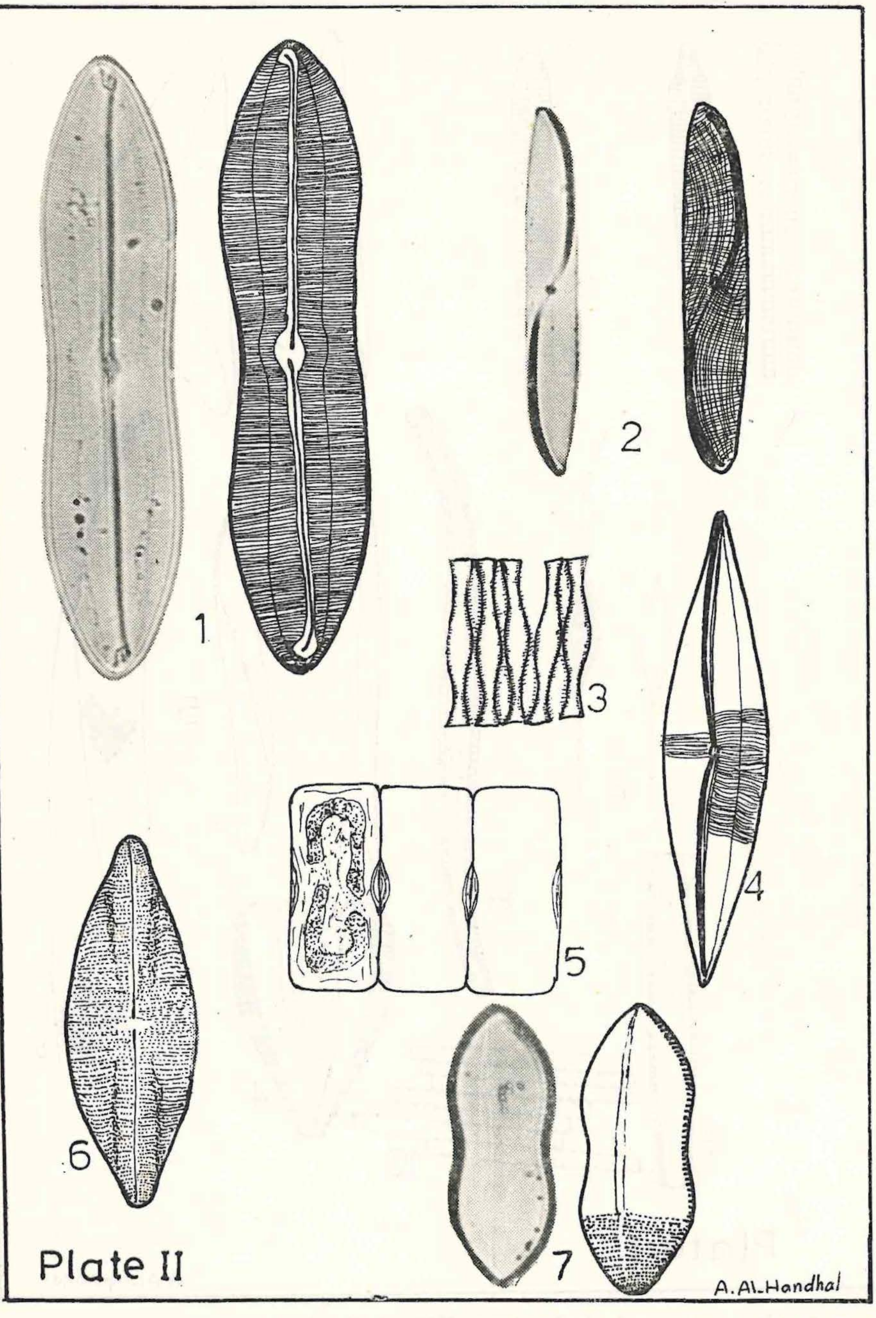
Populacija nutarnjeg zaljeva drastično je osiromašena, uz zabilježeno prisustvo nekih oblika brakičnih voda *(Synedra ulna v. aequalis)*, isključivu pojavu psamofitnih vrsta *(Cymatosira belgica, Navicula distans* i *Amphora grevilleana v. constricta)* te dominaciju nekih planktonskih vrsta *(Skeletonema costatum,* praćena dijatomejom *Lithodesmium undulatum* te *Chaetoceros curvisetus, C. socialis, Biddulphia alternans* i *Leptocylindrus danicus).*

U prosjeku su stanični volumeni manji u zoni »oporavka« nego u nutarnjem zaljevu.

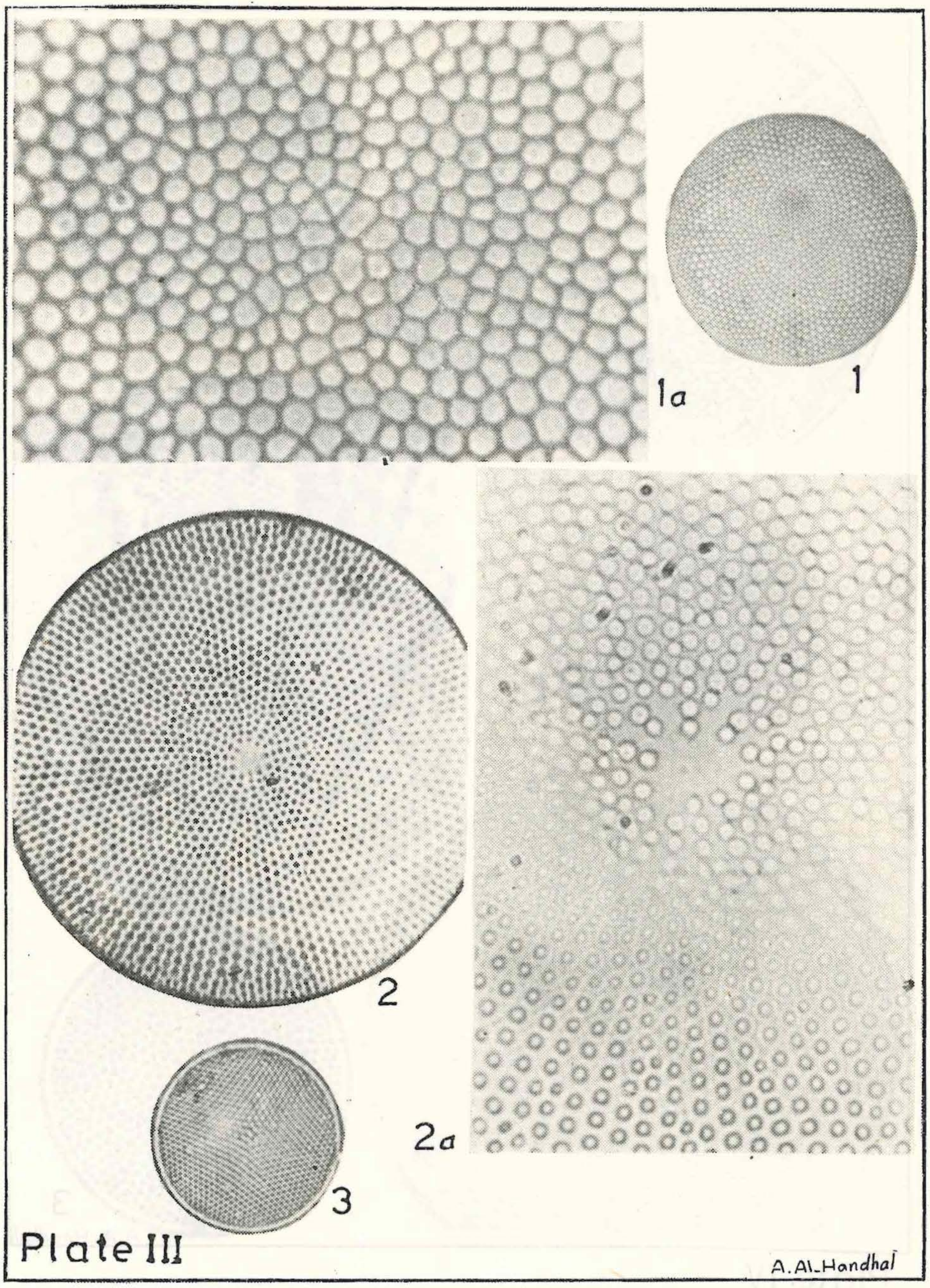
Kvantitativni ciklus, uspoređen s ranijim opažanjima, doživio je trajnu promjenu koja se povezuje s prestankom djeolvanja Nila, zajedno s povećanom polucijom.



1. Synedra ulna, valve and girdle views, X500, 2. S. ulna var. aqualis, X500, 3. Toxonidea insignis, X320, 4. Licmophora paradoxa, X500, 5. Pleurosigma obscurum, a X125, b. X320, 6. Nitzschia closterium, X320, 7. N. longissima, X320, 8. N. lorenziana, X320, 9. N. spathulata, X500, 10. Bacillaria paradoxa, X320, 11. Nitzschia sigma, var rigida, X320



1. Caloneis liber var. bicuneata, X700, 2. Donkinia recta, X320, 3. Cymatosira belgica, X500, 4. Tropidoneis lepidoptera, X320, 5. Stauroneis membrancea, X500, 6. Navicul carinifera, X500, 7. Nitzschia panduriformis, X525



1 .Coscinodiscus oculus iridis, X350, 1a. X2000, 2. C perforatus, X700, 2a. X2000, 3. C. exentricus, X350

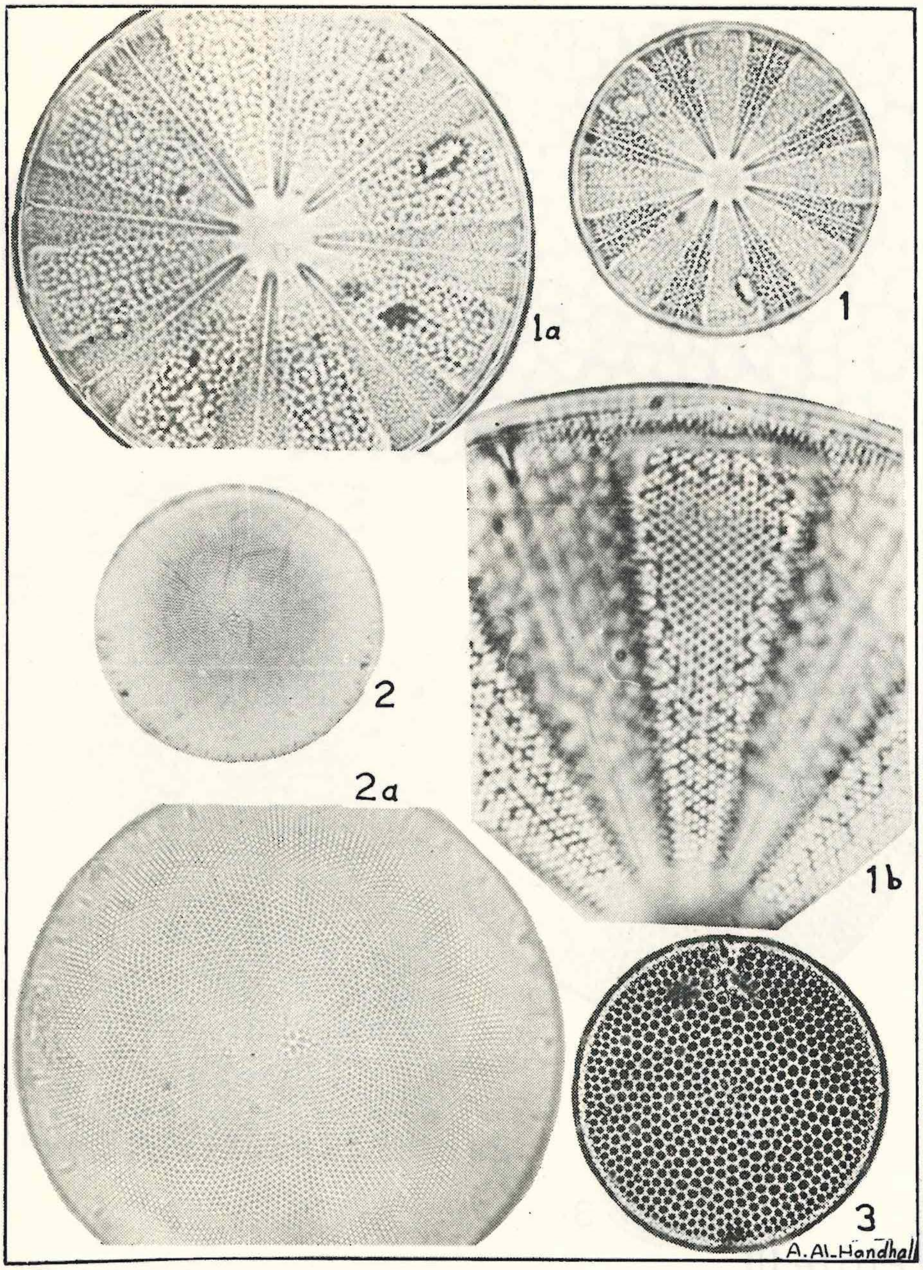
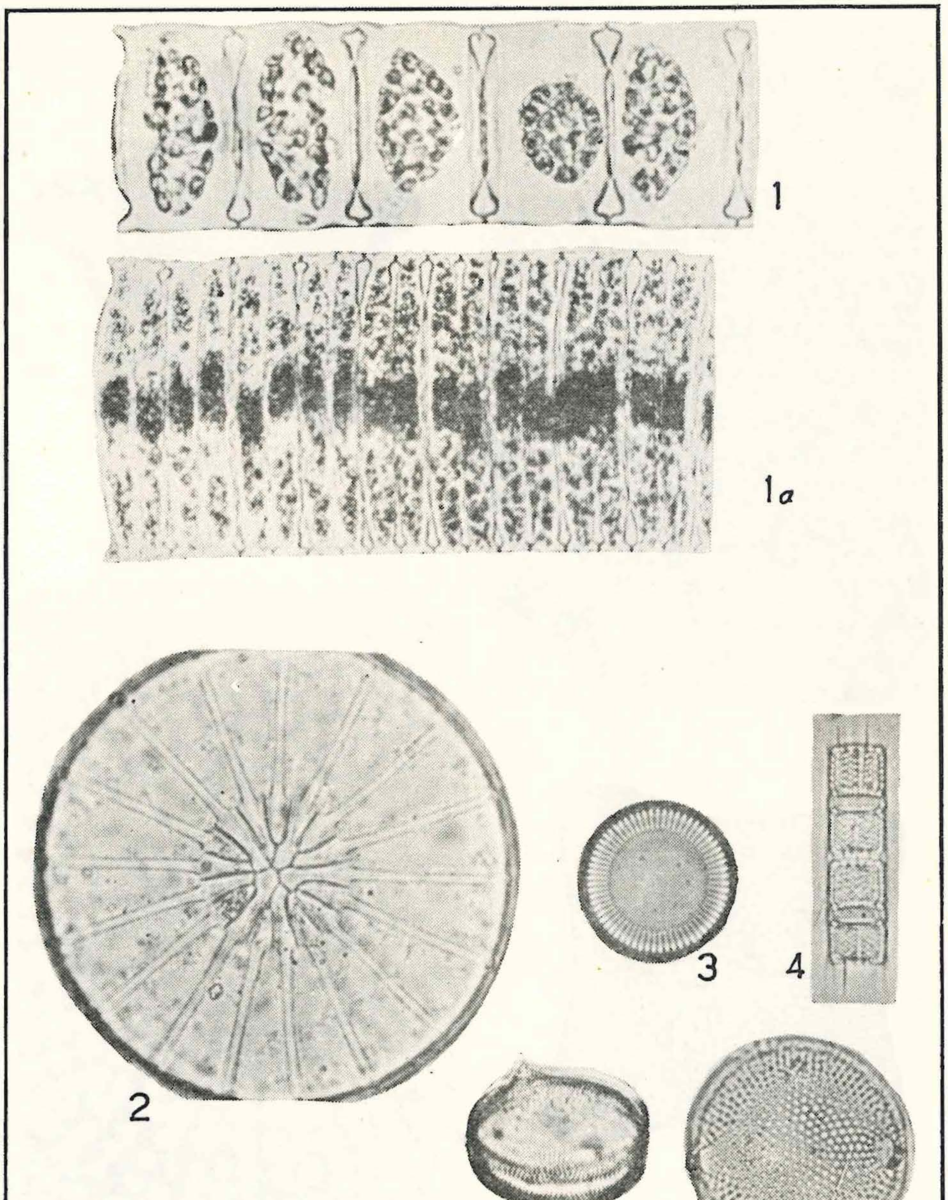
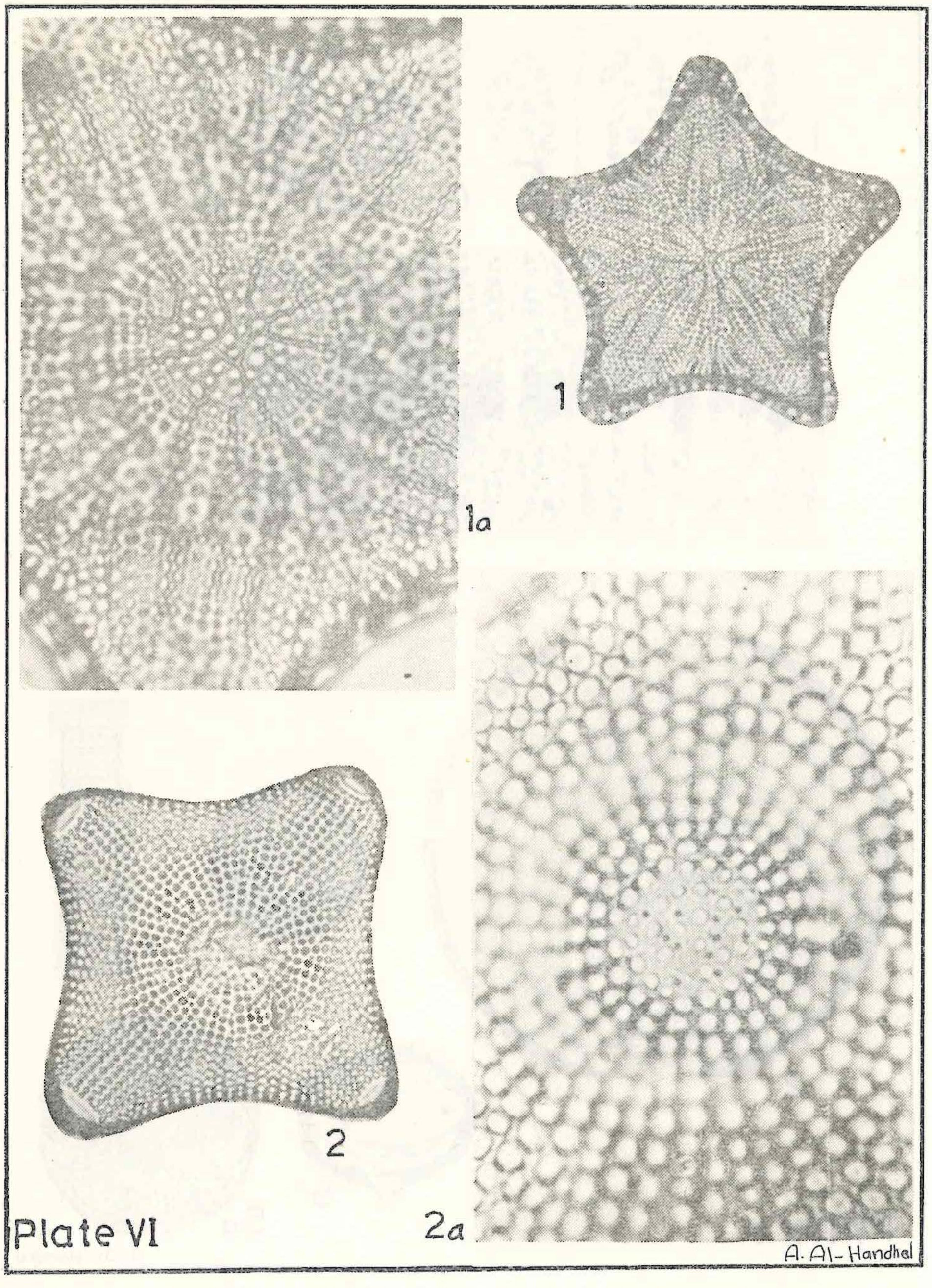


Plate IV

1 .Actinoptychus spendens, X350, 1a. X700, 1b. X2000, 2. Coscinodiscus centralis, X350, 2a. 700, 3. C. radiatus, X700



!. Bellerochia malleus, plankton chain, 1b. benthic chain, X700, 2. Asterolampra grevilleana, X700, 3. Cyclotella meneghiniana, X700, 4. Melosira granulata var. angustissima, X700, 5. Cerataulus smithii, girdle, 5a. Valve view, X700



1. Triceratium pentacrinus, X700, 1a. X2000, 2. T. antediluvianum, X700, 2a. X2000

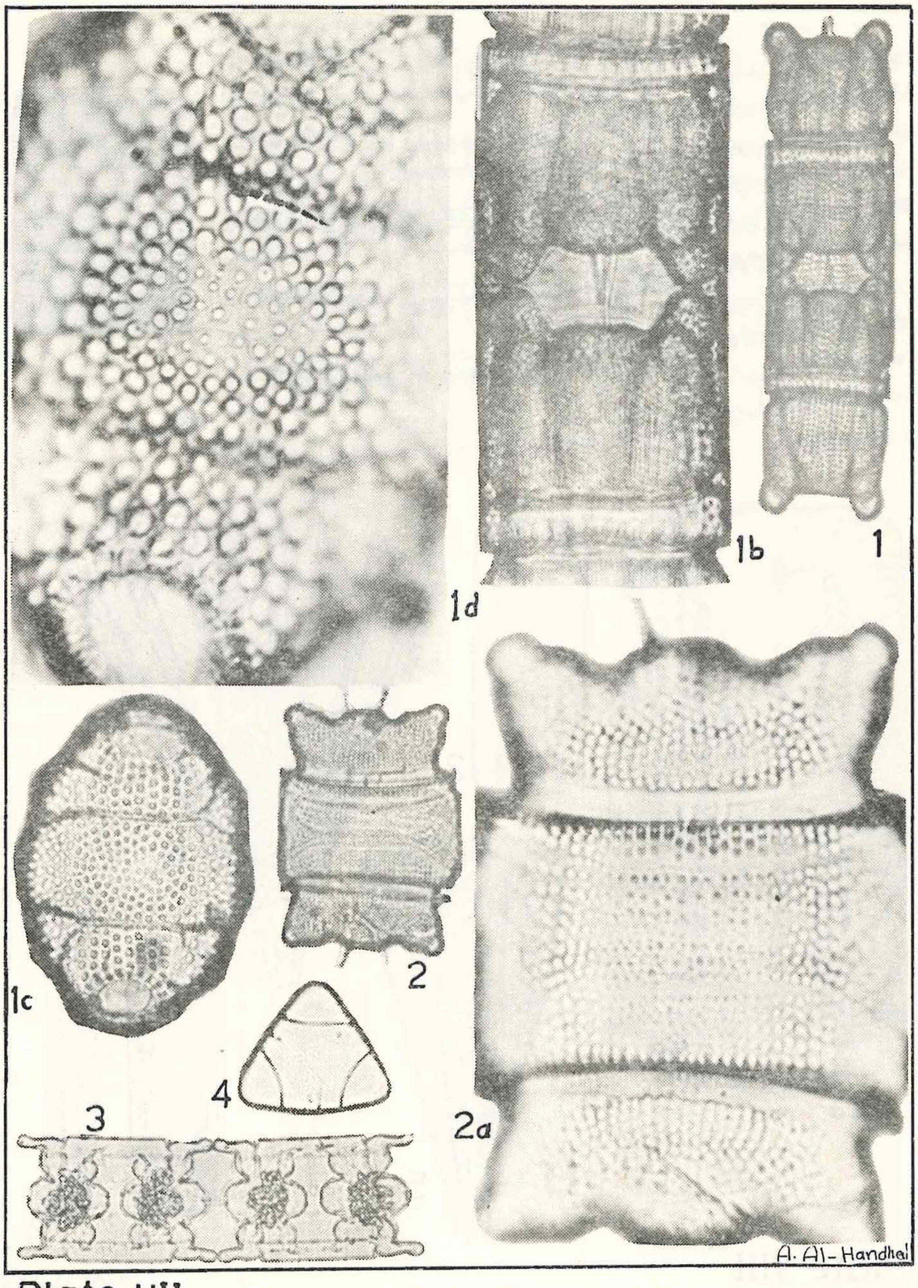
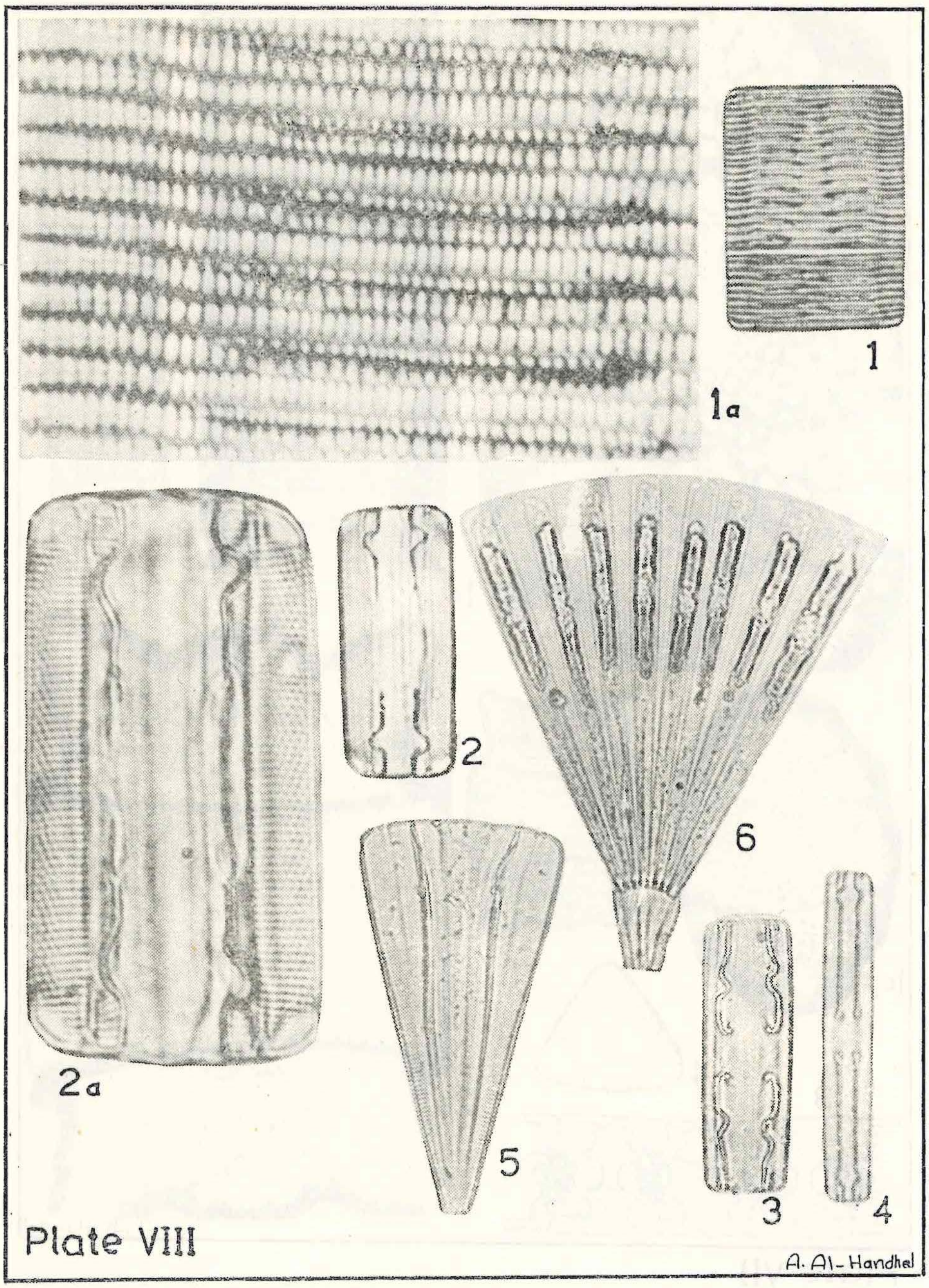
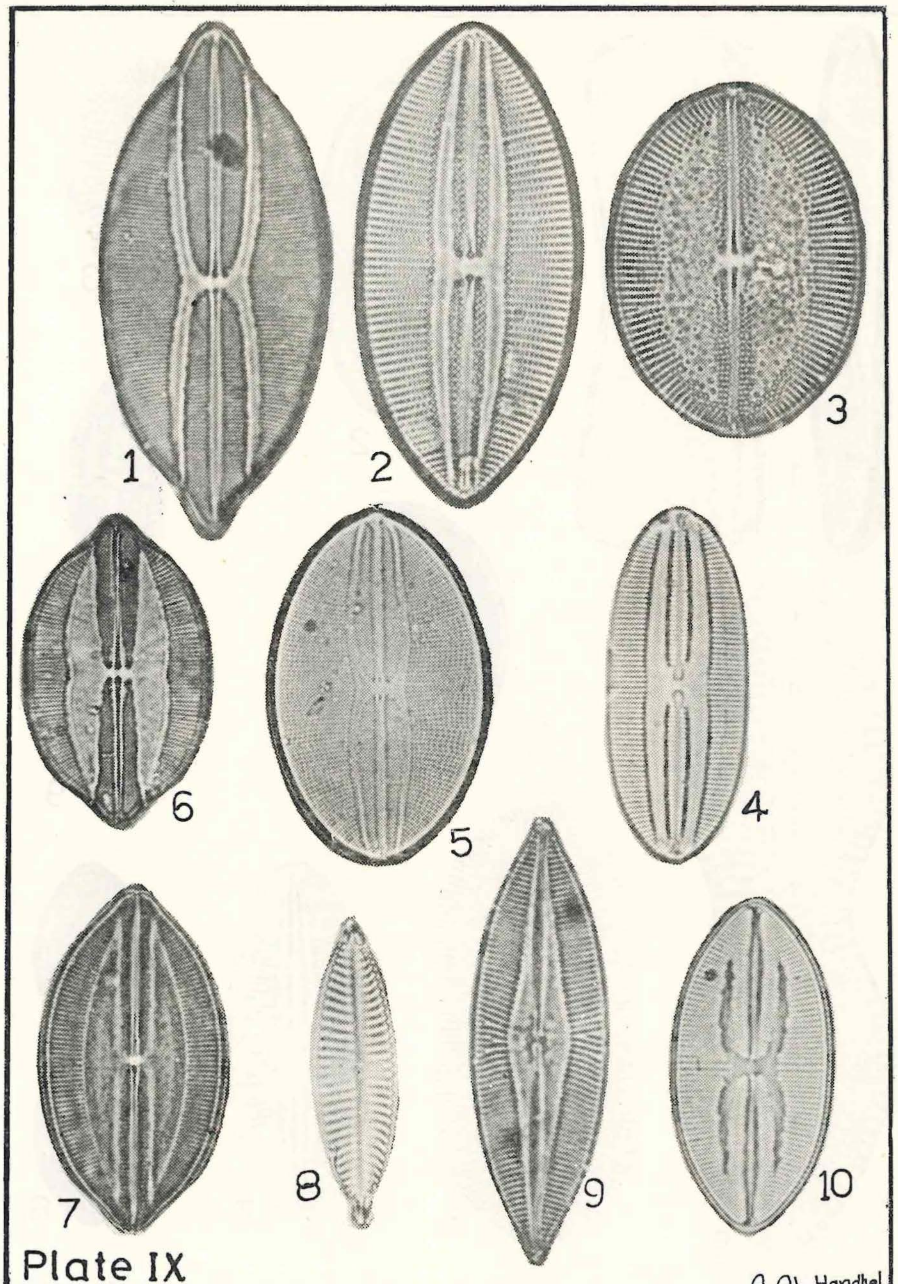


Plate VII

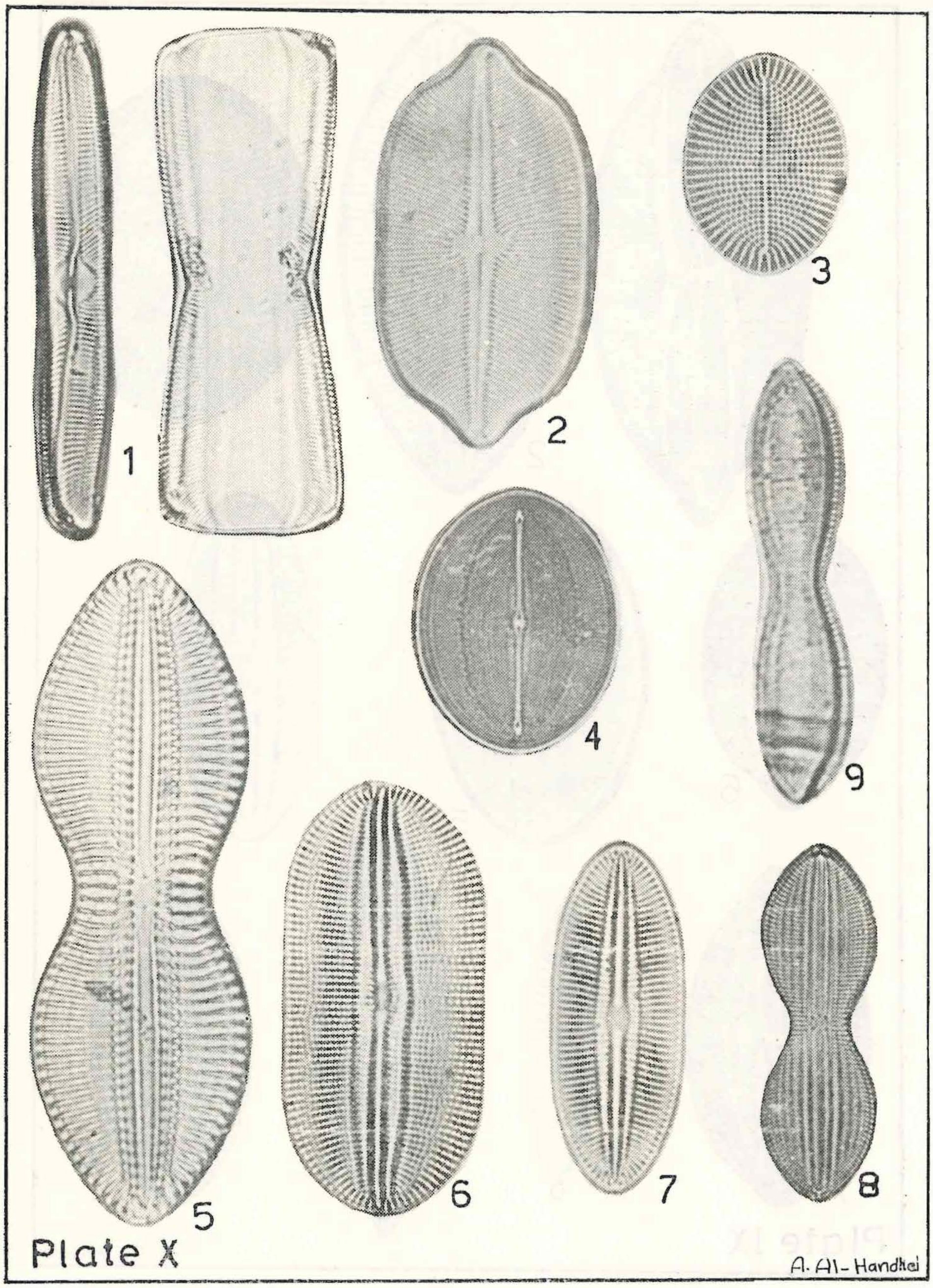
1. Biddulphia pulchella, X350, 1a, b. X700, 1c. X2000 2. B. aurita, X350, 2a. X2000, 3. B. tuomeyi, X350, 4. B. alternans, valve view, X700



1. Rhabdnomea adriaticum, X150, 1a. X2000, 2. Grammatophora marina, X700, 2a. X2000, 3. G. angulosa, X700, 4. G. macilenta, X700, 5. Licmophora lyngbyei, X700, 6. Licmophoro flabellata, X700



1. Navicula subcarinata, X700, 2. N. lyroides, X700, N. praetexta, X700, 4. N. forcipata, X700, 5. N. perplexa, X700, 6. N. clavata, X700, 7. N. hennedyii, X700, 8. N. crucifera, X700, 9. N. palpebralis, X700, 10. N. abrupta, X700



1. Pinnularia trevelyana, valve and girdle, X700, 2. Navicula humerosa, X700, 3. Cocconeis scutellum, X700, 4. C. pseudomarginata, X700, 5. Diploneis crabro, X700, 6. D. fusca, X700, 7. D. smithii, X700, 8. D. chersonensis, X500

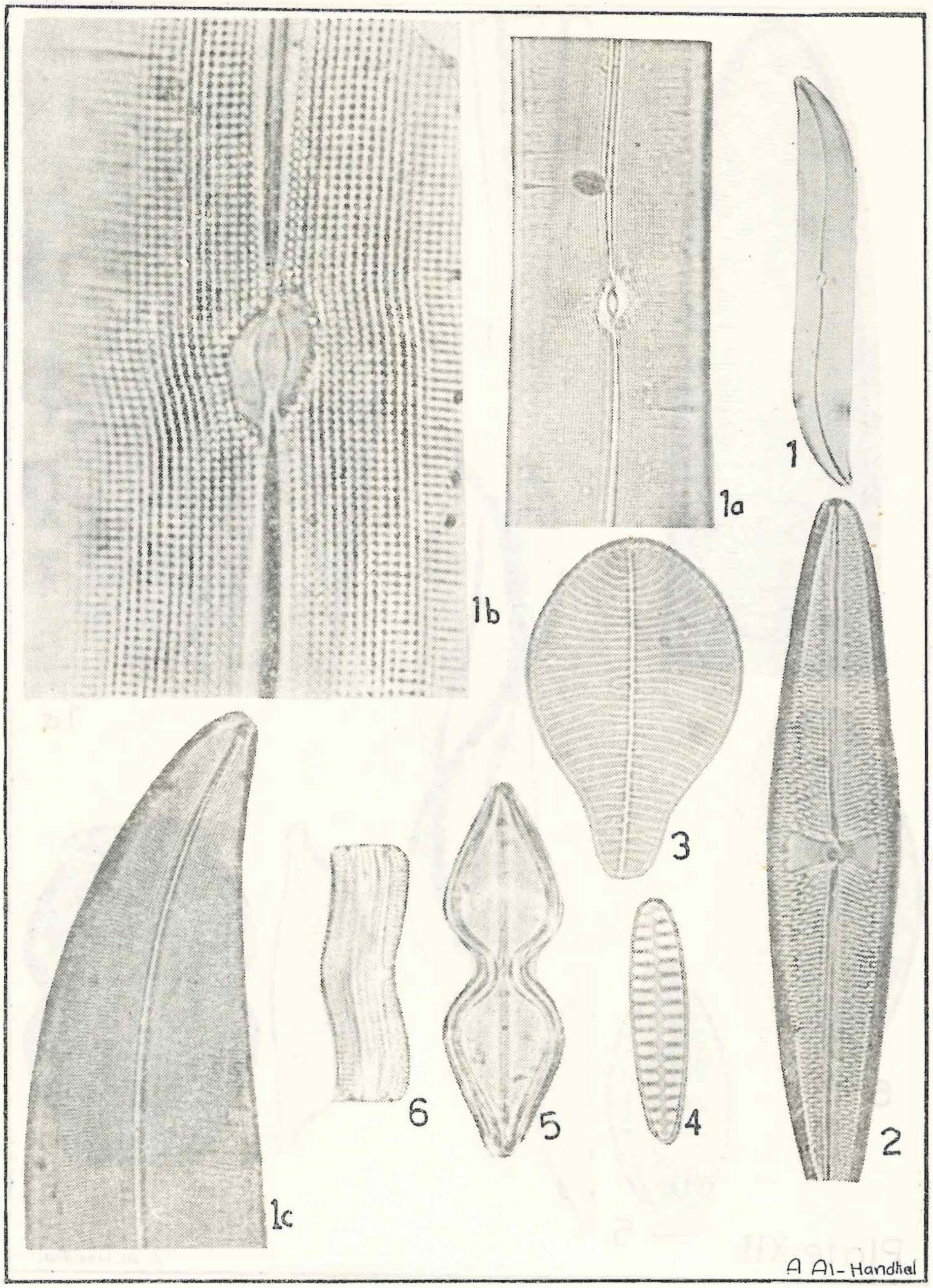
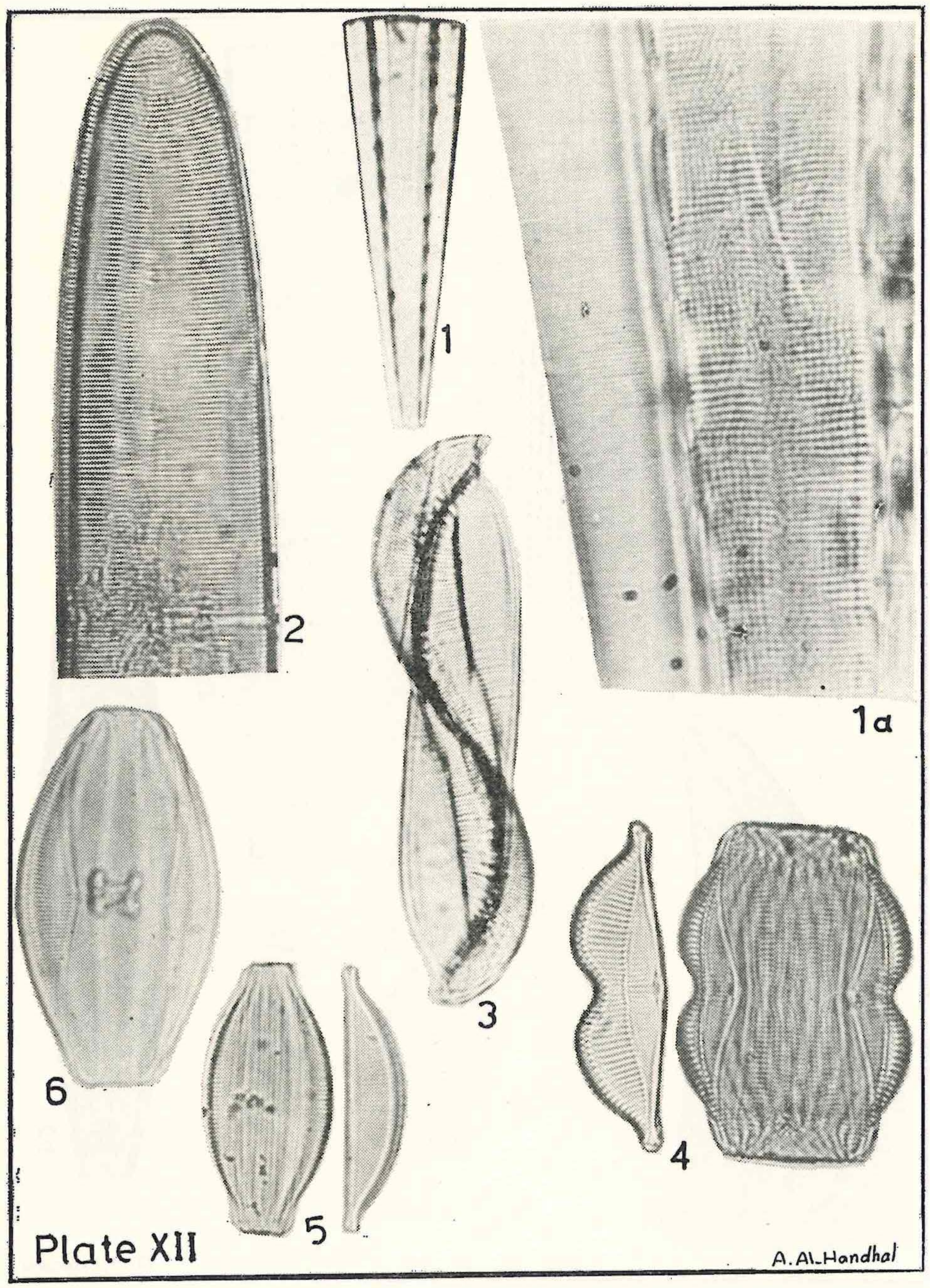
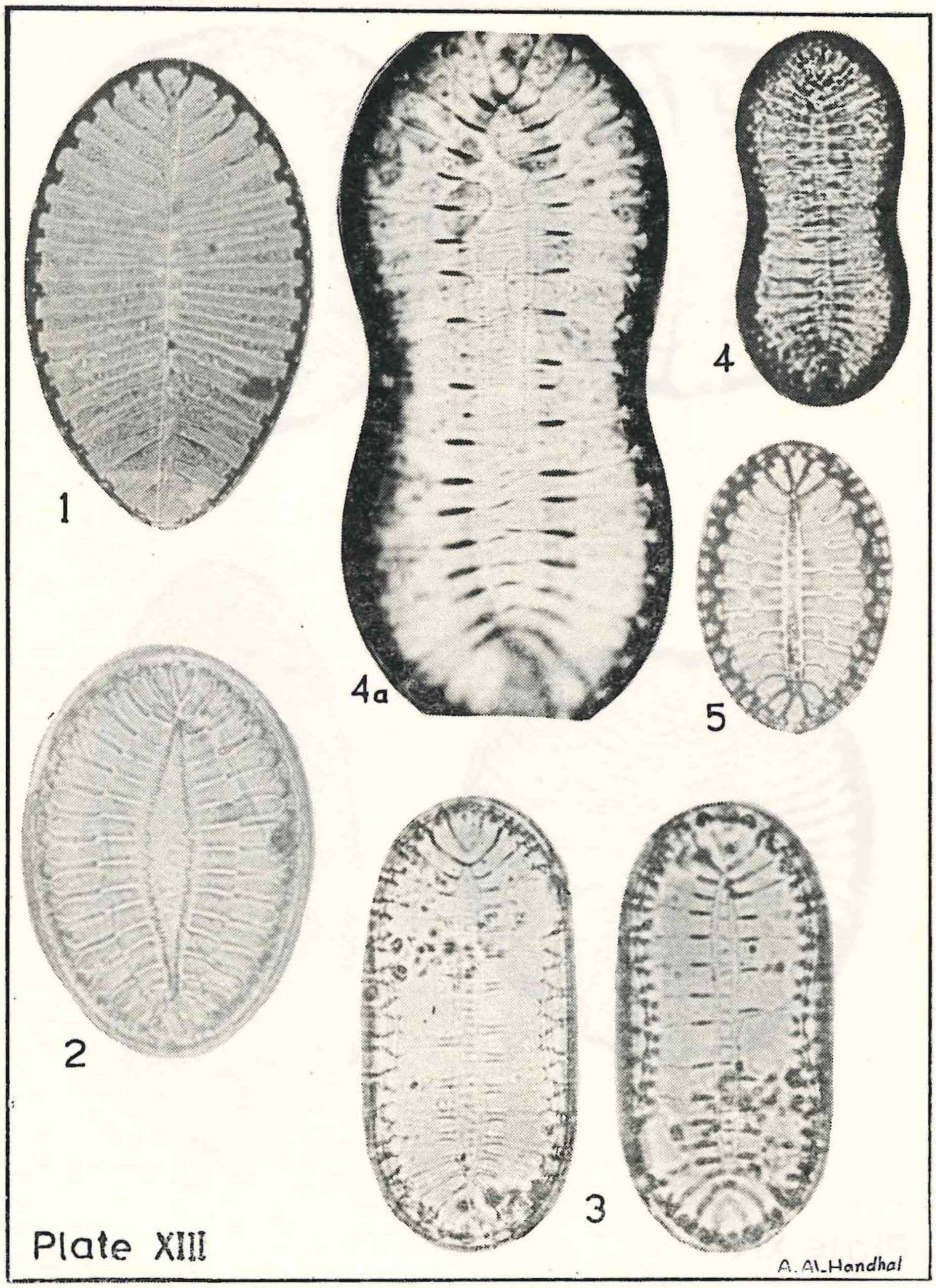


Plate XI

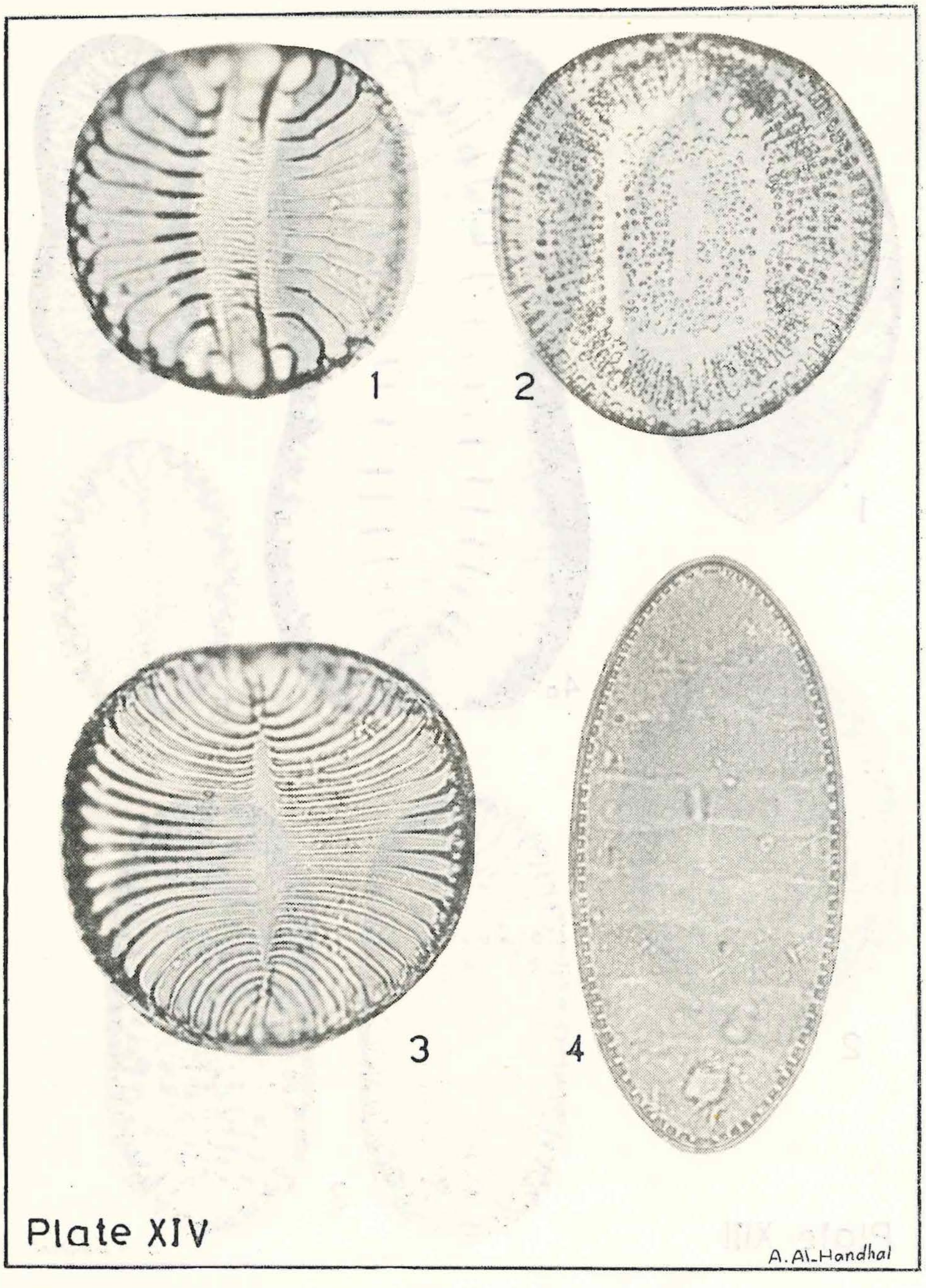
1. Gyrosigma balticum, X150, 1a. X700, 1b. and c. X2000, 2. Trachyneis aspera, X700, 3. Podocystis adriatica, X700, 4. Opephora schwartzii, X700, 5. Dictyoneis marginata, X700, 6. Achnanthes longipes, X700



1. Climacosphenia moniligera, X150, 1a. X2000, 2. Synedra baculus, X700, 3. Amphiprora alata, X700, 4. Amphora grevilleana var. contricta, valve & girdle, X700, 5. A. cymbifera, valve &girdle, X700, 6. A. proteus, X700



1. Surirella striatula, X700, 2. S. fastuosa, X700, 3. S. hybrida, different focusses, X700, 4. S. pandura, X350, 4a. X700, 5. S. amoricana, X700



1. Campylodiscus fastuosus, X700, 2. C. echeneis, X700, 3. C. decorus, X700, 4. Cymatopleura elliptica, X700