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C.M. 1988/L:5
Biological Oceanography Committee

PHYTOPLANKTON BLOOM EVENTS IN THE COASTAL AREA OF THE NETHERLANDS 1973-1984

by

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ABSTRACT

Phytoplankton has been monitored in a 70 km wide area along the coast of the Netherlands. In this study some main characteristics in bloom season, year-to-year frequencies and distribution of the longest lasting bloom events of 9 diatoms and 9 dinoflagellates were described for the period 1973-1983 (and partly for 1984).

Le phytoplancton a été échantillonné mensuellement sur la côte de la Hollande en zône de 70 km.
Cette étude présente quelques caractéristiques importantes des saisons de floraison, les fréquences d'année en année et les distributions des diatomées et des dinoflagellés (9 espèces) les plus continues.

CONTENTS

INTRODUCTION

With the increase of anthropogenic activities the influence of man on its environment may increase. Effect studies are needed to registrate eventual ecological disturbances. The aim of the phytoplankton study in the Dutch coastal area of the North Sea was to support effect studies in this environment by detecting possibly variations in abundances and distribution related to the influx of fresh river water. The discharge of the river Rhine, Meuse and Scheldt attributed among others to the reduction of salinity off the coast to an average value of 32 g/kg and eutrophication of the seawater. This continuous nutrient burden and probably the release of chemical pollutants are expected to have influence upon phytoplankton development through the seasons. Such a change in turn could lead to consequences for other marine organisms.

In the framework of this effect study the surface water in a 70 km wide area along the Dutch coast has been monthly sampled since 1973.

In the late seventies development of some diatoms led to longer lasting, fluctuating bloomperiods. For the same period some dinoflagellates decreased in cell numbers (Kat, 1988).

Some main characteristics in bloom season, year-to-year frequencies and distributions of the longest lasting bloom events of diatoms and dinoflagellates will be described for the period 1973-1983 (and 1984 for a part).
For the period 1973-1981 the sequence of 4 diatoms and 3 dinoflagellates was described. Cell numbers of a few diatom species sometimes appeared correlated (80%) to lowered salinities (Kat, 1982a).

MATERIAL AND METHOD

Samples of 2 litre water from approx. 1.5 m depth were taken at monthly intervals between February and November at distances of 10, 20, 30 and 70 km offshore along 6 transects seawards from the Dutch coast. A concentrated subsample representing about 100 ml (depending on the phytoplankton density) was counted in an Utermöhl Counting Chambre and calculated to cells per ml.

RESULTS

Of the area investigated (figure 1) the maximal observed cell numbers of 9 diatoms and 9 dinoflagellates were arranged into three dimensional graphs (figure 2 and 3). The third dimension of these figures expressed in 32 symbols of varying gray tones between the minimum and the maximum cell numbers (mentioned in the figures) are covering white to black completely.

The medians of the maximal observed cell numbers per month for the period 1973-1984 were depicted in figure 4.

The distribution of the described diatoms and dinoflagellates were depicted in figure 5 - 23.

SEASONAL AND YEAR-TO-YEAR FREQUENCIES

- diatoms (figure 2)

For the period of the study 1973-1984 blooms of *Rhizosolenia delicatula* lasted 3 to 8 months of the year. The peak periods were fluctuating and shifted from August in 1973 and 1974 to early Summer in the years to follow. The density of the blooms gradually increased from year to year up to 1980 and thereafter maintaining in the same order of magnitude.
With a view upon the medians (figure 4) *R. delicatula* can be considered as a year round diatom species which tends to peak in June.

With reasonable longlasting bloomperiods of 6 months with peaks in July and August, *Rhizosolenia shrubsolei* showed from year to year a gradual increase in bloom densities upto 1979. In the 1980's the high densities maintained, whereas periods of massive bloom became shorter. From the medians (figure 4) could be read, that *R. shrubsolei* tends to peak in August succeeding the peak of *R. delicatula.*

The spring to summer bloom of *Rhizosolenia stolterfothii* turned on a more dense summer bloom period in 1978 with seasonal fluctuations during the 1980's comparable with *R. delicatula.* The medians (figure 4) are pointing at the year round occurrence of this diatom with bloom peaks in July and August.

Ceratium bergonii --showing remarkable fluctuations from year-to-year-- was hardly detected in 1976 and 1982. Although *C. bergonii* usually occurred year round with peaks in June, 1975 showed an exception, when the most dense bloom was recorded for September.

Leptocilindrus danicus was not observed in spring for the period of the study. The variation in bloom density sharply differed from year to year since 1973. During 1982 and 1984 this diatom was scarcely present. According to the median *L. danicus*` occurred massively in July.

The genus *Thalassiosira* was mainly represented by *T. rotula* and *T. nordenskjöldii* and showed for the complete time serie maximum concentrations during early spring. After short periods of interruption, second --less dense-- blooms were recorded in autumn with an exceptional dense bloom in June 1978. *Thalassiosira* species showed in 1982 a poor presence.

Ditylum brightwellii never showed a very dense bloom. For the period 1973-1975 the highest concentrations were observed in autumn, which turned on spring-summer bloom periods for 1977 to 1981. After 1981 *D. brightwellii* was scarcely observed.

The year-to-year fluctuations of *Eucampia zodiacus* have not been very strong. Although *E. zodiacus* tends to a year round species, its bloom periods are not always continuing through the seasons. Interruptions were recorded both between spring and summer blooms and between summer and autumn blooms. In 1982 the presence of *E. zodiacus* has been very poor.

Guinardia flaccida showed from year-to-year a strong variation in density and length of the bloom period. Up to 1977 the species showed a year round character. After 1981 both bloom density and bloom period decreased.

- **dinoflagellates (figure 3)**

The bloom periods in spring of *Gyrodinium spirale* gradually extended after 1976 including summer period. An exceptional bloom has been observed during August 1983.

Less frequent occurring showed *Nematodinium armatum* in 1977, 1978 and 1986 massive blooms during June. An autumn bloom was only recorded in October 1978.

The dense blooms of *Ceratium fusus* from July till September, period 1973-1975, drastically decreased after 1975. A moderate bloom development recurred in 1981 and 1984.

Ceratium lineatum showed overlapping bloom occurrences with *C. fusus*. The four months lasting bloom periods in 1973-1975 changed into a short peak in May 1977. After 1977 *C. lineatum* was only very scarcely observed.

The year-to-year autumn blooms of *Prorocentrum micans* in 1973-1975 were interrumpted in 1976. After a short spring bloom in 1977, *P. micans* was observed in 1978 both in spring and autumn. After long lasting bloom periods in 1979 and 1980, *P. micans* blooms were only observed during September, decreasing in density. In the years to follow bloom periods were short and showed seasonal fluctuations.

Prorocentrum minimum was only observed after 1975.-Usually occurring in summer bloom period continued into September. No bloom of *P. minimum* was observed in 1982, but the species recurred in 1983 and 1984.

Before 1977 the very small *Prorocentrum balticum* was not observed. The dinoflagellate showed --since 1978-- a peak in June, but turned to July and August in 1978 and 1979. The exceptional bloom in June 1981 exceeded 10^6 cells per litre.

In four successive years 1973-1976 blooms of *Prorocentrum triestinum* were observed during September and sometimes October. After a break of four years, *P. triestinum* was again observed in 1981-1983 in less dense blooms.

Dinophysis acuminata a toxic dinoflagellate --causing diarrheic shellfish poisoning-- occurred very seasonal in August, mostly culminating in September.

THE SEQUENCE OF THE DIATOMS AND DINOFLAGELLATES

Both diatoms and dinoflagellates were arranged in sequence of the median peak bloom per month (period 1973-1984). Figure 4 thus showing the continuous bloom events through the seasons. Most of the species described are present year round, although the density per species appeared very distinct.

The early spring dominance of *Thalassiosira* could be accompanied by *Cerataulina bergonii, Rhizosolenia delicatula* and *R. stolterfothii* in low numbers. The median bloom peaks of *R. delicatula, Leptocilindrus danicus* and of *R. shrubsolei* and *R. stolterfothii* were distinctive for respectively June, July and August. Less pronounced were the peaks of *Eucampia zodiacus* and *Guinardia flaccida.*

Some of the dinoflagellates show a continuity through the year, such as *Gyrodinium spirale, Prorocentrum balticum, P. micans* and *P. minimum* in their median peak bloom. There is obviously a sequence in the Prorocentrum species. The decreasing bloom period of *P. balticum* after June is overlapping the peaks of *P. minimum,* whereas *P. triestinum* appeared to peak in autumn only. The toxic *Dinophysis acuminata* occurred mainly in August and September (Kat, 1983a) in the study period. However in 1971 a toxic bloom of this dinoflagellate has been observed in the Eastern Scheldt (Kat 1979, 1983b).

DISTRIBUTION

- diatoms

Rhizosolenia delicatula Cleve
(The distribution of *R. delicatula* was only presented when anywhere in the area of investigation the concentration was >500 cells per ml: figure 5).
In the total area of investigation *R. delicatula* was observed in June 1978, April 1979 and July 1980, although the density was usually higher at lower salinities (30-33 g/kg). In contrast with these results was the distribution in June 1980 where the highest concentrations were observed at ± 35 g/kg salinity. In June 1982 the *R. delicatula* blooms were more limited to the closest coastal stations.

Rhizosolenia imbricata Cleve
(Only occurrences of >200 cells/ml anywhere in the area were depicted in figure 6).
The general impression of *R. imbricata* distribution creates that the highest concentrations were observed at salinity range of 30-33 g/kg.

Rhizosolenia stolterfothii Peragallo
(Only peaks of >100 cells per ml anywhere in the area investigated were depicted: figure 7). The distribution of *R. Stolterfothii* shows clearly a very patchy pattern, in which no correlation between cell numbers and salinity are to expect.

Cerataulina bergonii Peragallo
In the depicted distributions (figure 8) of September 1975, June 1978, June 1979, July 1980 and April 1981, in which at least at any station 150 cells per ml were observed, the most dense bloom of *C. bergonii* were recorded at salinity up to 33 g/kg.

Leptocilindrus danicus Cleve
Mass development of this diatom was often observed at 70 km offshore salinity 35 g/kg, whereas in June 1977 and August 1978 also at lower salinity of 30-33 g/kg massive bloom occurred. (Distribution was only depicted when at any station at least 600 cells per ml were observed: figure 9).

Thalassiosira species
The distribution of *Thalassiosira* species (*T. rotula* and *T. nordenskjöldii*) were only shown in figure 10 when cell concentrations exceeded 75 per ml. Occurring during spring or early summer the most dense blooms of *Thalassiosira* were observed at low salinity, although in March 1979 reasonable concentration were observed at 35 g/kg salinity.

Ditylum brightwellii West Grunow
Massive blooms of *D. brightwellii* were seldom observed. A selection for depicting the distribution was made for >10 cells per ml, which was observed in September 1973 and 1974 (figure 11) at salinity range of 30-33 g/kg.

Eucampia zodiacus Ehrenberg
E. zodiacus usually occurred in the same concentrations as *D. brightwellii*. Distribution was only depicted at concentrations of >20 cells per ml: figure 12. The exceptional bloom during September 1975 showed the highest concentrations at salinity range 30-33 g/kg.

Guinardia flaccida (Castr.) Peragallo
(Only distribution depicted at <40 cells per ml: figure 13). Although in contradiction with the occurrence of *G. flaccida* in July 1973 at low salinity, the highest concentrations of this diatom were most often observed at 35 g/kg salinity.

- **dinoflagellates**

Gyrodinium spirale (Bergh) Kofoid and Swezy.
The distribution of *G. spirale* in May 1979 (figure 14) gives an impression of the average distribution in the area investigated and shows that the highest cell numbers were observed close to the rivers outflow, where salinity amounted approx. 30 g/kg.

Nematodinium armatum (Dogiel) Kofoid and Swezy
Also from the distribution of *N. armatum*. (figure 15) can be concluded that this specimen developed at salinity range 30-33 g/kg.

Ceratium fusus (Ehrenberg) Dujardin
The distribution of *C. fusus* (figure 16) shows for the period 1973-1975 development in inshore waters, the relationship between all numbers and salinity (August '74 $R_c = 0{,}46$) appeared not very convincing. Between 1973 and 1975 the maximal bloom period shifted from July till September. Since 1977 onwards the bloom periods did not last a very long

time and cell numbers remained low. Only in 1984 a "return" was observed. However in this case the most dense bloom occurred at salinity >33 g/kg.

Ceratium lineatum (Ehrenberg) Cleve
The occurrence of *C. lineatum* (figure 17) was in general observed in the northern part of the area investigated. The scarce distribution since October 1976 illustrates the disappearance of this dinoflagellate in the coastal zone of The Netherlands.

Prorocentrum micans Ehrenberg
Only during September 1973 and the end of August 1980, *P. micans* came to an extremely high dense bloom, which developed at salinity range of 30-33 g/kg (figure 18).

Prorocentrum minimum (Pavillard) Schiller
P. minimum has been observed for the first time in 1976 in the Dutch Waddensea (Kat, 1979). Dense blooms of *P. minimum* developed in the Dutch coastal area up to a maximum of 200.000 cells per litre during July 1980 and August 1984 at salinity range of 30-33 g/kg (figure 19). In the coastal waters of The Netherlands *P. minimum* appeared to be non-toxic (Kat, 1985).

Prorocentrum balticum (Lohmann) Loeblich III
The most dense blooms of *P. balticum* occurred during June 1980, 1981 and 1982 and shows (figure 20) that this species remained principally limited to offshore waters in which salinity of 35 g/kg prevailed (In the observations of Braarud et al 1948, *P. balticum* has been mentioned as being characteristic for the water of the Central North Sea).

Prorocentrum triestinum Schiller
Comparable with *P. micans, P. triestinum* developed at low salinities (figure 21). The regression coefficient between cell numbers and salinity amounted for the period October 1973 and September 1975 respectively 0.59 and 0.60.

Dinophysis acuminata Clarapède and Lachmann
D. acuminata is a yearly recurring toxic dinoflagellate in the phytoplankton community during August and September. Its distribution has been published (figure 22, Kat-1983) elsewhere and was observed at salinity range of 30-33 g/kg at temperature range of 15-19 ^{o}C. *D. acuminata* tends to appeare massively after calm sunny weather with low windspeed (figure 12).

Dinophysis c.f. skagi Paulsen
A one time occurring bloom of *D. c.f. skagi* in September 1981 (figure 23) could have contributed --together with a massive bloom of *D. acuminata* -- to a DSP outbreak in the Waddensea. Under these circumstances its toxicity could not be proved however. The ratio between *D. c.f. skagi* and *D. acuminata* cell numbers per litre amounted 1 : 24 for all stations.

CONCLUSION AND DISCUSSION

Considering the occurrence of the described bloom species it can be concluded that for the period of the study 1973-1984

a. Fluctuations in both year frequency and seasonal occurrence has been observed for most of the species mentioned (figures 2 and 3).

b. The medians of the maximal observed cell numbers per month for the period of the study (figure 4) give an impression of the main sequence of the blooms species and show the mean year round bloom of the species.

c. Some species of both diatoms and dinoflagellates show the most dense bloom in the area where salinity range is 30-33 g/kg. Other species were more abunded at higher salinities. Bloom peaks were observed at 35 g/kg salinity in the area at 70 km offshore where the influence of the fresh water input from the eutrophicated rivers is negligible.

d. During the study period some species tend to disappear from the Dutch coastal waters, while others emerge in the phytoplankton assemblies.

e. Very remarkable was the mainly seasonal occurrence of the toxic *Dinophysis acuminata* figure 22 and *D. skagii* figure 23 in August and September. This gave rise to DSP (Diarrheic Shellfish Poisoning) in mussels of the Eastern Scheldt and Dutch Waddensea. Even low numbers present in the Dutch Waddensea during October contributed to the continuing level of DSP in mussels from that area due to the decreasing water temperatures (Kat, 1988).

- **Salinity/nutrients**

In depicting the distribution patterns of the most abundant diatoms and dinoflagellates a contribution of the input of eutrophicated fresh water from the rivers could have contributed to the development and could be made visable. The highest cell numbers and lowered salinity to 30 g/kg show overlapping in some stations.
Considering the distribution of *Rhizosolenia imbricata* (figure 6), *R. stolterfothii* (figure 7), *Leptrocilindrus danicus* (figure 9), *Guinardia flaccida* (figure 13) and on the other hand the highest cell counts of (dense blooms) *Prorocentrum balticum* (figure 20) were found at 70 km offshore where salinity is about 35 g/kg and the fresh water input of the rivers is negligable.

- **Transport**

The phytoplankton species assemblies along the Dutch coast are qualitatively comparable with the assemblies in the adjacent areas.
Tracing of different water masses could be realized on the observations between differences in species density.
The origine of the coastal waters of the Netherlands is partly the water of the English Channel, which passes the Belgian coast supported by the South North current. This origine could be biologically traced in 1974 by *Pleurosigma planctonicus* and in 1980 by *Thalassiosira angstii* (Kat 1982a+b), both "new-comers" in the phytoplankton assembly.
Concerning the Ceratium blooms in the Dutch coastal area in 1973-1975, expected to have passed the Belgian coast, appeared not to have been originated from the South because the presence of both *C. fusus* and *C. lineatum* in Belgian coastal water were not mentioned before 1975 (Louis and Smeets 1981).
This phenomenon could point on the influence of British coastal waters in which Ceratium species were very common \(Dodge 1981).
The massive blooms of *Prorocentrum balticum* (> 10^6 cells per litre) in 70 km offshore stations (figure 20) could be considered as originated from the Central North Sea. The spreading of *P. balticum* in 1948 (figure 24) has been considered as a tracer for Central North Sea water (Braarud et al 1953).
The variability of drift routes in the North Sea 1969-1981 has been explained (Hainbucher et al 1986).

- **Climatological circumstances**

In particular wind speed appeared to have an enormous influence upon cell numbers of phytoplankton species in the surface layer. Figure 25 shows wind speed correlated to cell numbers of *Dinophysis acuminata* at salinity range 30-33 g/kg.

This paper provides a contribution in massive phytoplankton occurrences in the coastal waters of the Netherlands during a period of 12 years.

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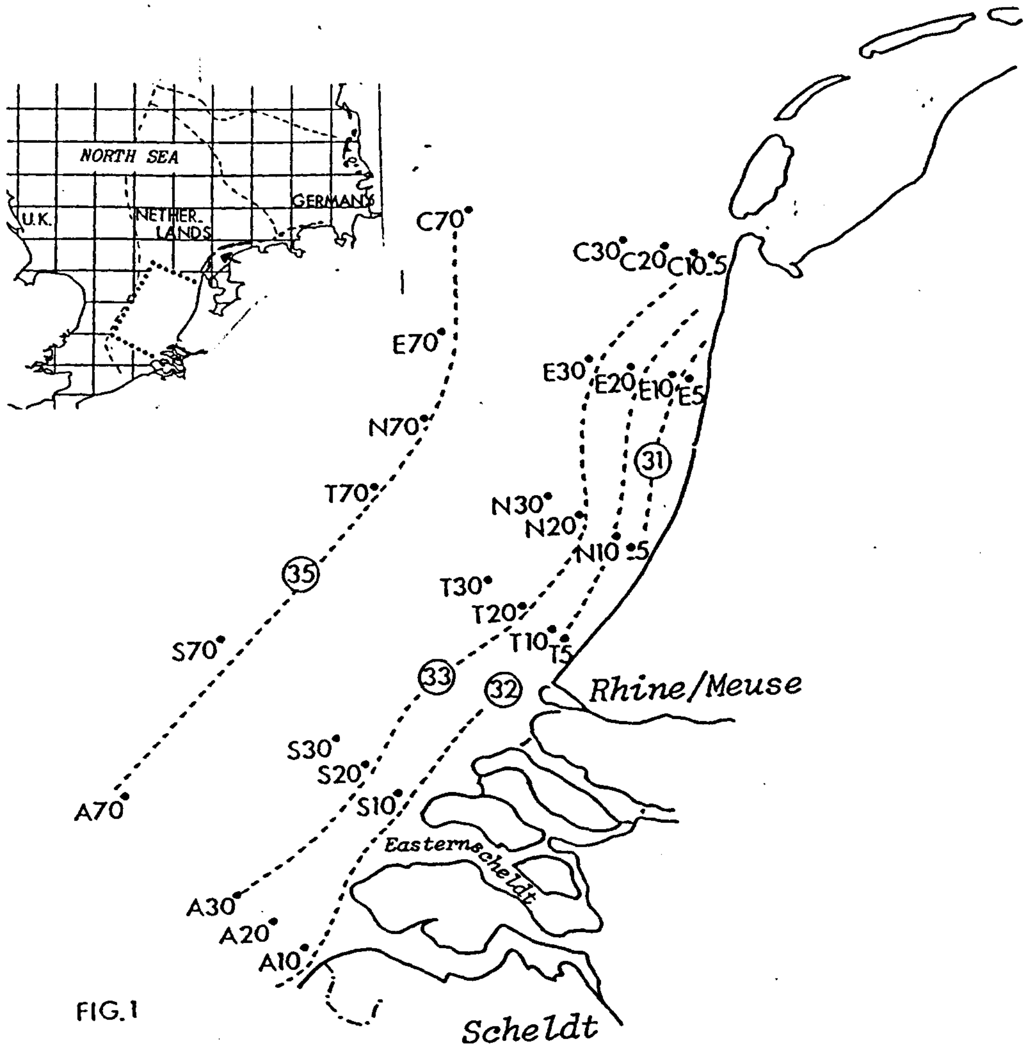
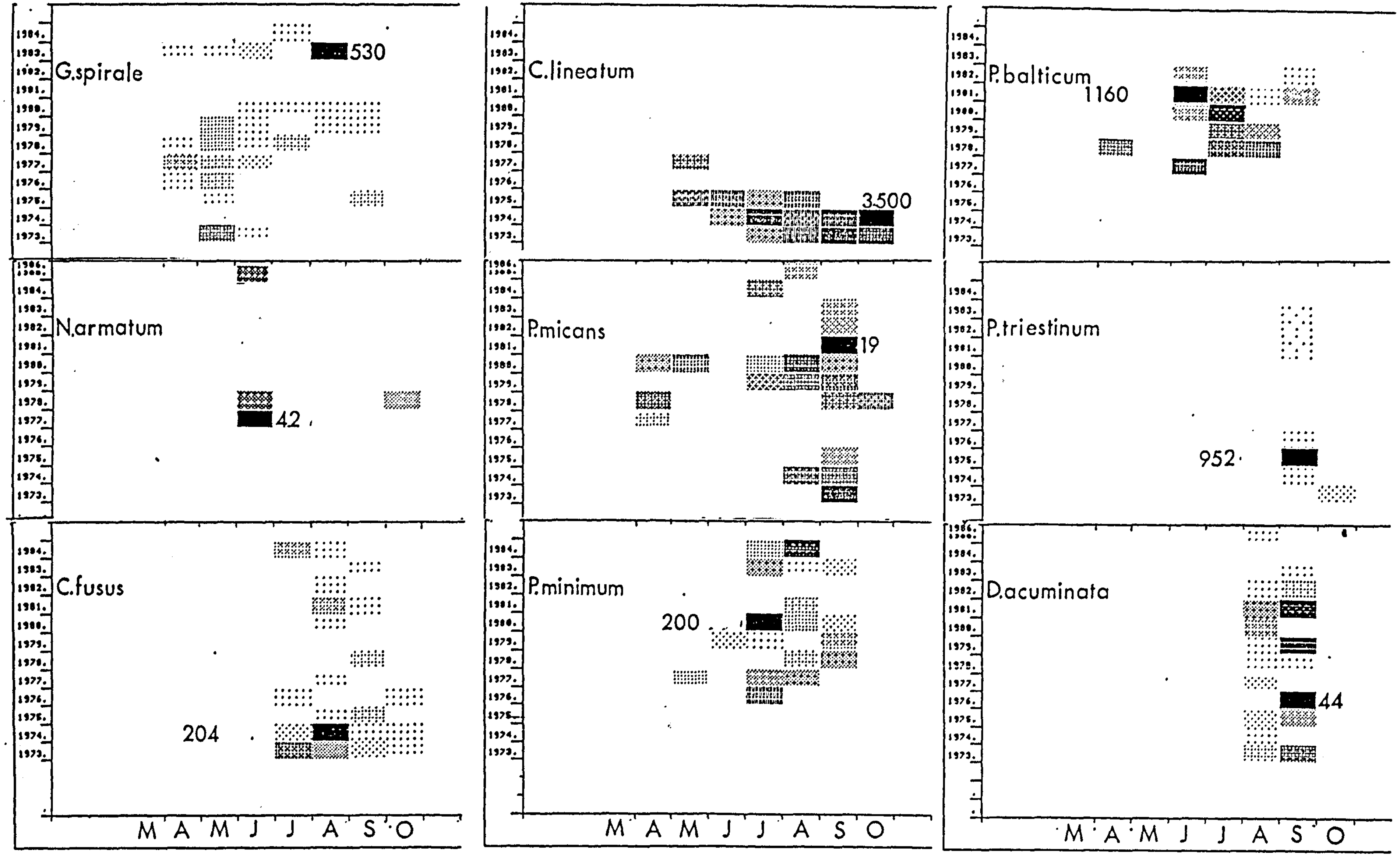


FIG.1

THE AREA OF INVESTIGATION (ENCIRCLED: SALINITY)



G.spirale
530
C.lineatum
3.500
P.balticum
1160
N.armatum
42
P.micans
19
P.triestinum
952
C.fusus
204
P.minimum
200
D.acuminata
44
M A M J J A S O
M A M J J A S O
M A M J J A S O

Figure 2

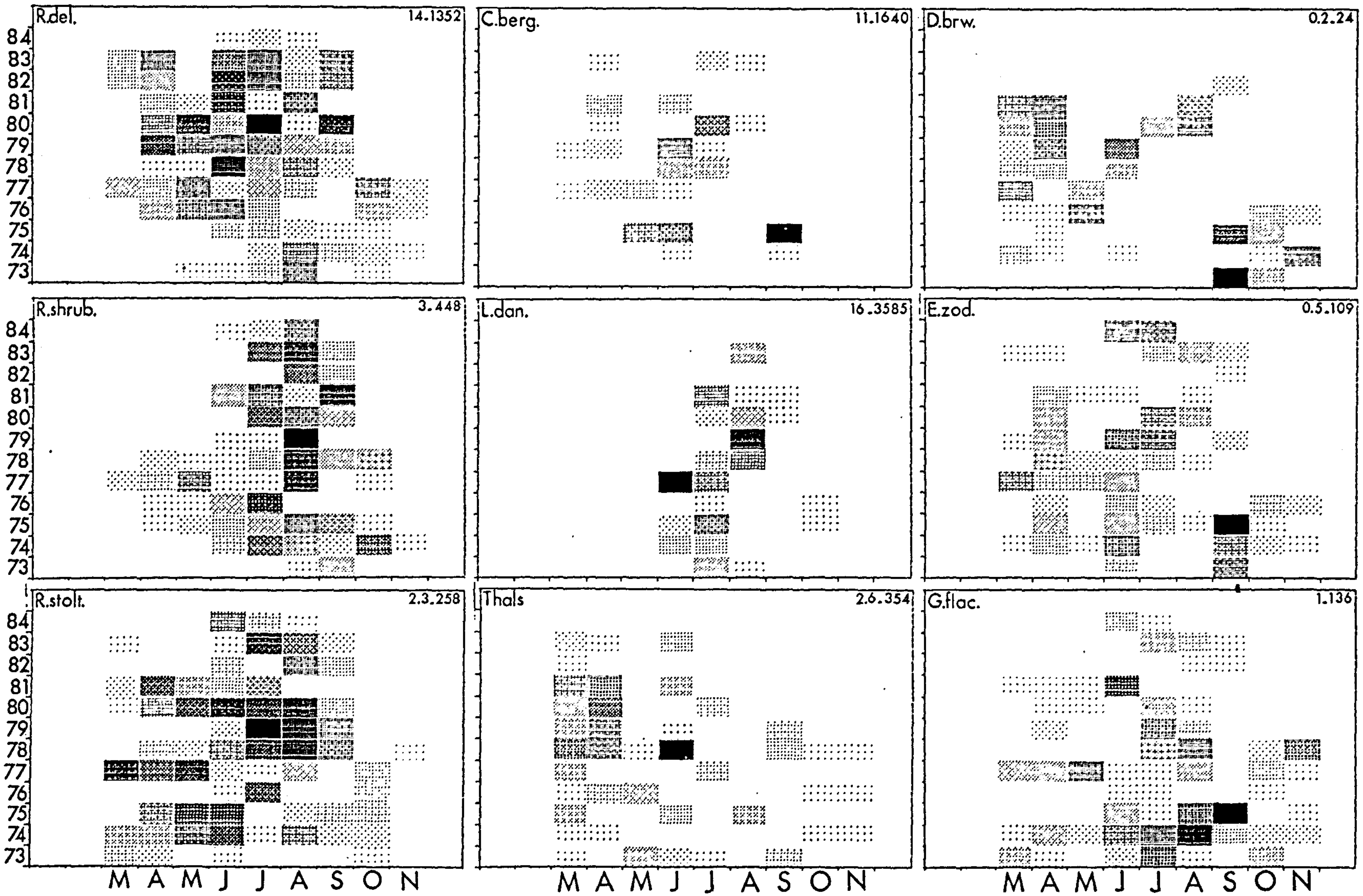

R.del.
14.1352
C.berg.
11.1640
D.brw.
0.2.24
R.shrub.
3.448
L.dan.
16.3585
E.zod.
0.5.109
R.stolt.
2.3.258
Thals
2.6.354
G.flac.
1.136
84 83 82 81 80 79 78 77 76 75 74 73
M A M J J A S O N

figure 3

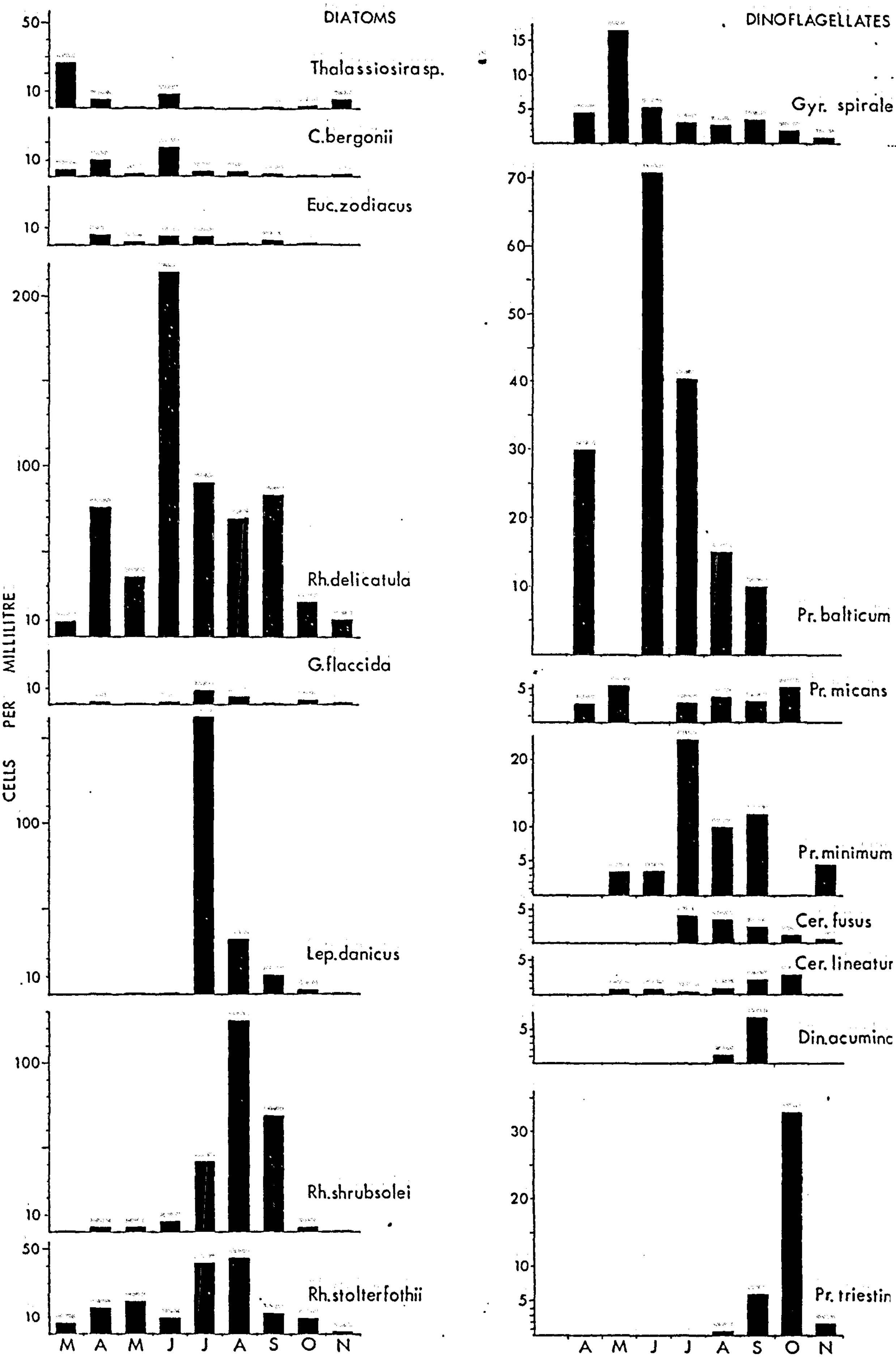


Figure 4 THE MEDIANS OF THE MAXIMAL OBSERVED CELL NUMBERS PER MONTH FOR THE PERIOD 1973-'84

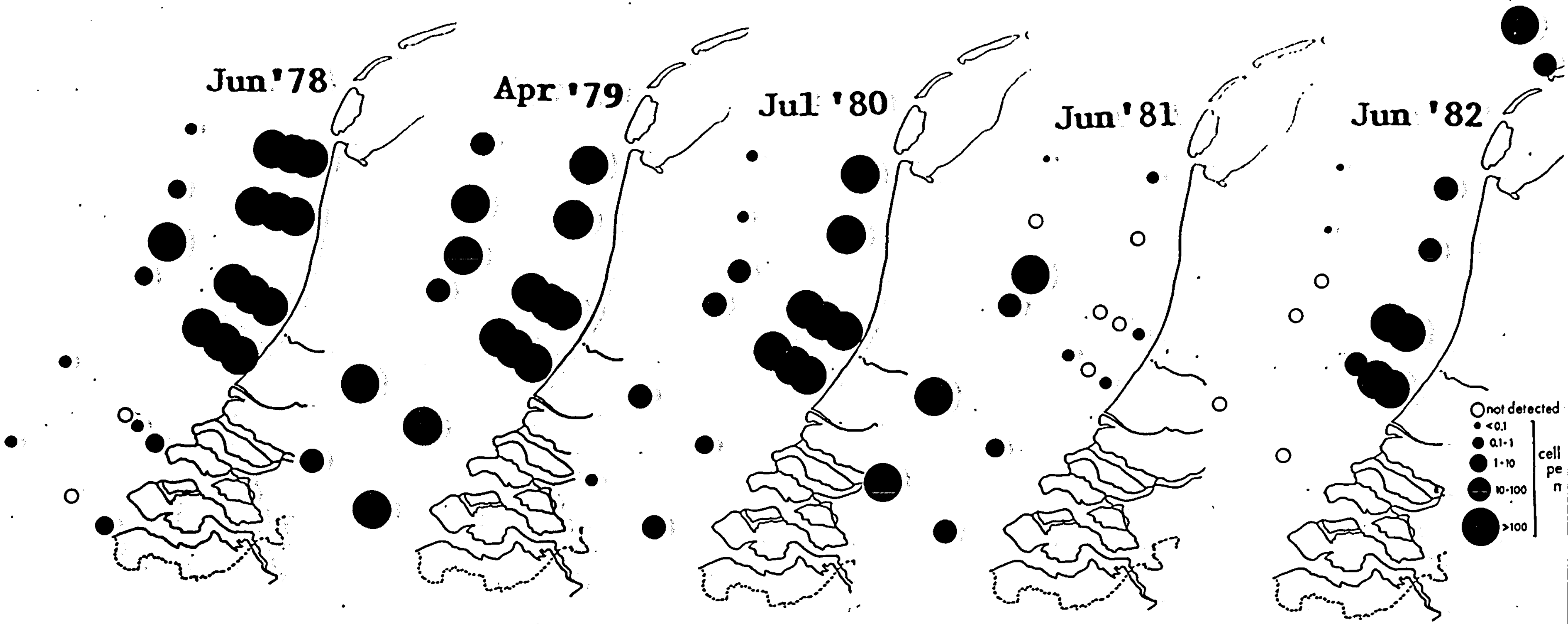


Figure 5 THE DISTRIBUTION OF RHIZOSOLENIA DELICATULA (>500/ml)

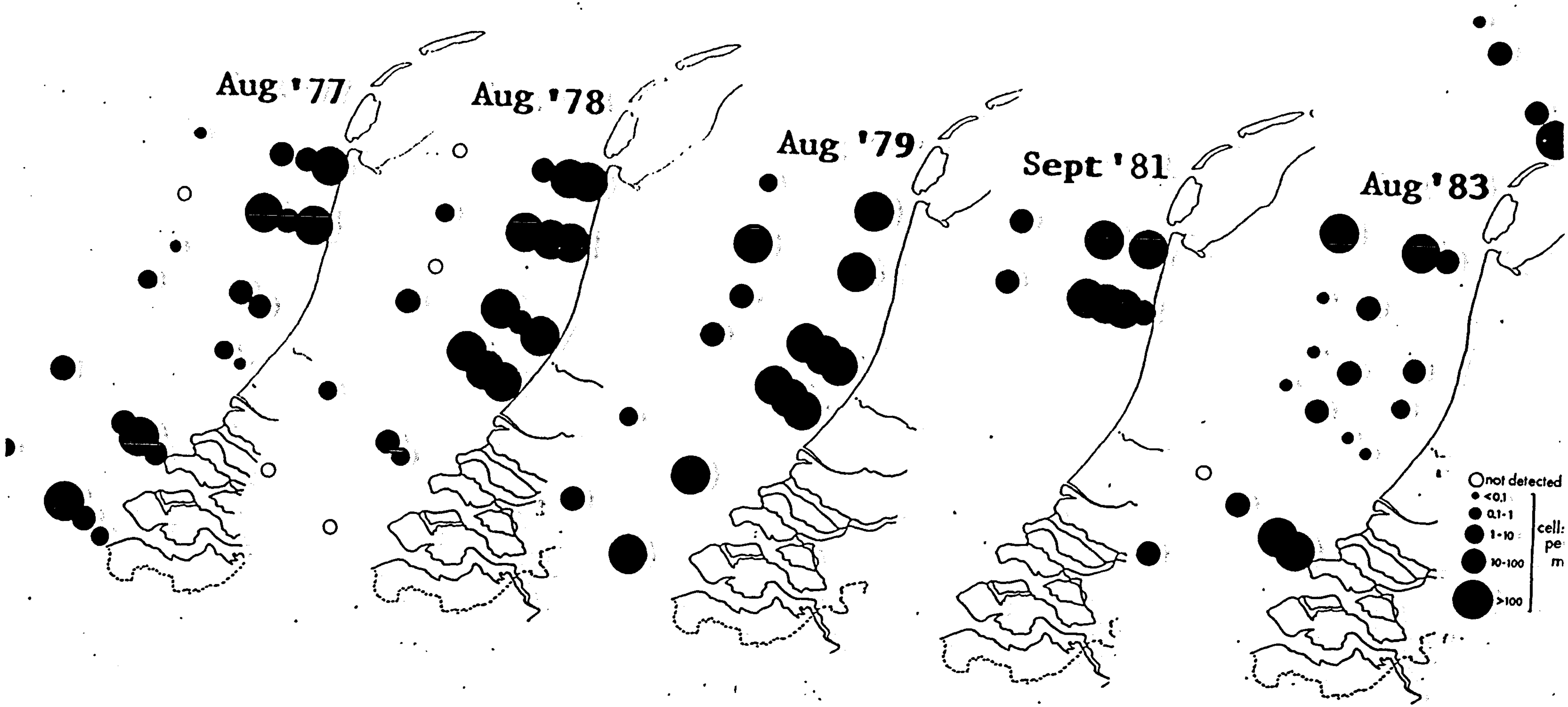


Figure 6 THE DISTRIBUTION OF RHIZOSOLENIA SKRUBSOLEI (> 200/ml)

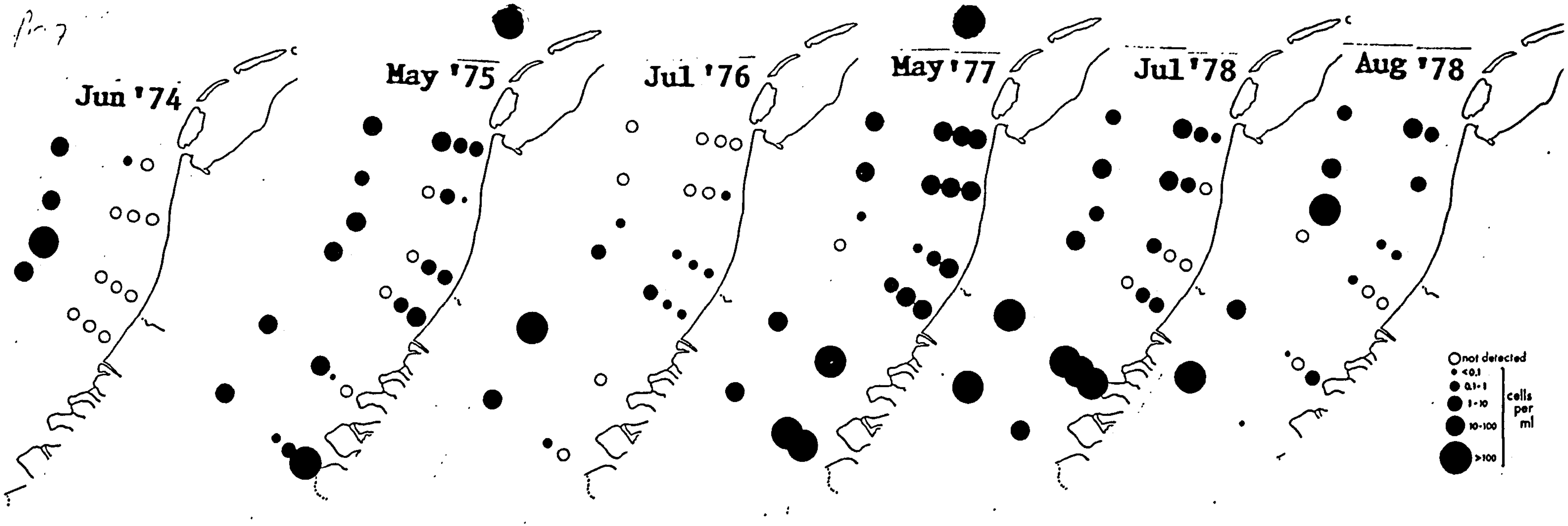
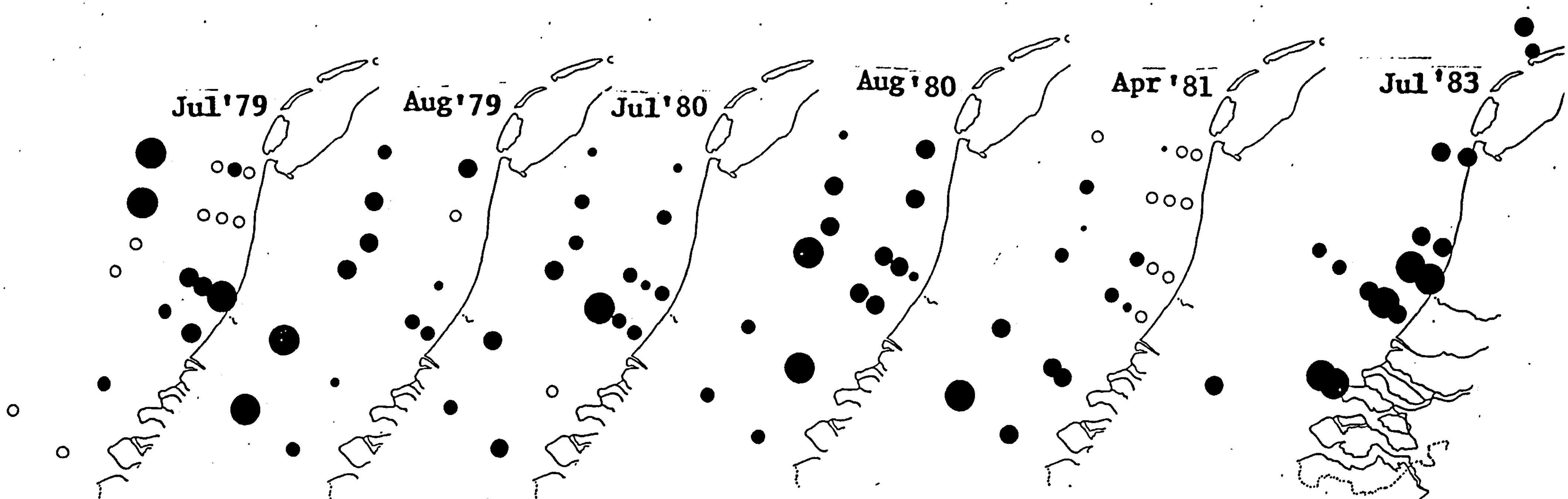


Figure 7 THE DISTRIBUTION OF RHIZOSOLENIA STOLTERFOTHII (> 100/ml)



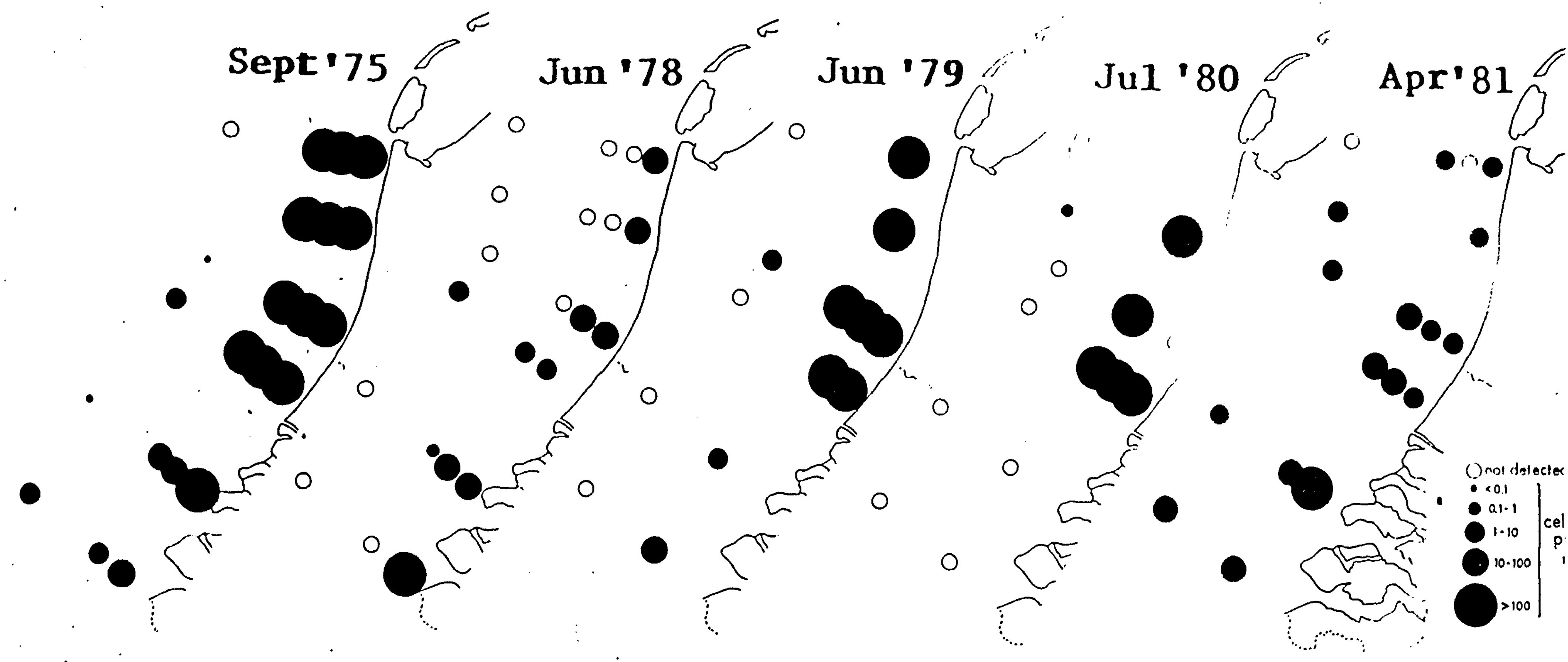


Figure 8 THE DISTRIBUTION OF CERATAULINA BERGONII (>150/ml)

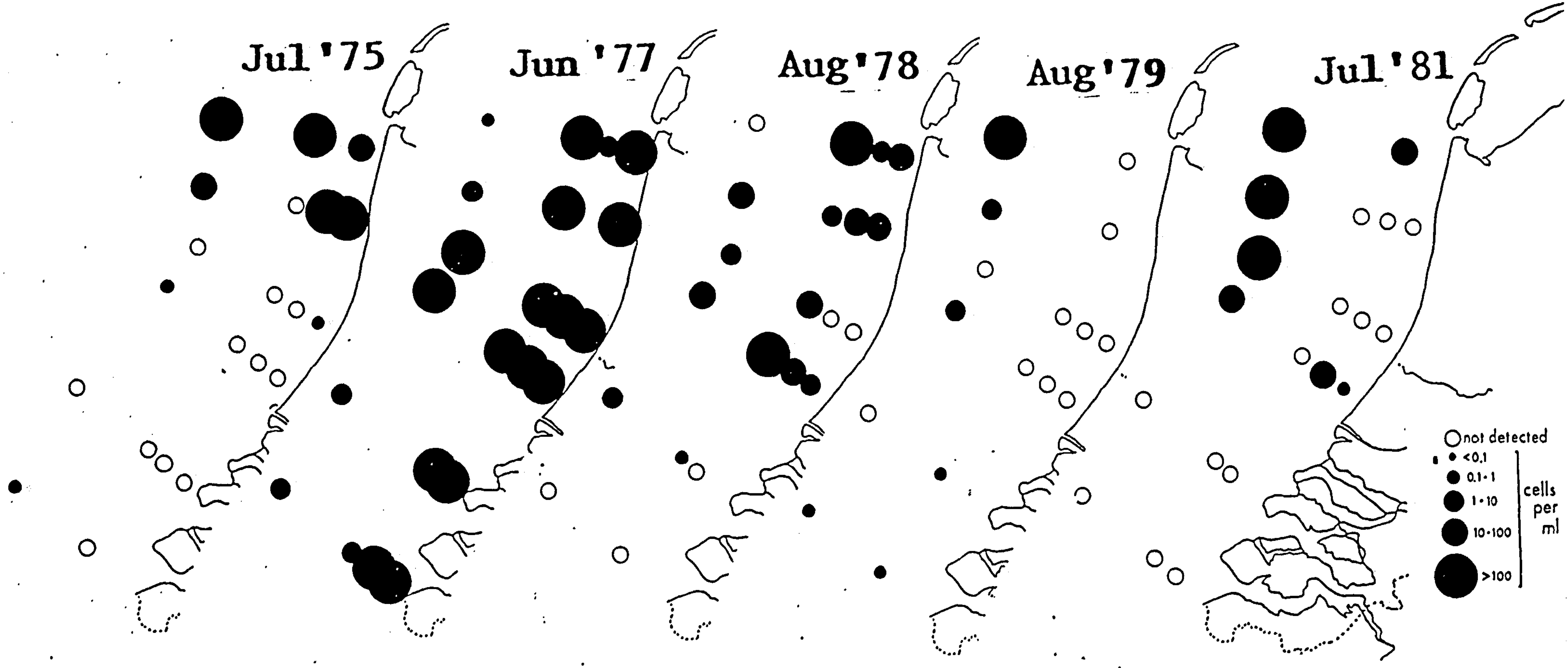


Figure 9   THE DISTRIBUTION OF LEPTOCILINDRUS DANICUS   (> 600/ml)

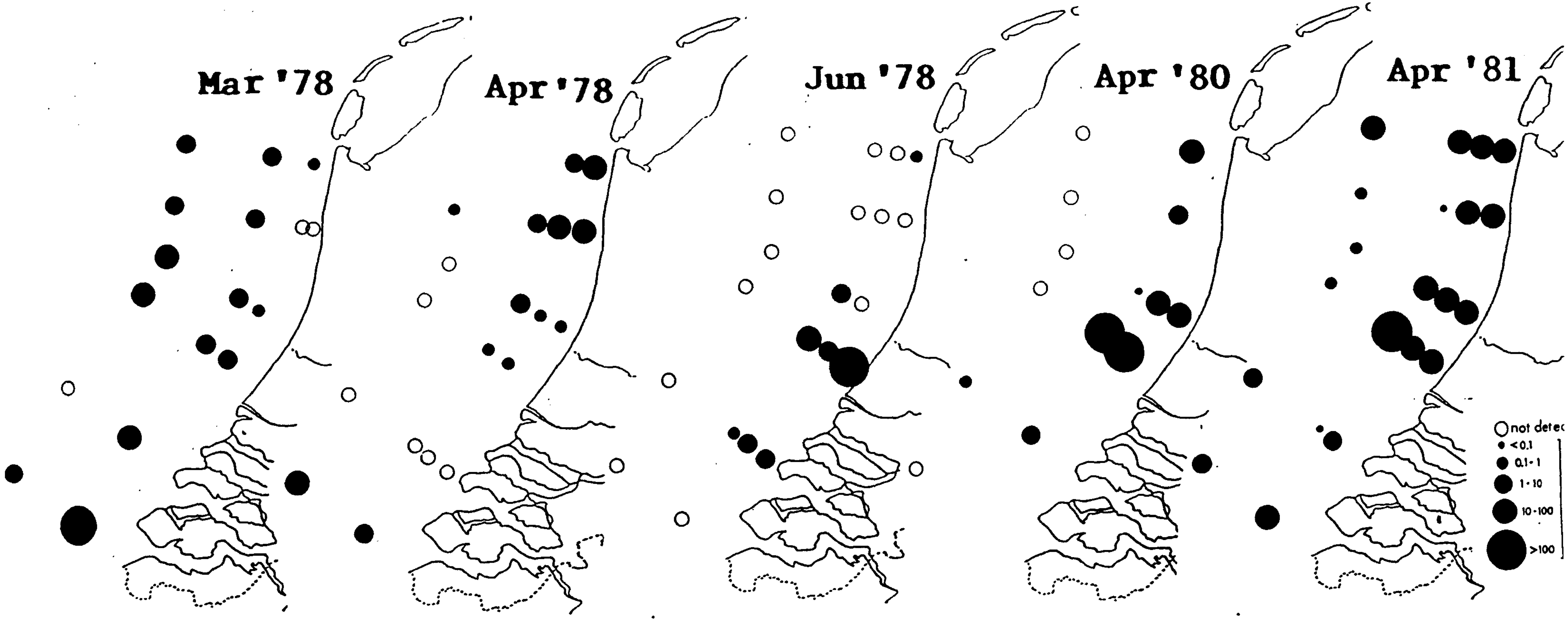


Figure 10 THE DISTRIBUTION OF THALASSIOSIRA SPECIES (> 75/ml)

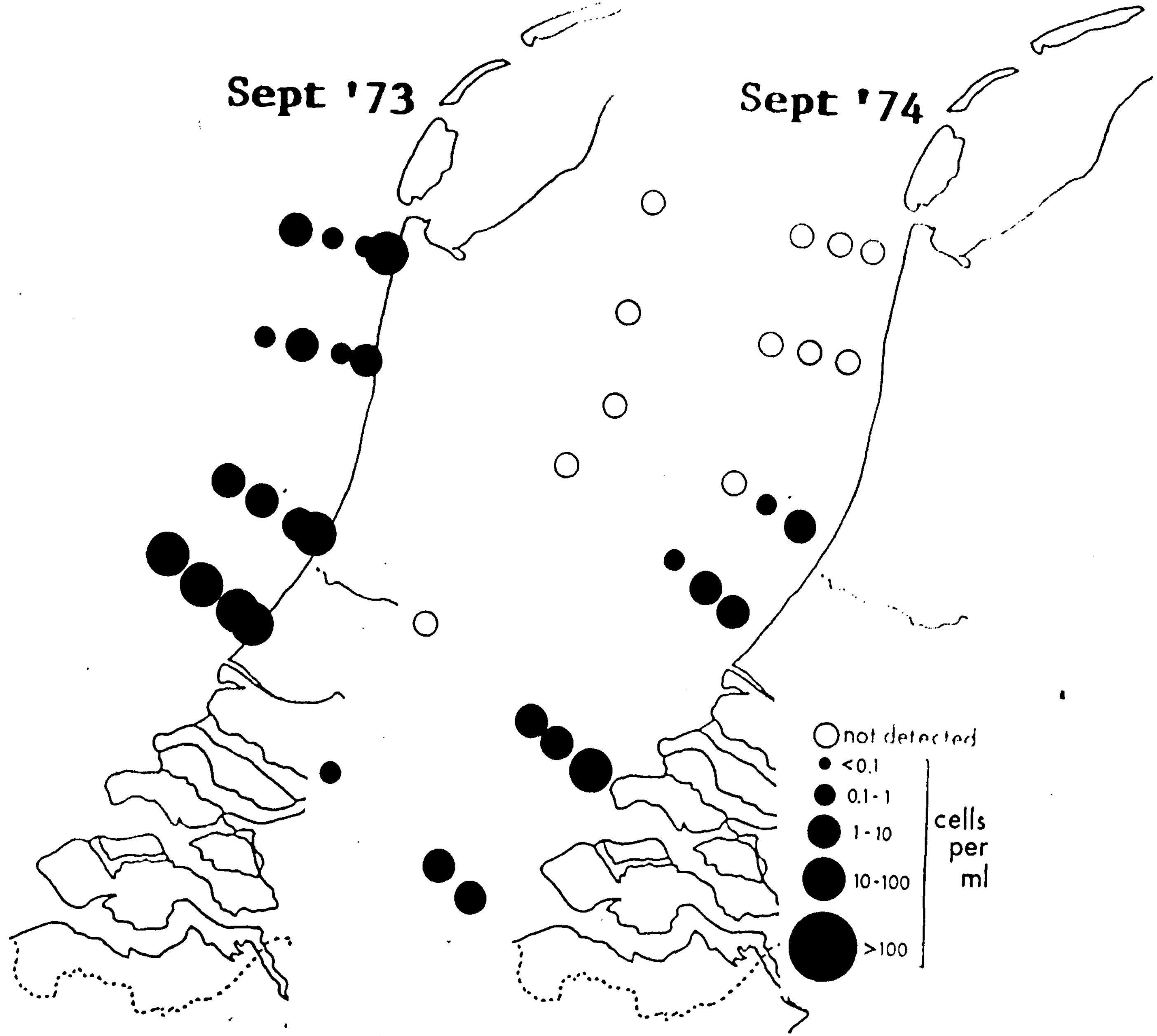


Figure 11 THE DISTRIBUTION OF DITYLUM BRIGHTWELLII (> 10/ml)

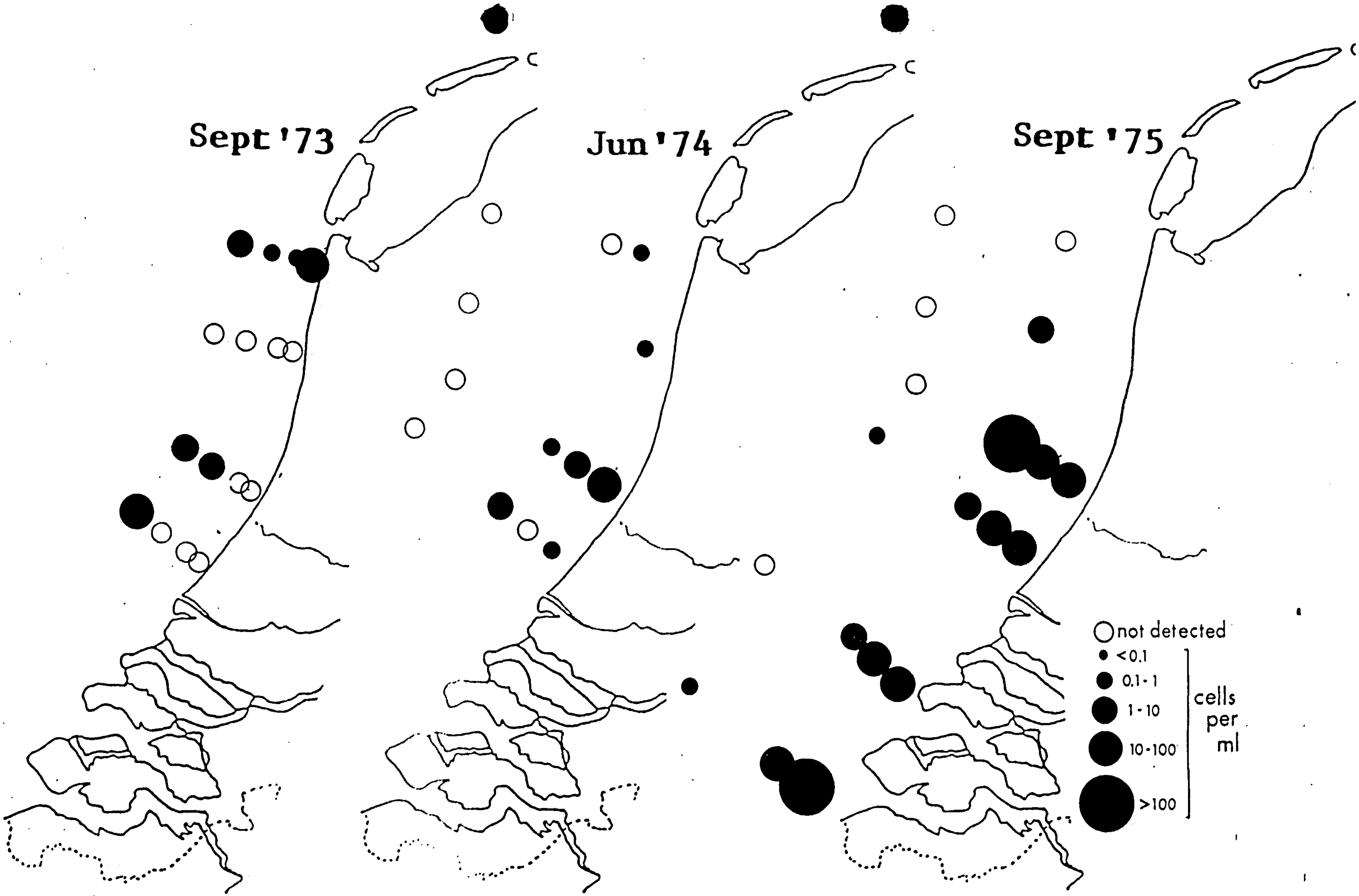


Figure 12 THE DISTRIBUTION OF EUCAMPIA ZODIACUS (> 20/ml)

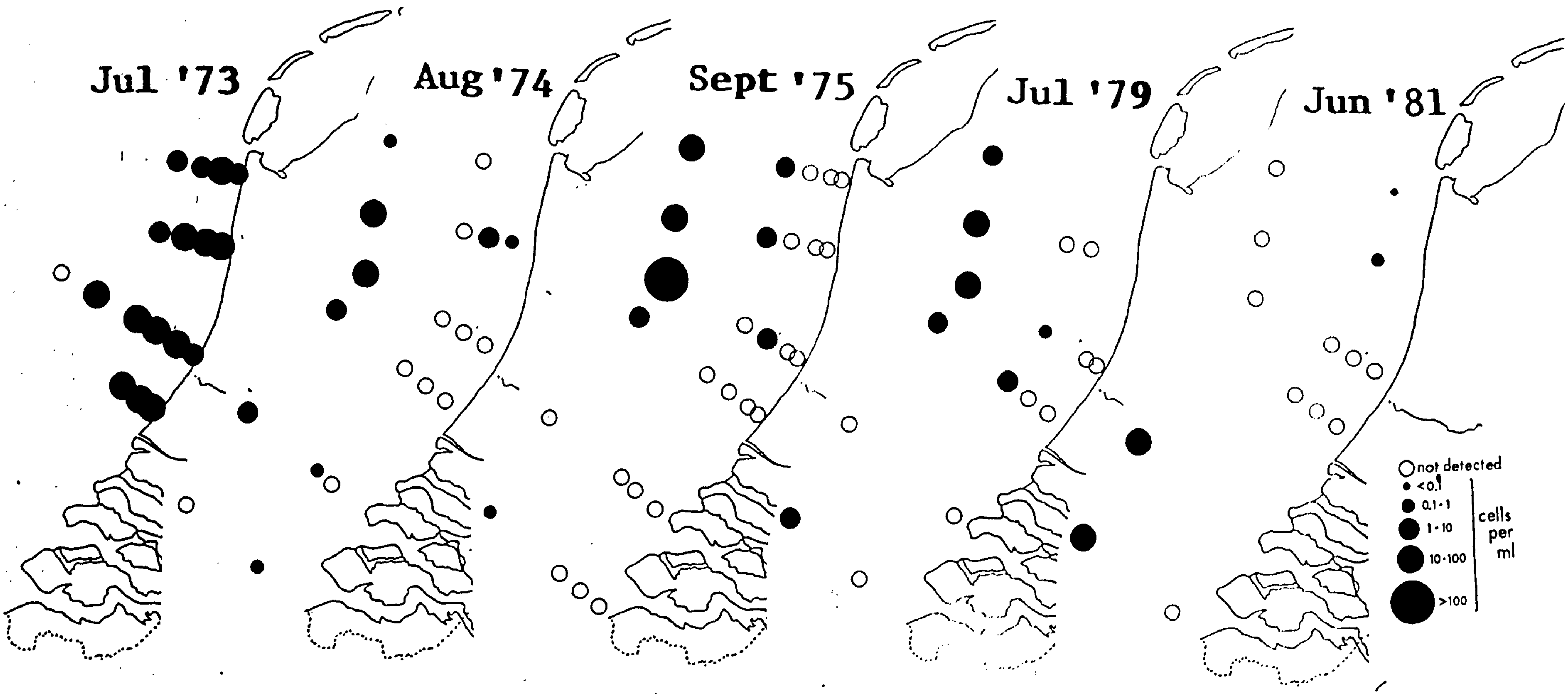


Figure 13 THE DISTRIBUTION OF GUINARDIA FLACCIDA (> 40/ml)

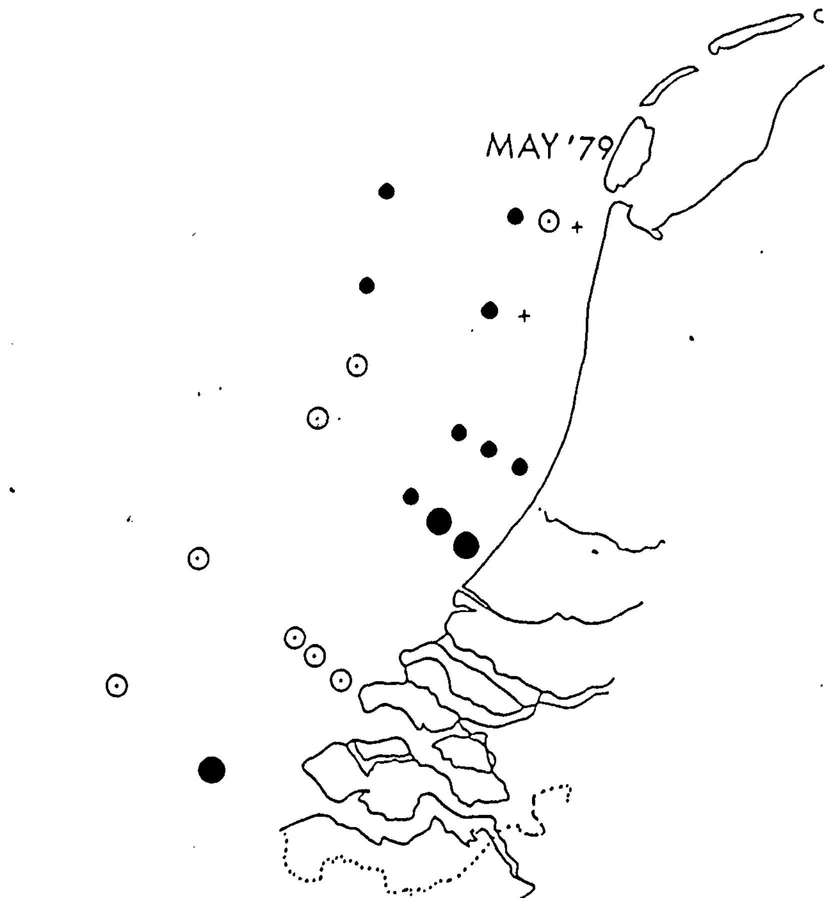


Figure 14
Distribution of Gyrodinium spirale

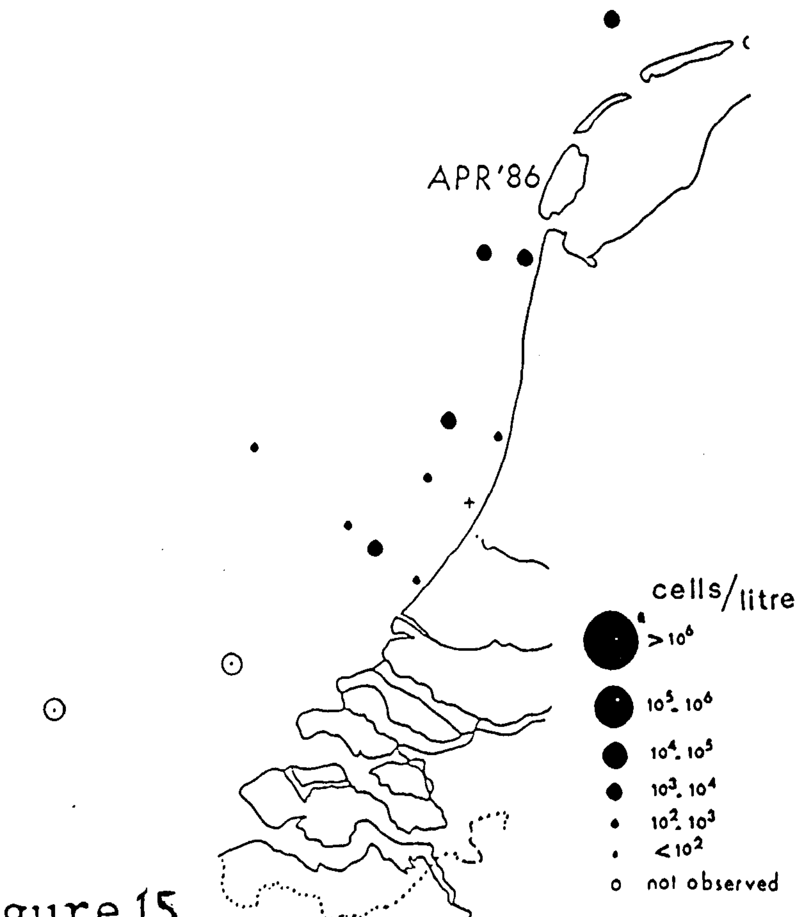


Figure 15
Distribution of Nematodinium armatu

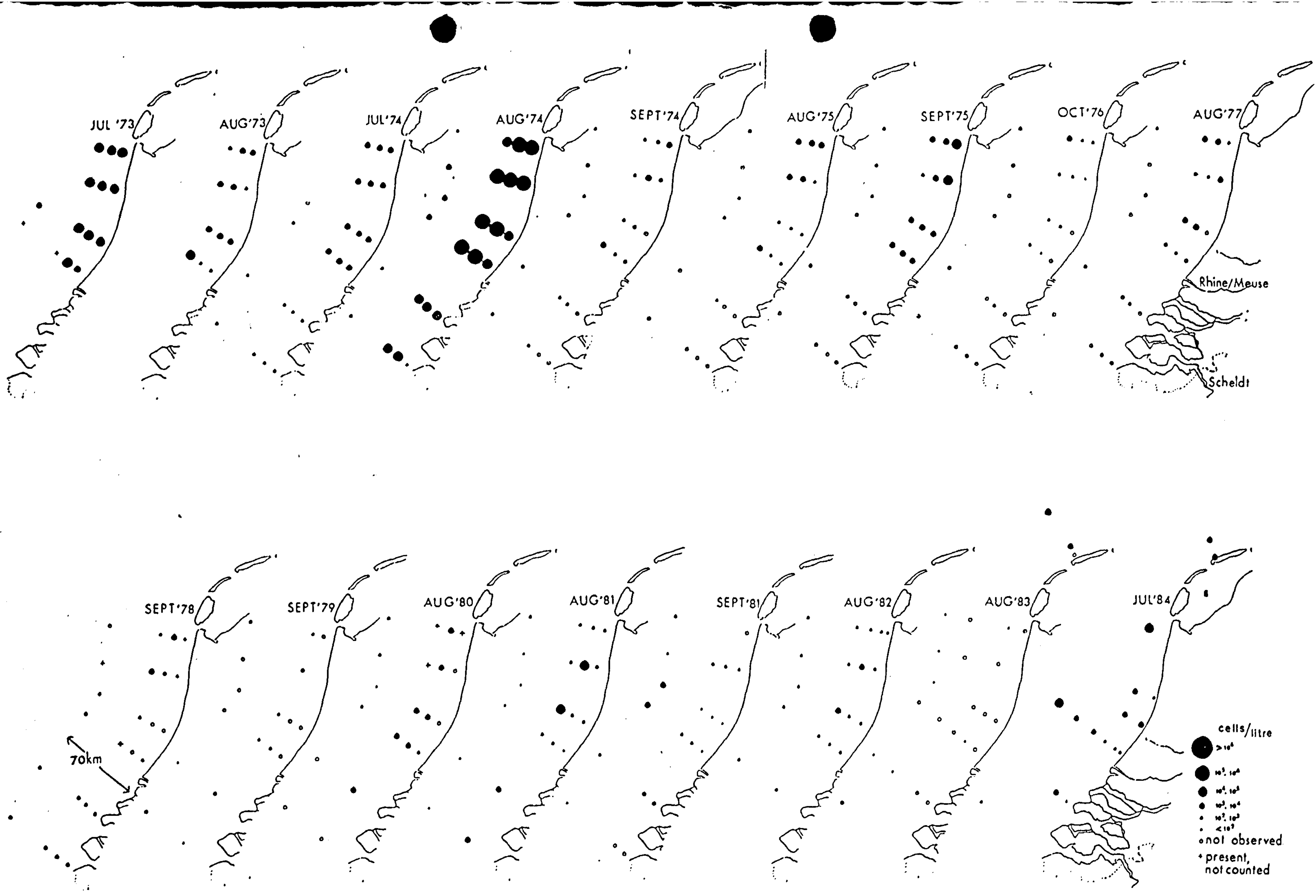


Figure 16
Distribution of Ceratium fusus

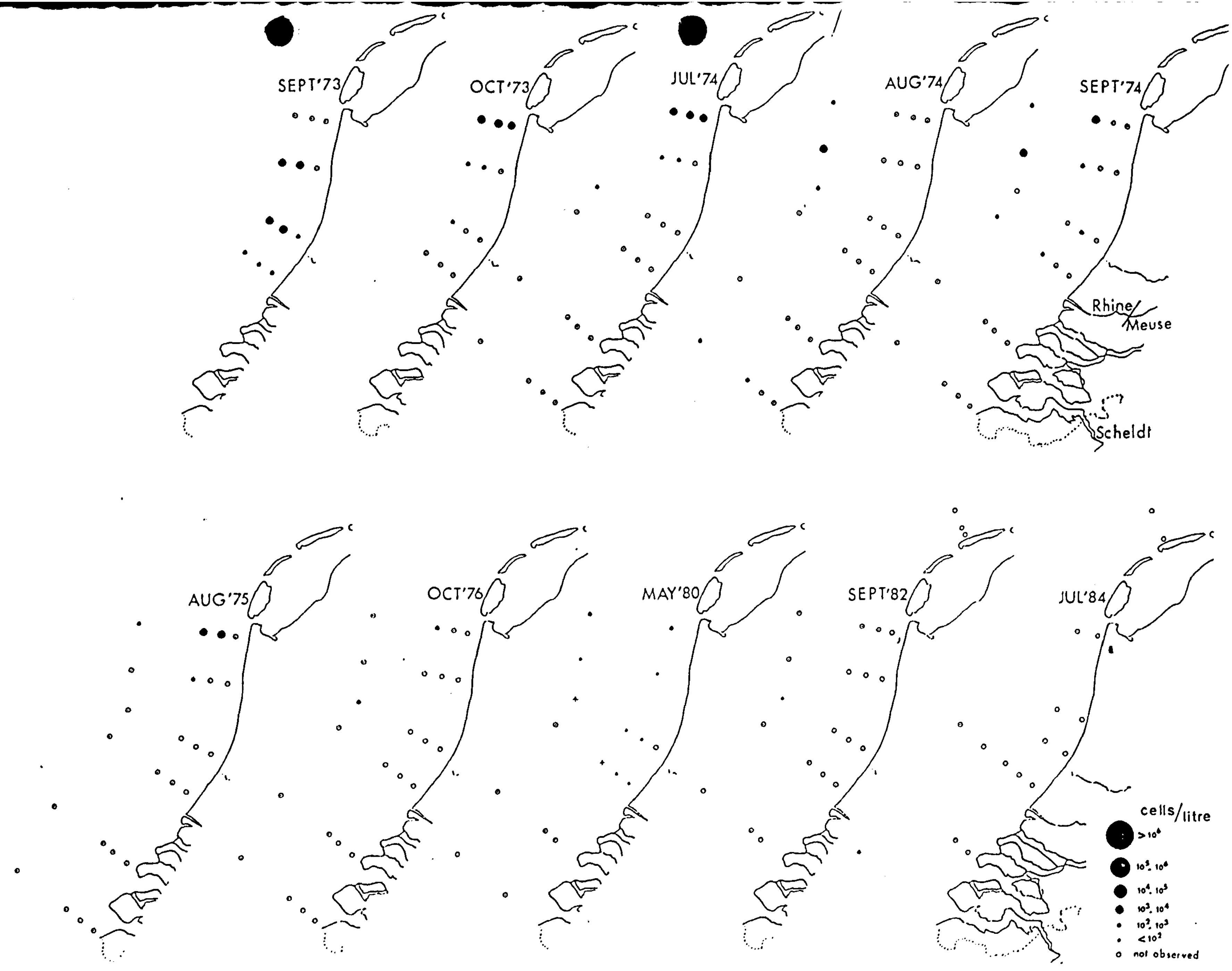


Figure 17 Distribution of Ceratium lineatum

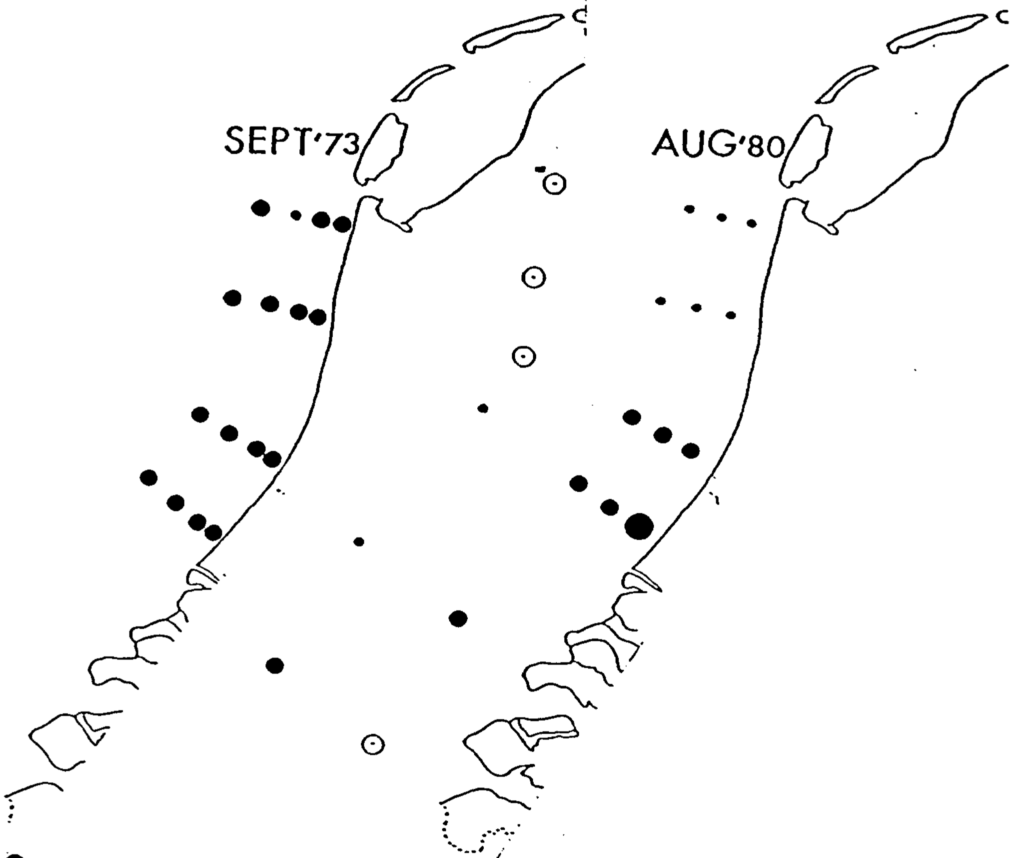


Figure 18
Distribution of Prorocentrum micans

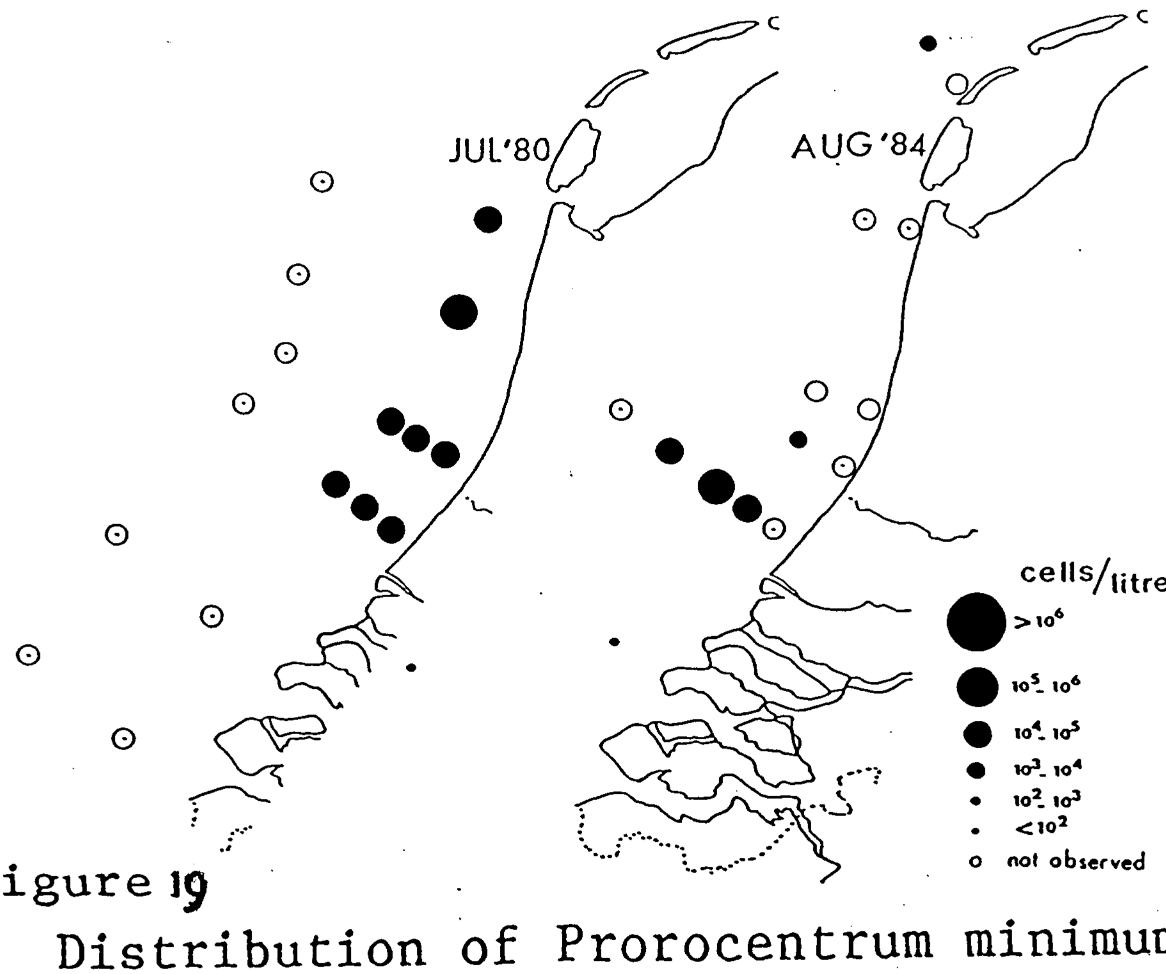


Figure 19
Distribution of Prorocentrum minimum

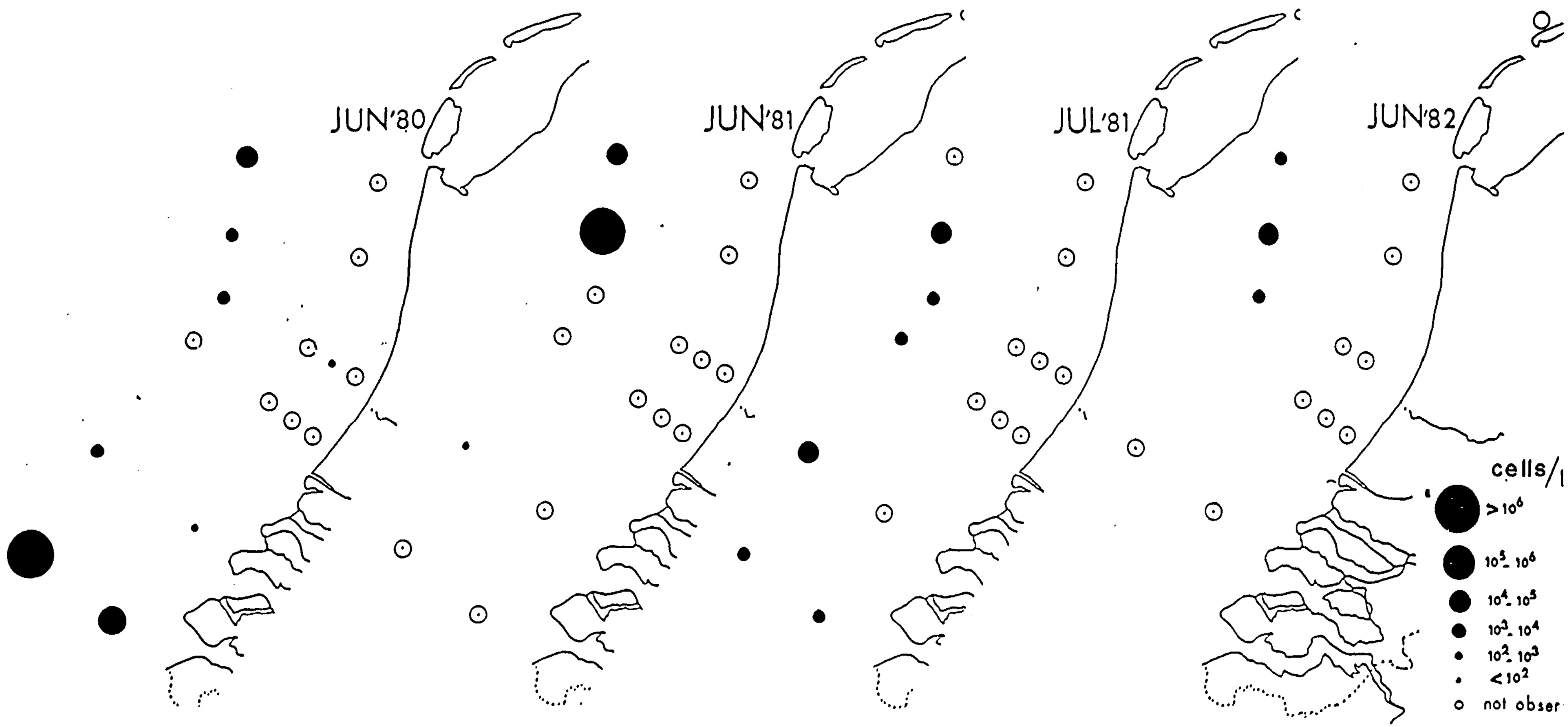


Figure 20
Distribution of Prorocentrum balticum

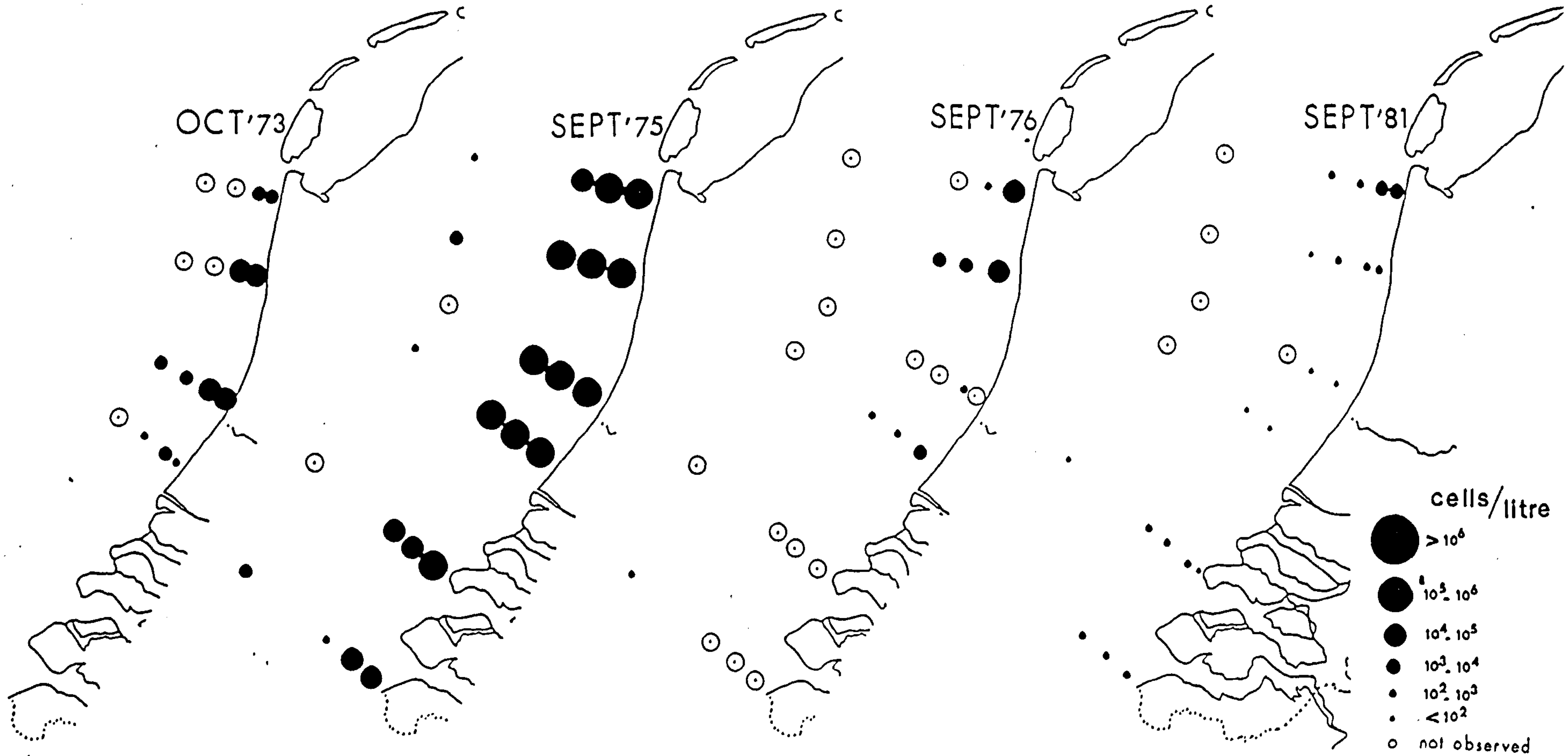


Figure 21
Distribution of Prorocentrum triestinum

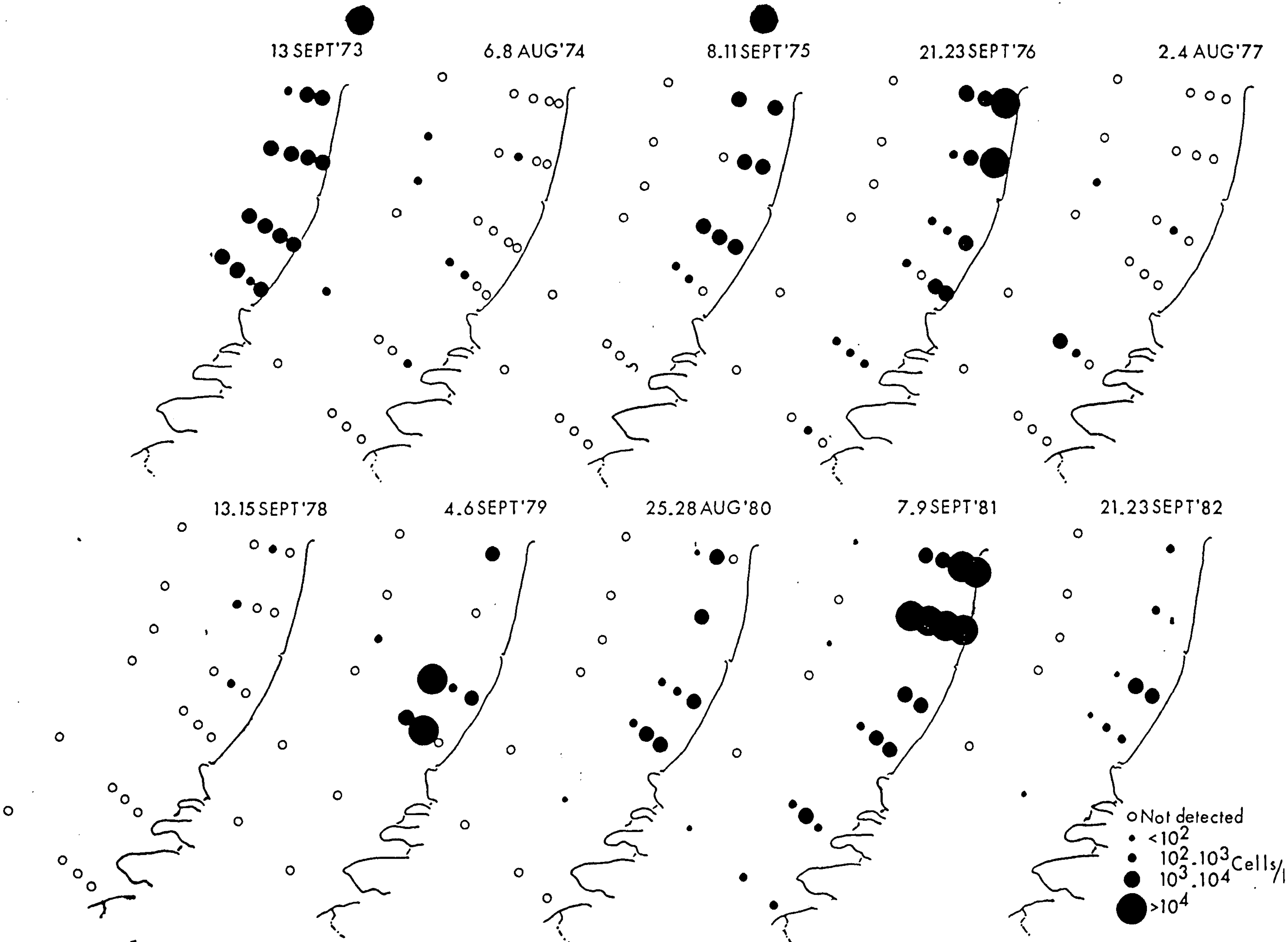


Figure 22
Distribution of Dinophysis acuminata

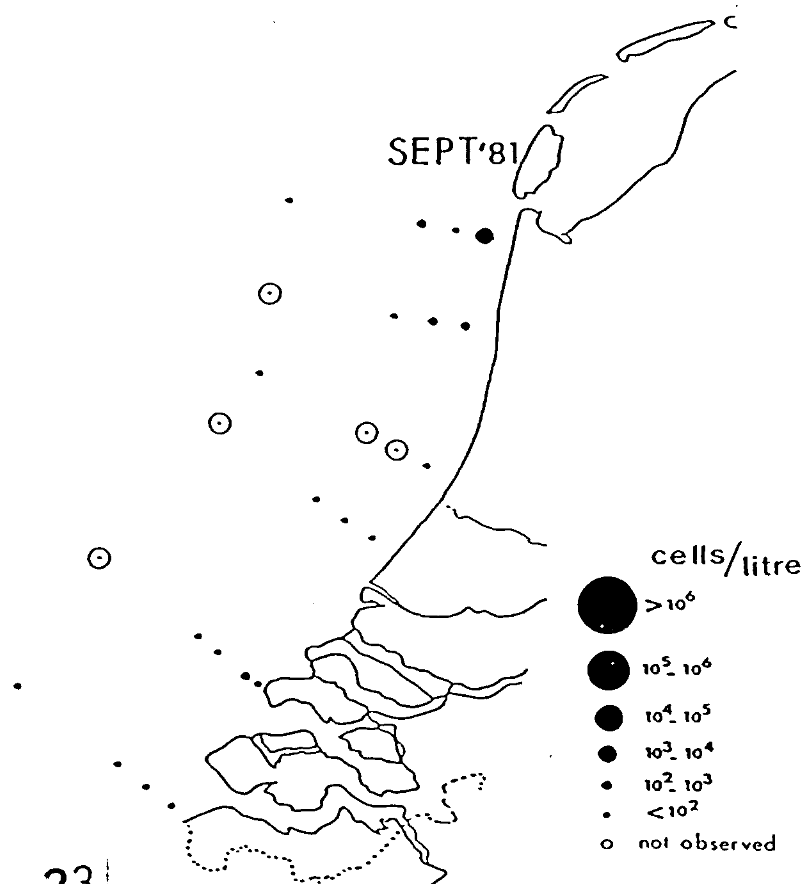


Figure 23
Distribution of Dinophysis cf skagi

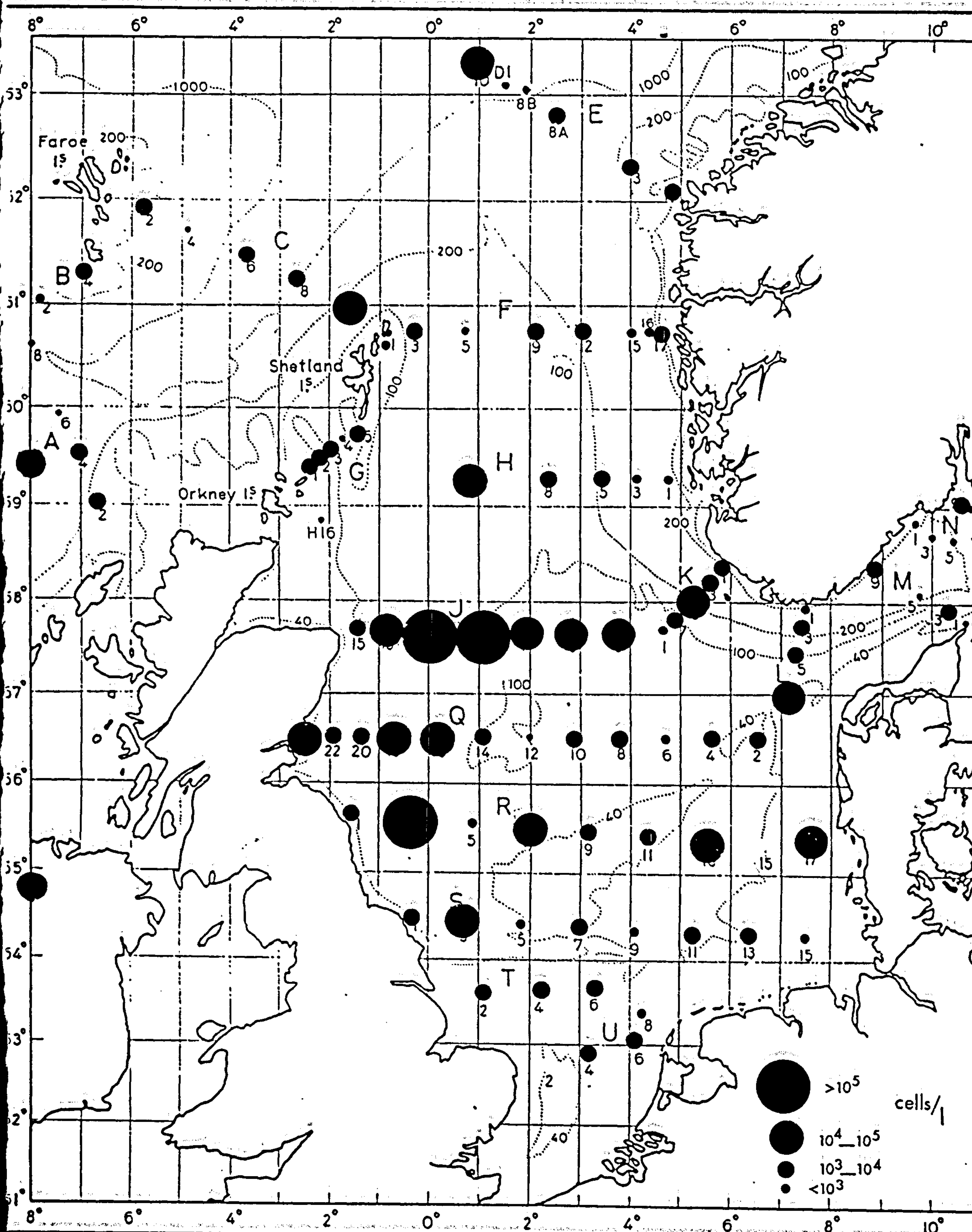


Figure 24 Prorocentrum balticum. May 1948. (Braarud et al. 1953)

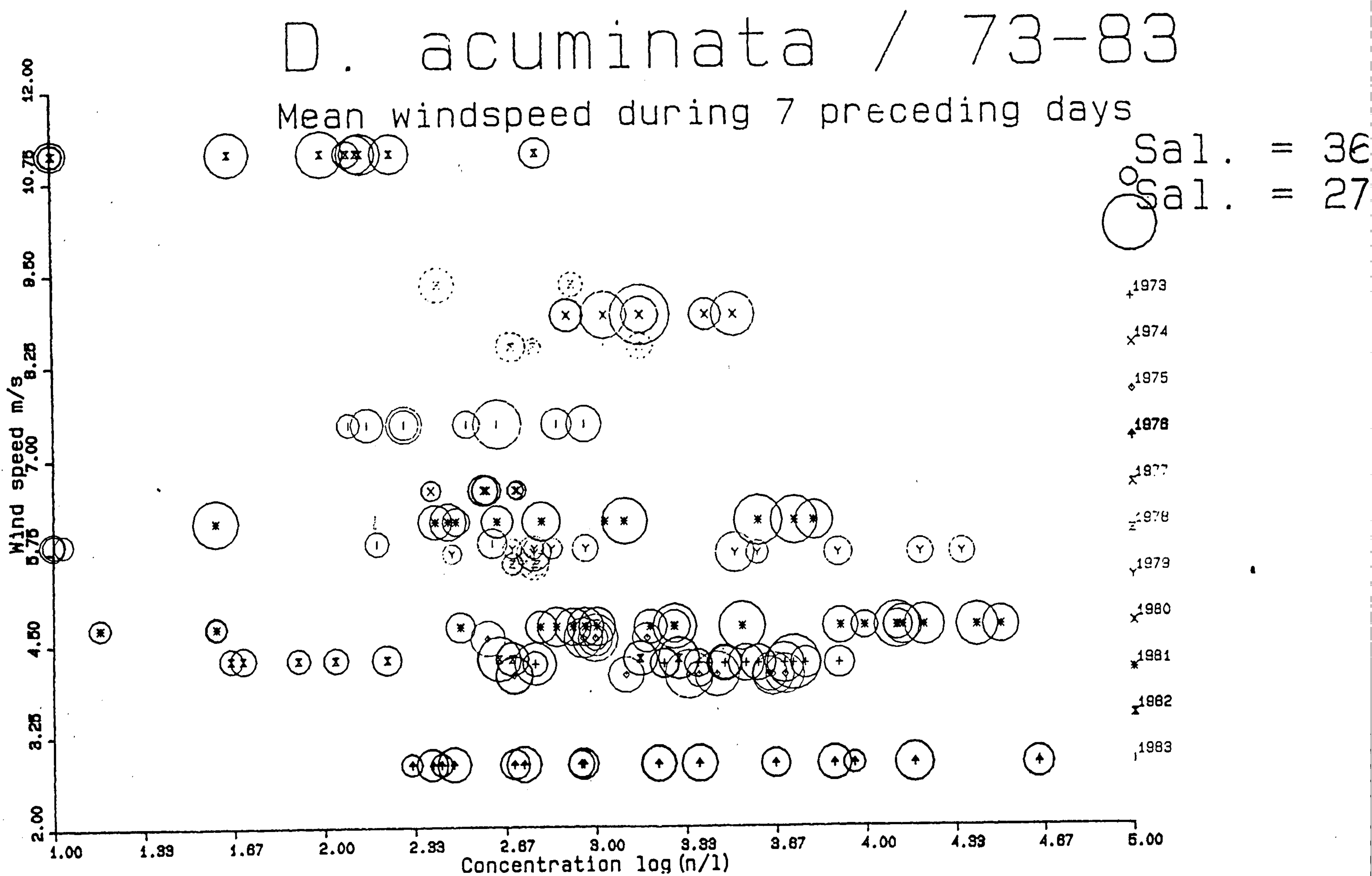


Figure 25 WINDSPEED TO CELL NUMBERS OF D. ACUMINATA