INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

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THE SEQUENCE OF THE PRINCIPAL PHYTOPLANKTON BLOOMS IN THE DUTCH COASTAL AREA (1973-1981).

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Summary.

In the present paper the sequences of the principal blooms of the diatoms: *Rhizosolenia delicatula, R. shrubsolei, R. stolterfothii, Skeletonema costatum;* the dinoflagellates: *Ceratium fusus, Prorocentrum redfieldii, Dinophysis acuminata* and the Haptophyceae: *Phaeocystis pouchetii* are described for the period 1973 - 1981. In particular the blooms of *D. acuminata* are mentioned because of its ability in producing a diarrhetic toxin.

Introduction.

Phytoplankton investigations in the Dutch coastal area (figure 1) have been conducted in a programme of monthly monitoring since 1973.
The main purpose of this study is to detect any major variations in phytoplankton abundance and distribution, related to the influx of river water. The area is influenced by the discharge of the rivers Rhine (quantitatively the most important), Meuse and Scheldt, which leads to reduction of salinity and enrichment by nutrients of the North Sea water along the Dutch coast. The sequence and distribution of the occurring phytoplankton species was studied for the period 1973 - 1981.

In the course of the nine years of research, it became clear that several phytoplankton species were tending to develop at salinity < 33.5 g/kg, implying an increase in nutrient burden because in this area the mean salinity comes to 32 g/kg (figure 1) (For the period January - March 1978, the striking correlation between nitrate content and salinity is depicted in figure 1 A). It appeared, that in this "fertilized" coastal water, in particular the area north of the influx of the rivers Rhine and Meuse (figure 1, the area, in which the transects T, N, E and C), several diatoms, dinoflagellates and a Haptophyceae developed to a tremendous bloom. Some species of the principal diatom genus *Rhizosolenia* show a remarkable sequence, in which both fluctuations in cell numbers and variation in bloom period from year to year were observed.

Although the dinoflagellates described in this paper also developed to considerable amounts, the dinoflagellate blooms never culminated to levels as observed on the diatom maxima.

Because of its toxin-producing ability, it is necessary, to watch the

development of *Dynophysis acuminata*. The blooms of *D. acuminata* in the Dutch coastal area gave rise to diarrhetic mussel poisonings in the Dutch Waddensea (KAT e.a. ICES 1982/E : 24 M.E.Q.C.).

The die-off, after the every year recurring massive spring bloom of *Phaeocystis pouchetii* sometimes causes foam on the Dutch beaches.

Method.

Surface (2 litre) water samples were taken at monthly intervals between February and November at distances of 10, 20, 30 and 70 km offshore, along six transects extending seawards from the Dutch coast (figure 1). The Utermöhl Counting Chamber and the inverted microscope were used for the enumeration of the phytoplankton species in a concentrated subsample.

To compare the principal blooms, the numbers of the prominent phytoplankton species were plotted to salinity.

For every month in the period 1973 - 1981, in which at least in 15 % of the samples from the area investigated, the cell numbers of *Rhizosolenia delicatula, R. shrubsolei* and *Skeletonema costatum* exceeded 50.000/ litre, the predicted values of the regression-line at salinity 32 g/kg (the mean salinity in the Dutch coastal area) are given in figure 2.

Beautiful examples of correlation between cell numbers of *R. delicatula* and *R. shrubsolei* to salinity are depicted in respectively figure 3 and 4.

Only for the diatom *R. stolterfothii* the predicted values of the regression-line at 34 g/kg salinity are used (see Appendix).

The data for the dinoflagellates: *Ceratium fusus, Prorocentrum redfieldii* and *Dinophysis acuminata* are worked out in the same way. The predicted values of the regression-line at 32 g/kg salinity for the months in the period 1973 - 1981, in which at least in 10 % of the samples from the area investigated, the dinoflagellate numbers of 5000 pro litre were exceeded, are depicted in figure 2.

Results.

From a multitude of data gathered during the period of phytoplankton investigated in the Dutch coastal area 1973 - 1981, some of the most remarkable sequences in blooms are described.

Blooms of the diatoms:

In the first year of the phytoplankton investigations in 1973, *Skeletonema costatum* culmunated at 3.95 millions of cells pro litre, the bloom maintained during 3 months. The distribution of *S. costatum* in the area investigated for July 1973 is given in figure 6.

In the next years 1974 - 1977 the increase of *Rhizosolenia delicatula* was remarkable. This trend was also observed on *R. shrubsolei* and in a less extent on *R. stolterfothii*.

During the period 1978 - 1980 the massive blooms of the *Rhizosolenia* species appeared to prevail in the Dutch coastal area, a separate spring- and autumn bloom was no longer distinguished for at least one of the *Rhizosolenia* species continued its abundance during the summer period. The distribution of the *R. delicatula* bloom in the area investigated for June 1978 is given in figure 5.

In 1981, *R. delicatula* and *R. stolterfothii* decreased drastically.

Blooms of the dinoflagellates:

The blooms of the prominent dinoflagellates *Ceratium fusus* and *Prorocentrum redfieldii* were exceeding 10.000 cell numbers pro litre in some succeeding years. They reached their maxima in respectively August 1974 and September 1975.

Blooms of *Dinophysis acuminata* occurred in September of 1973, 1976 and 1981. This micro-organism culminated in the northern part of the Dutch coastal area (Distribution of *D. acuminata* for September 1981 is depicted in figure 8). In September 1976 and September 1981, the blooms of *D. acuminata* touched the mussel growing sites in the Dutch Waddensea which gave rise to diarrhetic mussel poisoning.

Blooms of the Haptophyceae:

Colonies of *Phaeocystis pouchetii* were observed in massive blooms every year. In samples of April (1973 - 1981) their biomass was predominating compared with the total biomass of the occurring phytoplankton species. (No counts were performed on this micro-organism).

Detailed description of the phytoplankton species mentioned in this paper are given in the Appendix.

Discussion.

Considering the sequences of the blooms as described in this paper, some events are noteworthy.

The tremendous bloom of *Skeletonema costatum* never recurred during the period of investigation.

Massive blooms of *Ceratium fusus* and *Prorocentrum redfieldii* in respectively 1974 and 1975, coincided with slight blooms of the diatoms. During the period 1977 - 1980, in which *Rhizosolenia* species culminated, *Ceratium fusus* diminished till a scarcely occurring species, whereas *Prorocentrum redfieldii* and *Dinophysis acuminata* were not present.

After the dramatic decrease of in particular *R. delicatula* and *R. stolterfothii*, pulses of *Ceratium fusus* and *Dinophysis acuminata* recurred in the phytoplankton assemblies. Fluctuations in the sequence of the principal phytoplankton blooms in the Dutch coastal areas as outlined in this paper are difficult to interpret, it can not be explained in simple terms of eutrophication. It could be a consequence of at least more environmental factors. As water from the Atlantic North of Scotland drifting towards the south along the British coastline is united with English Channel water in the southern North Sea at about 53° N, Dutch coastal water will be slightly influenced by this admixture during the period 1973 - 1975. The influence of Atlantic water upon the Dutch coastal area could have decreased in the period 1976 - 1980, because this watermass turned round at higher latitude only touching the Dutch coast north of the Wadden isles. In 1981 the North Atlantic water with its characteristic *Ceratium* species again could have influenced the phytoplankton community in the Dutch coastal area.

1. *Rhizosolenia delicatula Cleve.*

The diatom is a "year-round" species, which was observed in the sampling period February - November 1973 - 1981. Although in 1973, 1974 and 1975 bloom occurred of *R. delicatula* the species appearance increased dramatically since 1976, not only in cell number but also the period of bloom was prolonged. The dominance in the spring bloom of 1977 did not recur in 1978, when the bloom period took place in June and August. The spring bloom of *R. delicatula* in 1979 recurred in July. After the extremely continuous dominance in 1980, the diatom decreased in 1981. An example of the distribution in the Dutch coastal area in June 1978 is given in figure 5.

	Maximal observed cells x 10^3/litre		Salinity g/kg
1973	July	53	32.47
	August	360	32.98
1974	August	253	33.34
1975	June	66	34.94
1976	April	139 ')	33.97
	May	403 ')	32.51
	June	335 ')	35.15
	July	200	32.11
	Oct.	105 ')	35.08
1977	March	137	33.57
	April	292	33.19
	May	362	31.15
	July	120 ')	34.15
	Oct.	274 ')	33.39
1978	June	1042	31.46
	July	157 ')	34.55
	August	237	30.24
1979	April	852	31.71
	May	265	34.71
	June	130 ')	34.67
	July	388	32.02
1980	April	264	35.21
	May	812	31.56
	July	1352	25.97
	Sept.	654	32.07
1981	April	76	32.82
	June	610	34.66
	August	390	33.08

') Local pulse, no real bloom in the investigated area.

2. *Rhizosolenia shrubsolei Cleve.*

Although not always present in early spring, *R. shrubsolei* is almost a year-round diatom. The massive blooms occurred principally in July or August during the period of investigation. The yearly increase in cell numbers since 1973 reached the maximum in 1979 followed by a remarkable decrease in 1980. In 1981 the level as recorded in 1977 was reached again.

	Occurrence	Maximal observed cells x 10^3/litre		Salinity g/kg
1973	June - Oct.	August	54	34.14
1974	April - Nov.	July	156	33.50
		Oct.	187 ')	34.14
1975	April - Oct.	July	42	34.32
		August	120	30.49
1976	April - Nov.	July	200	34.84
1977	Febr. - Oct.	August	220	32.73
1978	Jan. - Nov.	August	240	32.20
1979	Febr. - Sept.	August	448	33.64
1980	April - Oct.	August	126	34.51
1981	April - Sept.	July	132	28.88

') local pulse, no real bloom observed in the area investigated.

3. *Rhizosolenia stolterfothii Peragallo.*

During the period of investigation *R. stolterfothii* occurred in general from March - October in the phytoplankton assembly of the Dutch coastal area. An increase in cell numbers was observed in the period 1973 - 1979. There is some variation in the season of the bloom. The length of the bloom period reached its maximum in 1980 viz. 4 months.
Also for *R. stolterfothii* cell numbers diminished fairly in 1981.

	Occurrence	Maximal observed cells x 10^3/litre		Salinity g/kg
1973	Febr. - Oct.	March	11	34.27
1974	Febr. - Nov.	May	54	35.22
		June	106 ')	35.28
1975	April - Oct.	June	111	34.35
1976	April - Nov.	July	106	35.02
1977	Febr. - Nov.	March	123	34.25
		April	91	34.21
		May	166	33.19
1978	March - Nov.	July	156	33.50
		August	203	34.46
1979	Febr. - July	July	258	34.64
		August	198	34.81
1980	March - Oct.	May	106	33.18
		June	123	31.71
		July	158	34.75
		August	135	35.00
1981	March - Oct.	April	106	34.69

') Local pulse no real bloom observed in the area investigated.

4. *Skeletonema costatum (Greville) Cleve.*

The notable bloom of *S. costatum* in 1973 has never recurred in the Dutch coastal area during the period of investigation 1973 - 1981.

	Occurrence	Maximal observed cells x 10^3/litre		Salinity g/kg
1973	May - Sept.	May	24	30.07
		July	3950	28.40
		August	375	30.88

In the period 1974 - 1981 *S. costatum* did not develop till bloom, distributed in the area investigated.
The distribution of *Skeletonema costatum* in the Dutch coastal area in July 1973 is depicted in figure 6.

5. *Ceratium fusus Ehrenberg.*

In 1973 and 1974 *C. fusus* appeared to be a very common dinoflagellate in the Dutch coastal area. After the extraordinary bloom in August 1974 a decrease in cell numbers was observed during 1975 and 1976. In the period 1977 - 1980 *C. fusus* was only scarcely present. Since 1981 the dinoflagellate recurred in considerable amounts.

	Occurrence	Maximal observed cells x 10^3/litre		Salinity g/kg
1973	June - Dec.	July	68	31.78
1974	June - Nov.	August	204	33.45
1975	August- Dec.	Sept.	10	30.33
1976	July - Nov.	Oct.	1.6	33.25
1977	August		< 0.1	
1978	Sept.		< 0.1	
1979	Sept.		< 0.1	
1980	June - July		< 0.1	
1981	August- Sept.	August	15	32.89

In figure 7 "Distribution of *C. fusus* in the Dutch coastal area 1973 - 1976", the development in the area with salinities <33.5 g/kg was depicted.

6. *Prorocentrum redfieldii Bursa.*

The dinoflagellate was not present every year. During the period 1976 - 1980 the species was not observed in the Dutch coastal area.
P. redfieldii is mostly accompanied by *P. micans*. In the pulse of *P. redfieldii* in September 1975, *P. micans* was only present till up to 2200 cells pro litre.

	Maximal observed cells x 10^3/litre		Salinity g/kg
1973	Oct.	39	31.49
1974	Sept.	16	-
1975	Sept.	952	28.90
1976	Sept.	15	31.59
1981	Sept.	6	30.40

7. *Dinophysis acuminata Claparède and Lachmann.*

During the period of investigation the dinoflagellate was observed in late summer, but not every year. From 1977 - 1980 *D. acuminata* was not detected.
In September 1976 and September 1981 the highest density was observed in the most northern part of the area investigated. The species appeared to be related to the diarrhetic mussel poisoning in the Dutch Waddensea.
The distribution of *D. acuminata* in the Dutch coastal area is depicted in figure 8.

	Period of occurrence	Maximal observed cells x 10^3/litre		Salinity g/kg
1973	August- Sept.	Sept.	9	33.53
1975	Sept.	Sept.	1.6	33.94
1976	Sept.	Sept.	44	33.06
1981	August- Sept.	Sept.	31.5	31.90

8. *Phaeocystis pouchetii (Hariot) Lagerheim.*

This member of the Haptophyceae is already present in March in the Dutch coastal area. The tremendous increase in April makes this organism qua biomass to the fairly predominant species of the spring bloom. Its dominance maintained during May in 1977 and 1978 (no counts were made). The die-off of this species sometimes causes foam on the Dutch beaches.

	Period of dominance
1973	April
1974	April
1975	April
1976	April
1977	April - May
1978	April - May
1979	April
1980	April
1981	April

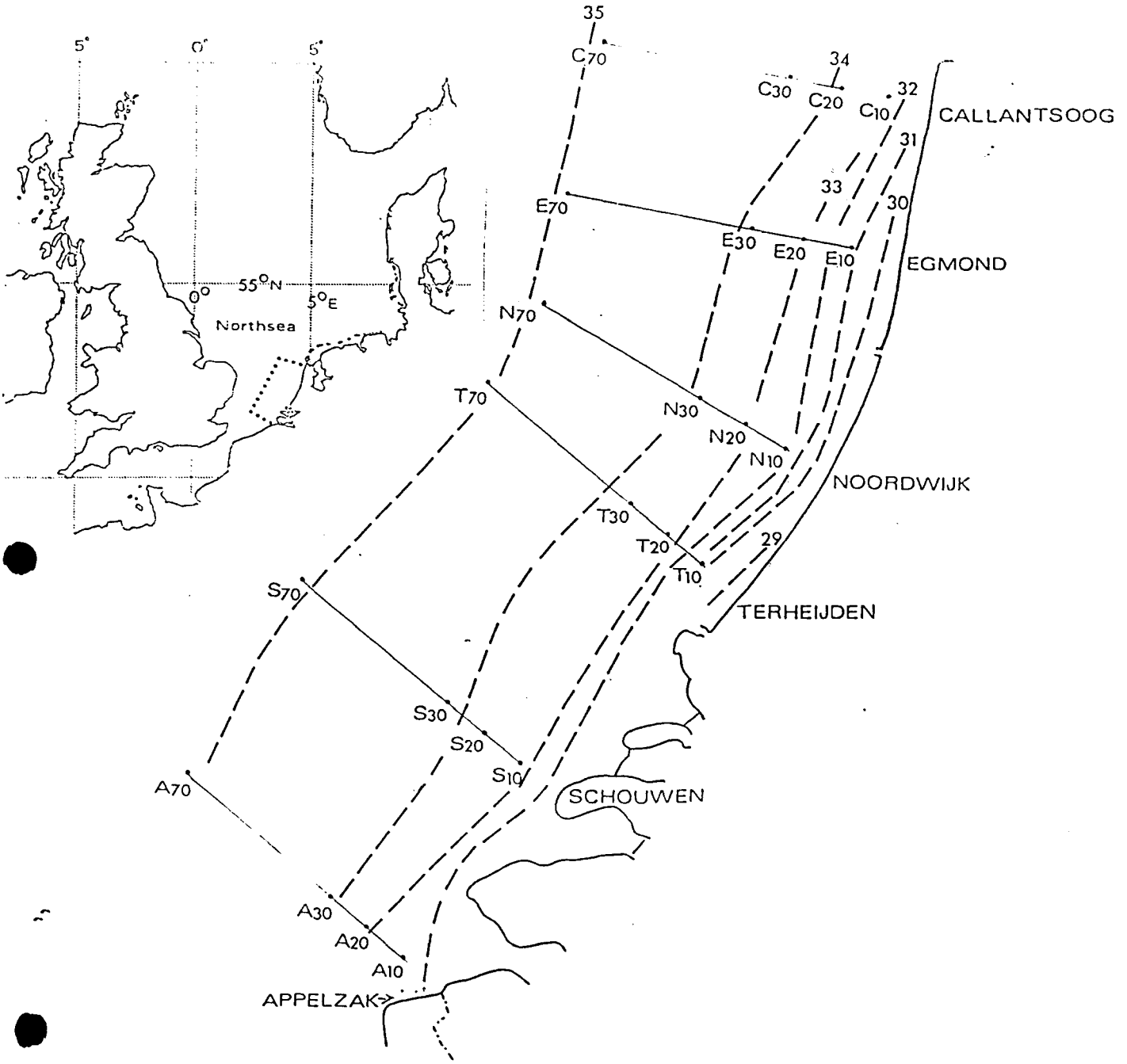

Figure 1 - The Dutch coastal area.

Dotted lines: Isohalines for the summer period.

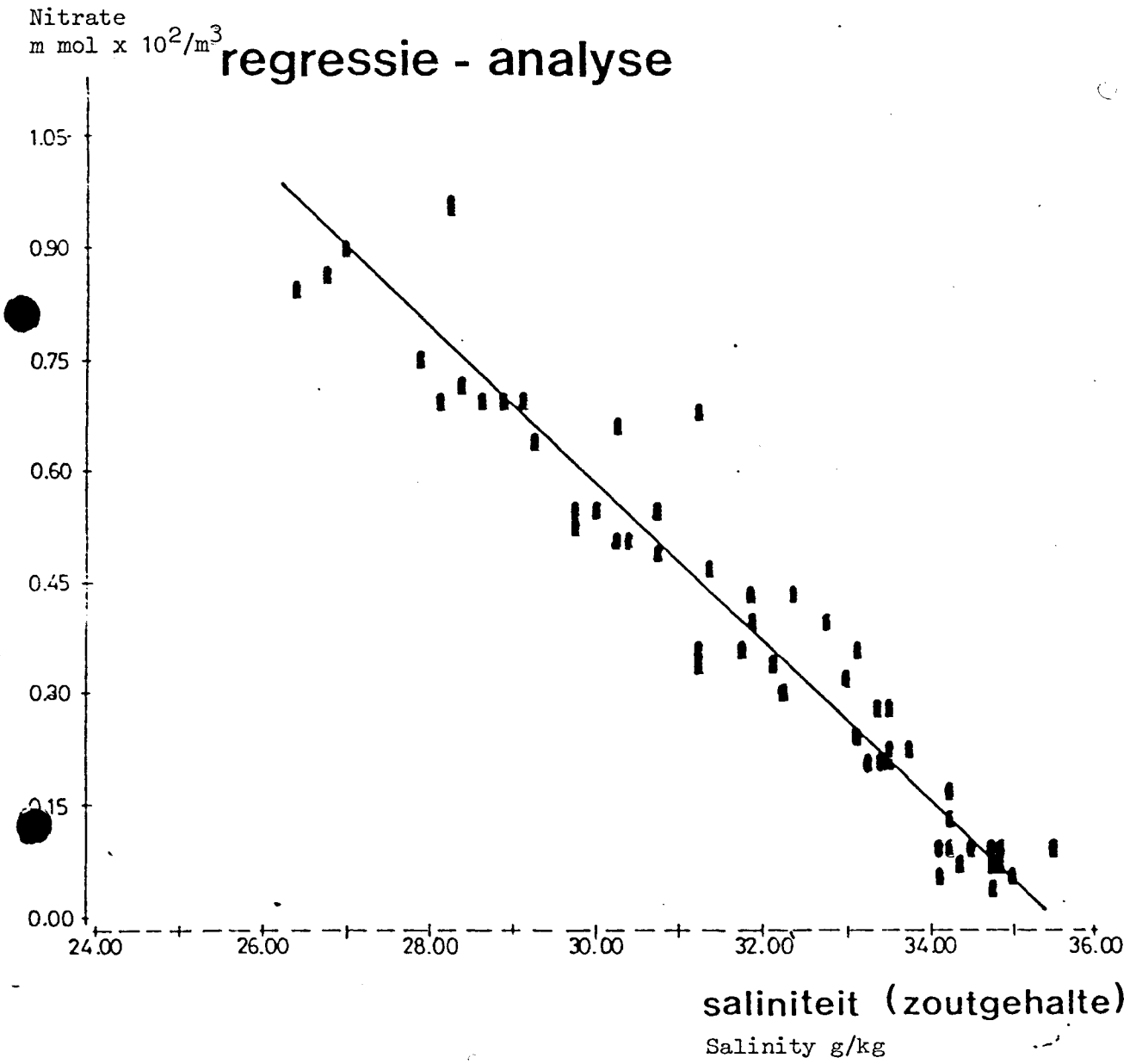

Figure 1A - Regression-line of Nitrate concentrations to salinity in the Dutch Coastal Area for the period January - March 1978 (Pieters, Netherlands Institute for Fishery Investigations, 1982).

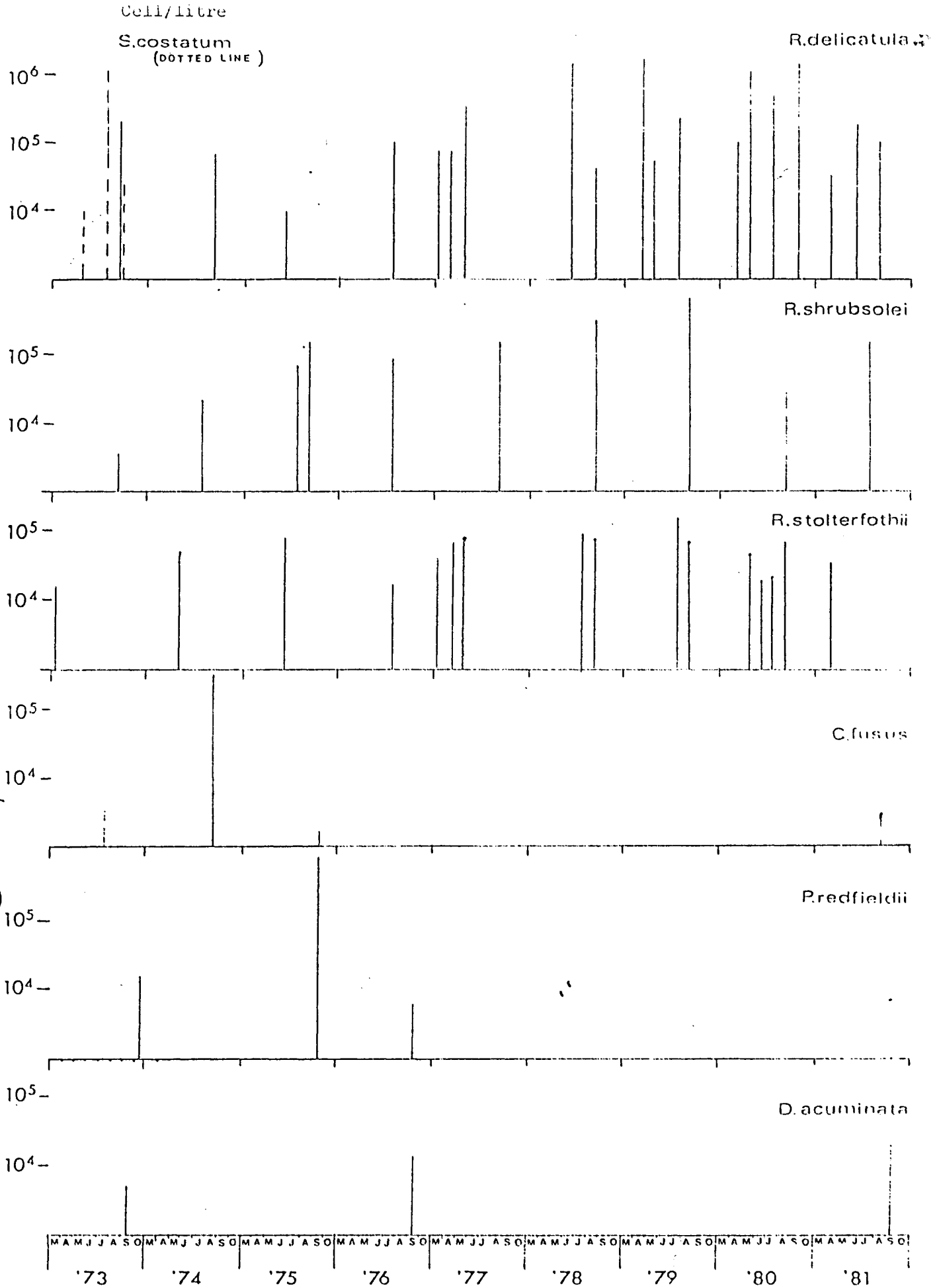

Figure 2 - The predicted values of the regression-line at 32 g/kg salinity. (for *R. stolterfothii* at 34 g/kg salinity).

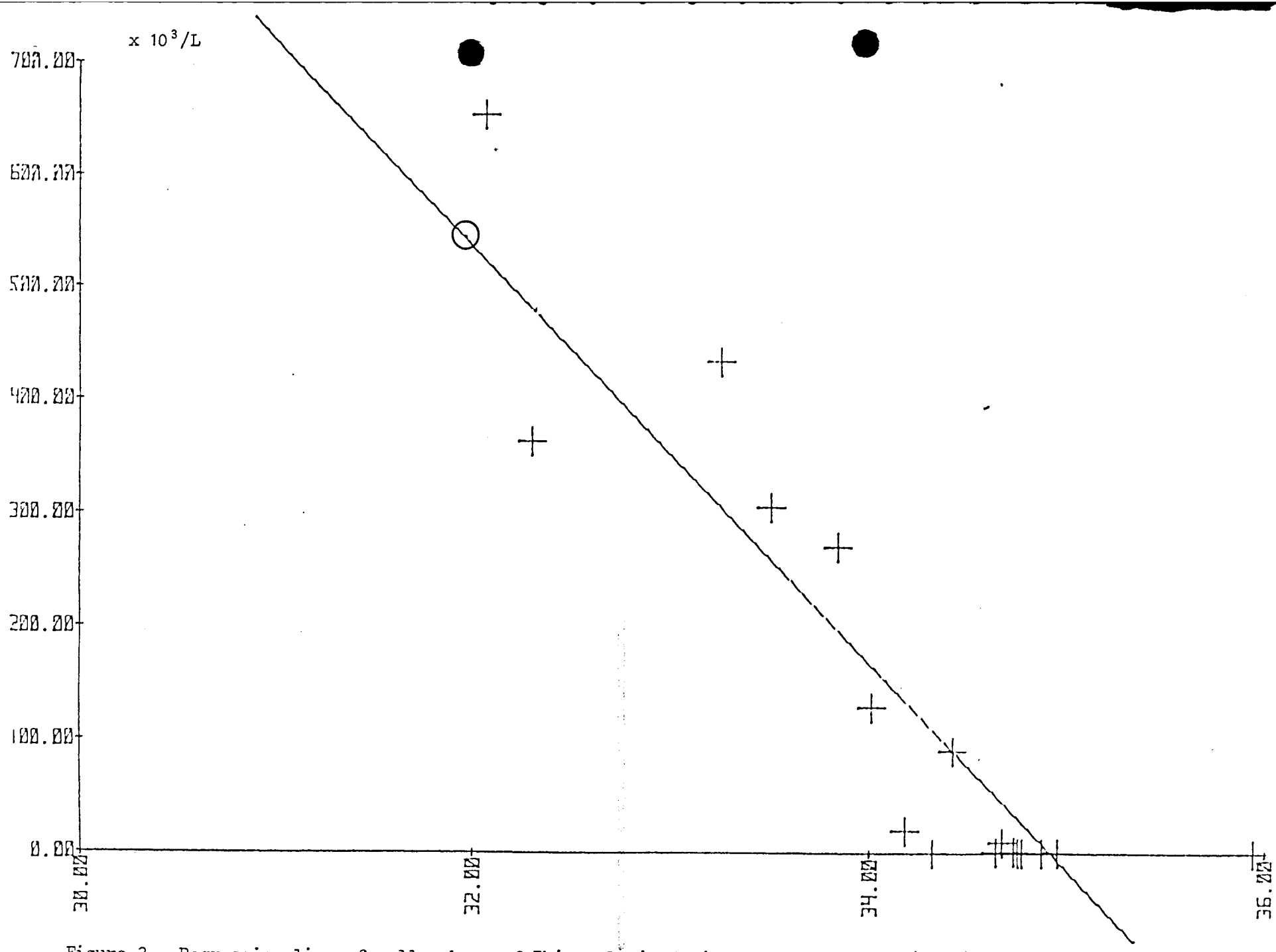

Figure 3 - Regression-line of cellnumbers of Rhizosolenia delicatula to salinity (g/kg) September 1980 r = 0.8

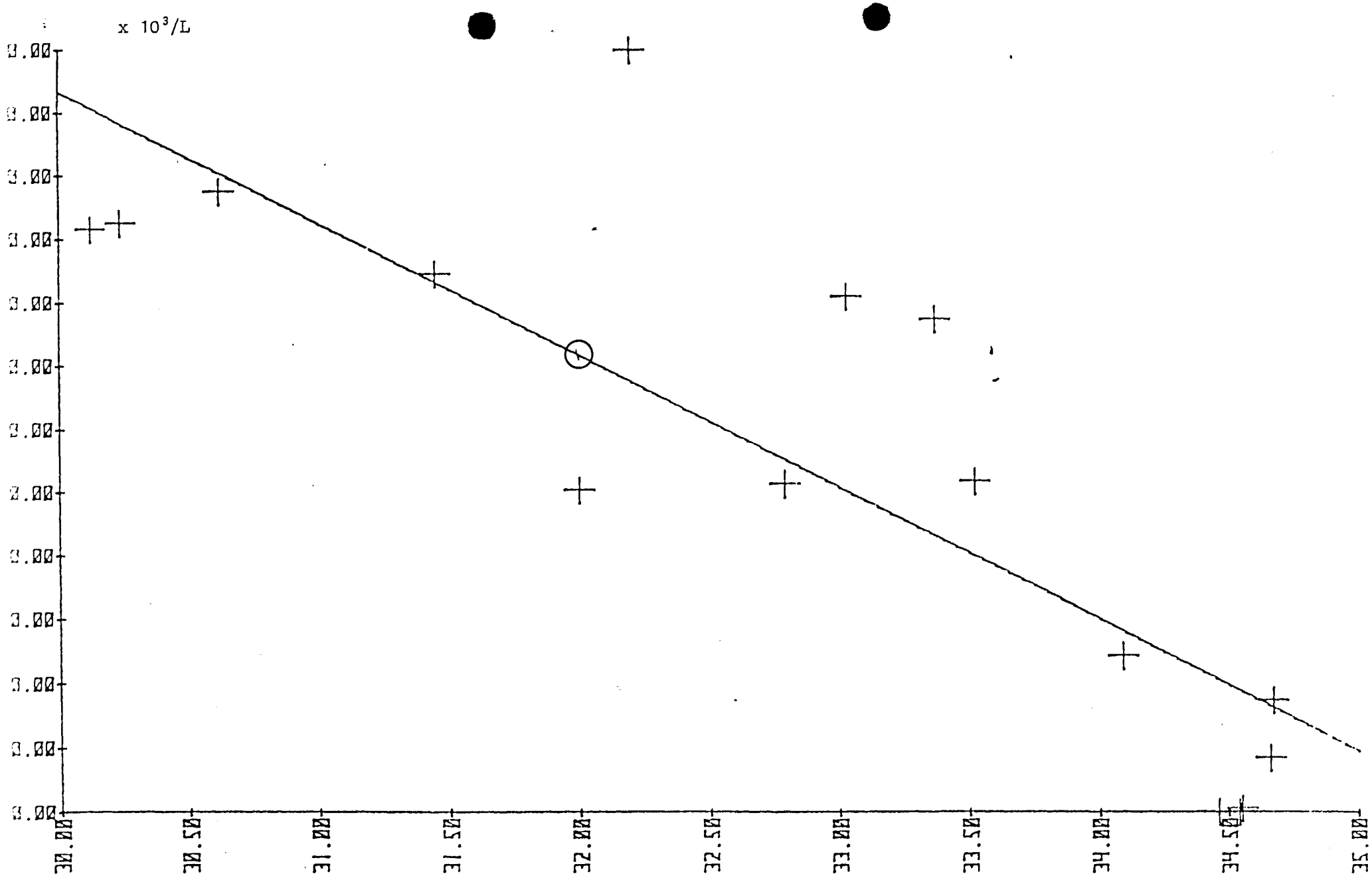

Figure 4 - Regression-line of cellnumbers of Rhizosolenia shrubsolei to salinity (g/kg) August 1978 r = 0.7

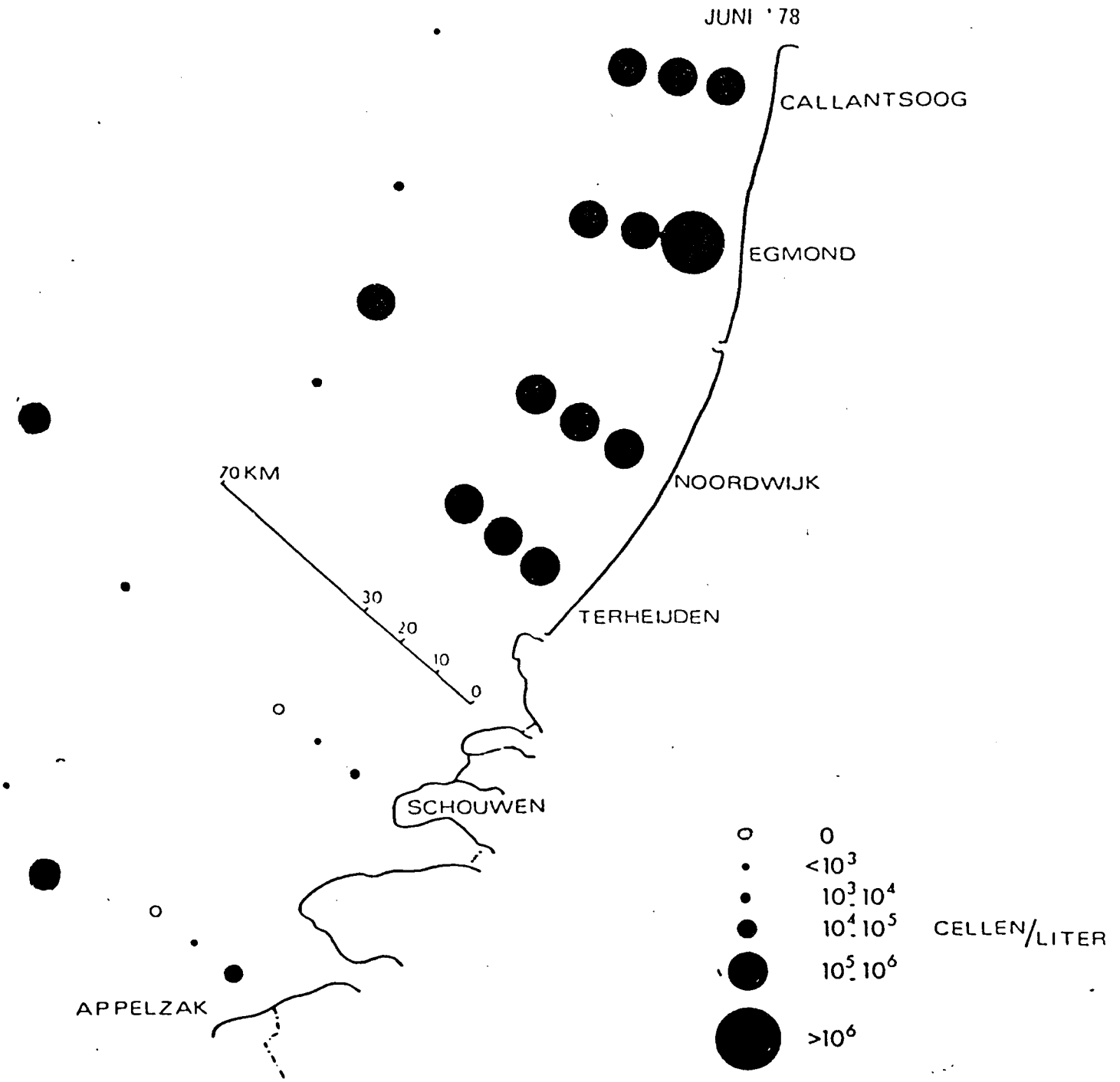

Figure 5 - Distribution of Rhizosolenia delicatula in the Dutch Coastal Area in June 1978.

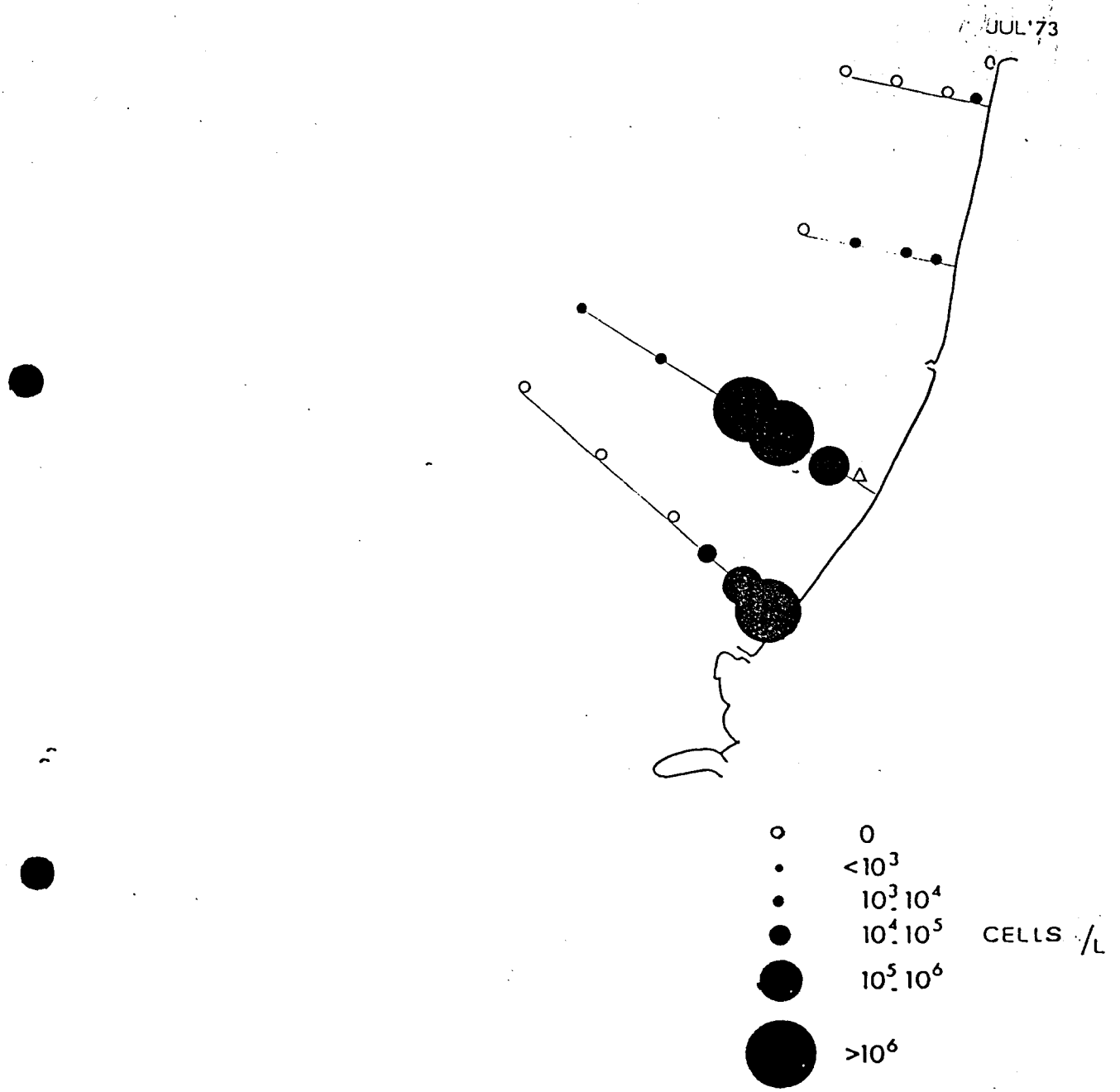

Figure 6 - Distribution of *Skeletonema costatum* in the Dutch coastal area in July 1973.

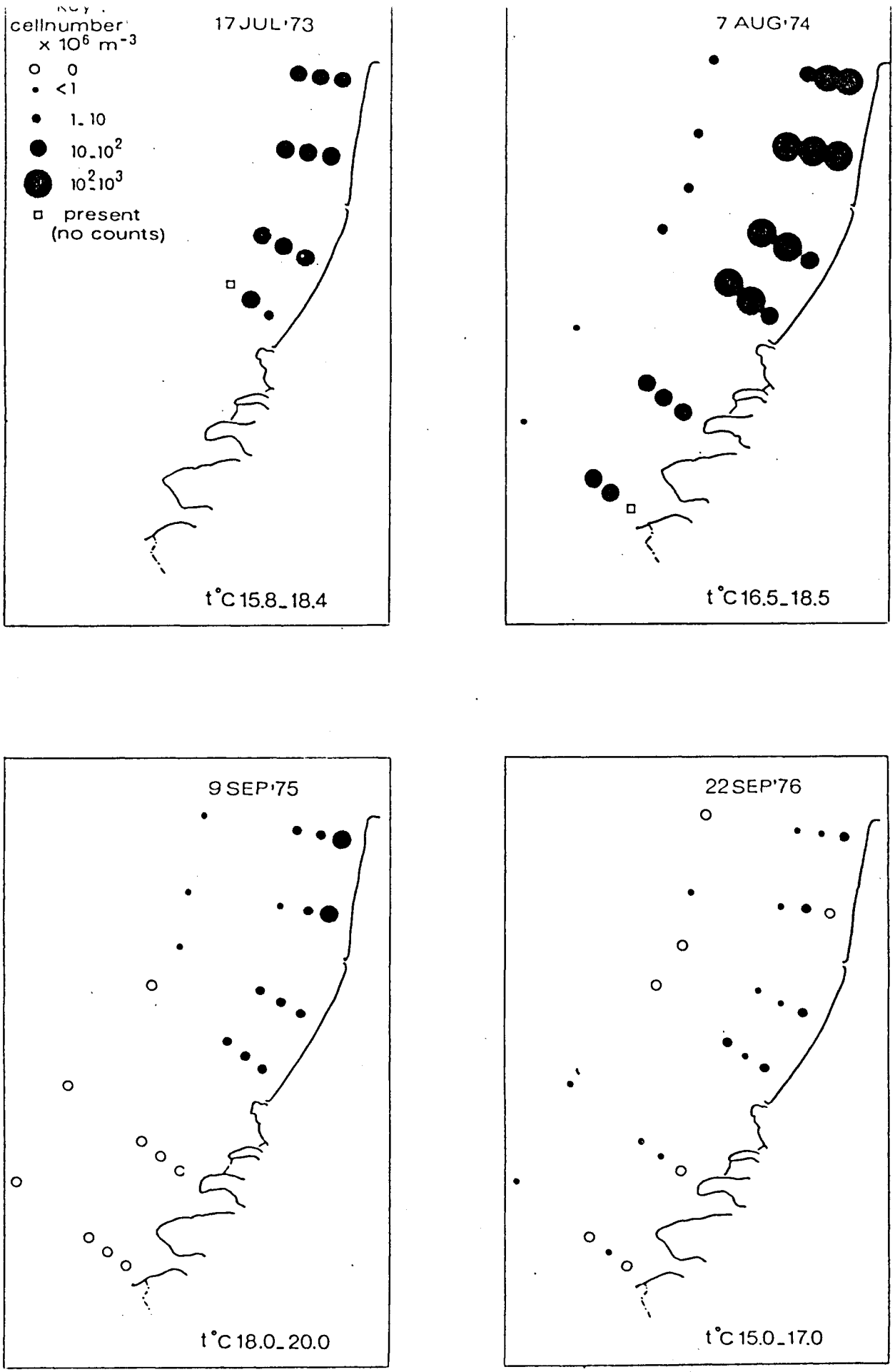

Figure 7 - Distribution of Ceratium fusus in the Dutch Coastal Area in four successive years 1973 - 1976.

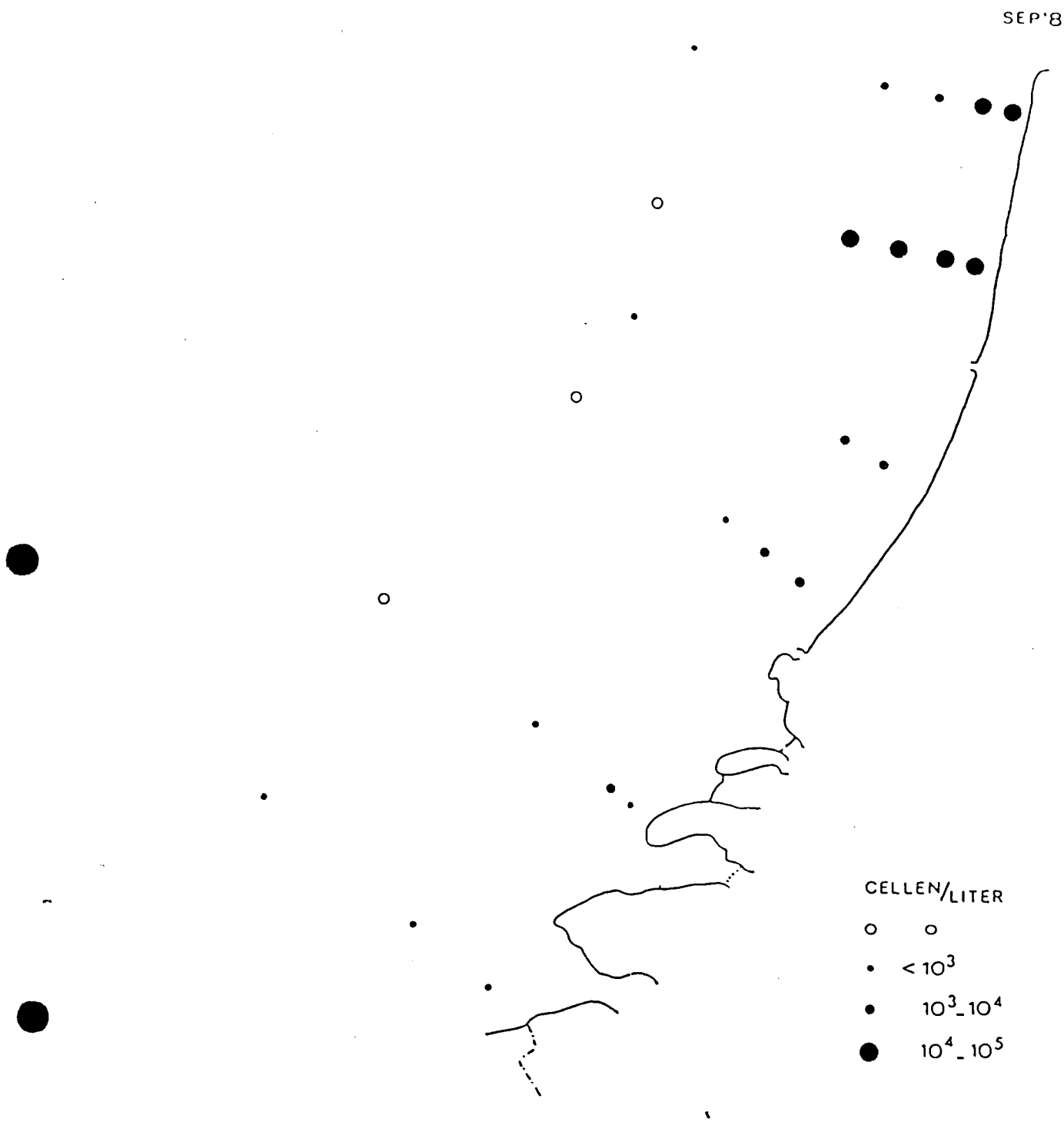

Figure 8 - Distribution of Dinophysis acuminata in the Dutch Coastal Area.