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Seasonal occurrence of *Dinophysis* sp. along the French coast between 1983 and 1987

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Abstract

On the basis of hydrological and biological data collected between 1983 and 1987 along the French coast, and especially in the southern approaches to Brittany, it has been possible to compare different parameters in an attempt to explain the seasonal variations of a toxic dinoflagellate: *Dinophysis* sp. Several species were identified and their seasonal distribution patterns are described. The origin of the blooms, from either coastal endemic or offshore populations, is considered.

Keywords : *Dinophysis*, seasonal distribution, French coast.

Manifestation saisonnière de Dinophysis *sp. sur les côtes françaises entre* 1983 *et* 1987.

Résumé

A partir de données hydrologiques et biologiques obtenues entre 1983 et 1987 sur les côtes françaises, et en particulier en Bretagne Sud, il a été possible de comparer différents paramètres pour tenter d'expliquer les variations saisonnières d'un dinoflagellé toxique: *Dinophysis* sp. Plusieurs espèces ont été identifiées et les modalités de leur distribution sont décrites. Le problème de l'origine de ces efflorescences: populations côtières endémiques ou venant du large, est considéré.

Mots-clés : *Dinophysis*, distribution saisonnière, côtes françaises.

INTRODUCTION

Several outbreaks of Diarrheic Shellfish Poisoning (DSP) have been reported in the European coastal waters since 1961. Initially, about 164 cases of diarrheic intoxications further to the consumption of mussels on the Dutch coastal area were attributed to the effects of a toxic alga, although the phytoplankton observed in the vicinity of mussels beds was considered as non toxic (Kat, 1979). Some years later, in 1976, 1979 and 1981 similar intoxications occurred along the Dutch coast and *Dinophysis acuminata* was suspected as the responsible toxic agent (Kat, 1983). Other DSP outbreaks were reported by Tangen (1983) in the Oslo fjord (1971 and 1974) and, still in Norway, by Dahl and Yndestad (1985) during the 1984-1985 winter season. The responsible species were *D. acuminata*, and *D. acuta*, and many other countries have been confronted with that problem over the past 10 years: Spain, Denmark, France, Germany, still with several species of *Dinophysis* postulated as being the toxic agent (Durant-Clément *et al.*, 1988; Fraga *et al.*, 1984; Fraga and Sanchez, 1985; Lassus *et al.*, 1985 *a* and *b*; Paulmier and Joly, 1985; Kat, pers. comm.). The toxic effects were, on a general basis, more thoroughly studied than the ecological features

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of *Dinophysis* blooms. A large amount of work has been done by Japanese investigators since *Dinophysis fortii* was identified in 1980 as the dinoflagellate responsible for DSP outbreaks which occurred along the Japanese coasts in 1976, 1978 and 1982. (Yasumoto *et al.*, 1978, 1980) and since the diarrheic toxin was isolated and characterized by Murata *et al.* (1982) as a methyl-okadaïc acid. Later on, Kumagai *et al.* (1986) demonstrated that the okadaïc acid was one of the toxic components involved in DSP outbreaks in French, Dutch and Swedish mussels, whereas several toxins (DTX and PTX) had to be suspected in DSP epidemia in Japan (Yasumoto *et al.*, 1984).

Concerning the hydrological parameters correlated with *Dinophysis* blooms, a few studies are available on European species (Kat, 1984; Lassus *et al.*, 1985; Paulmier and Joly, 1985; Dahl and Yndestad, 1985; Durand-Clément *et al.*, 1988). It is assumed that all species studied (*D. acuminata, D. acuta, D. sacculus*) are neither correlated with physicochemicals parameters (e. g. nutrients) nor with any specific temperature/salinity patterns. Some correlations may be observed with low wind speeds, some earlier blooms of diatoms and, especially, the general coastal current systems. Migration occurs over a 24 hours cycle, with a typical diurnal spreading in the upper layers and ETM observations clearly indicate chloroplasts, in *D. acuminata* specimens, evidencing a conventional photosynthetic behaviour. Concerning *D. fortii* ecological features, comprehensive data can be found in Japanese literature (Ozaka, 1985; Igarashi, 1986; Iwasaki, 1986): every year, the distribution of this species along the Japanese coasts clearly indicates an extensive transport by oceanic currents from the west coast (Japan sea) to the north and north east coasts (Pacific ocean), with peak densities in June (seldom in excess of 10^4 cell/dm^3). The highest densities can be observed in small semi-closed bay systems where endemic bottom populations coexist in summer with offshore introduced new populations. *D. fortii* is clearly differentiated from European *Dinophysis* by the need for a temperature/salinity pattern of 10-15 °C and $33.0\text{-}33.5 \times 10^{-3}$ in order to observe a maximum growth.

This particular feature was used by Japanese investigators in a simple predictive mathematical model which has not yet been successfully tested over several years.

Some other predictive parameters are used (Igarashi, 1985; Ozaka, 1985) such as the summer extension of oceanic cold bottom currents along the north east coast (correlated with DSP levels in shellfish) and biological indicators such as other coincident dinoflagellate species (*D. acuminata* and *Gonyaulax spinifera*). However, the role and origin of trace elements as growing factors have not yet been clearly demonstrated in this interesting study: do they stimulate *Dinophysis* growth in eutrophicated bays or in some stratified offshore areas with particular hydrological patterns?

In this paper an attempt is made to analyze these questions from data collected along the French coasts from 1983 to 1987.

METHODS

The Vilaine bay sampling grid was extented from 14 surface stations in 1983 to 17 in 1984, whereas in 1985, 1986 and 1987 a North-South transect of 7 to 8 stations was set up in order to investigate phytoplankton and hydrological parameters at several depths: 1, 3, 5, 10, 20 and 30 m. Samples were collected twice a month or more during summer and monthly otherwise. The measured parameters were: temperature, salinity, dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), silicates and dissolved oxygen. Phytoplankton cells preserved in acetic lugol were identified and counted with an inverted microscope, using the Utermöhl method. In 1986 and 1987, researches were conducted along the southern Brittany coastlines, using oceanographic vessels, and the 10 m surface layer was sampled for phytoplankton and hydrographic parameters (temperature and salinity) at 1, 3, 5 and 10 m depths.

RESULTS

General seasonal distribution pattern

Every year, for the period ranging from 1983 to 1987, the same distribution patterns, such as represented in *figure* 1 (data compiled from a phytoplankton national monitoring program) — are observed on the Atlantic and Channel coasts: maximum concentrations occur in June for southern Brittany and in July/August in Normandy (*fig.* 1). Along the Normandy coasts, and especially in the eastern area of the Seine bay, *Dinophysis* cf *acuminata* was the dominant species, whereas along the Brittany coasts *D. sacculus* and probably some other species (*D. norvegica* and *D. acuminata lachmanii*, (Balech, pers. comm.) coexist during blooms (*fig.* 2). It is rather difficult to suspect a transport by oceanic currents as this is actually the case in Japan for *D. fortii*, as all areas are generally affected at the same time.

Maximum cell concentration thresholds (10^4/dm^3 in the Vilaine bay and more than 10^5 cell/dm^3 in Antifer harbour) and relative DSP levels in farmed shellfish were the only obvious factors allowing any comparison to be made from year to year between all contaminated areas. No case of *Dinophysis* discoloured water was reported, even for concentrations in excess of 10^5 cell/dm^3, as this species was never reported as the dominant species among dinoflagellate communities.

Several "critical areas" are nevertheless noticed: the bay of Douarnenez and the Vilaine bay for southern Brittany, and the Antifer harbour for Normandy,

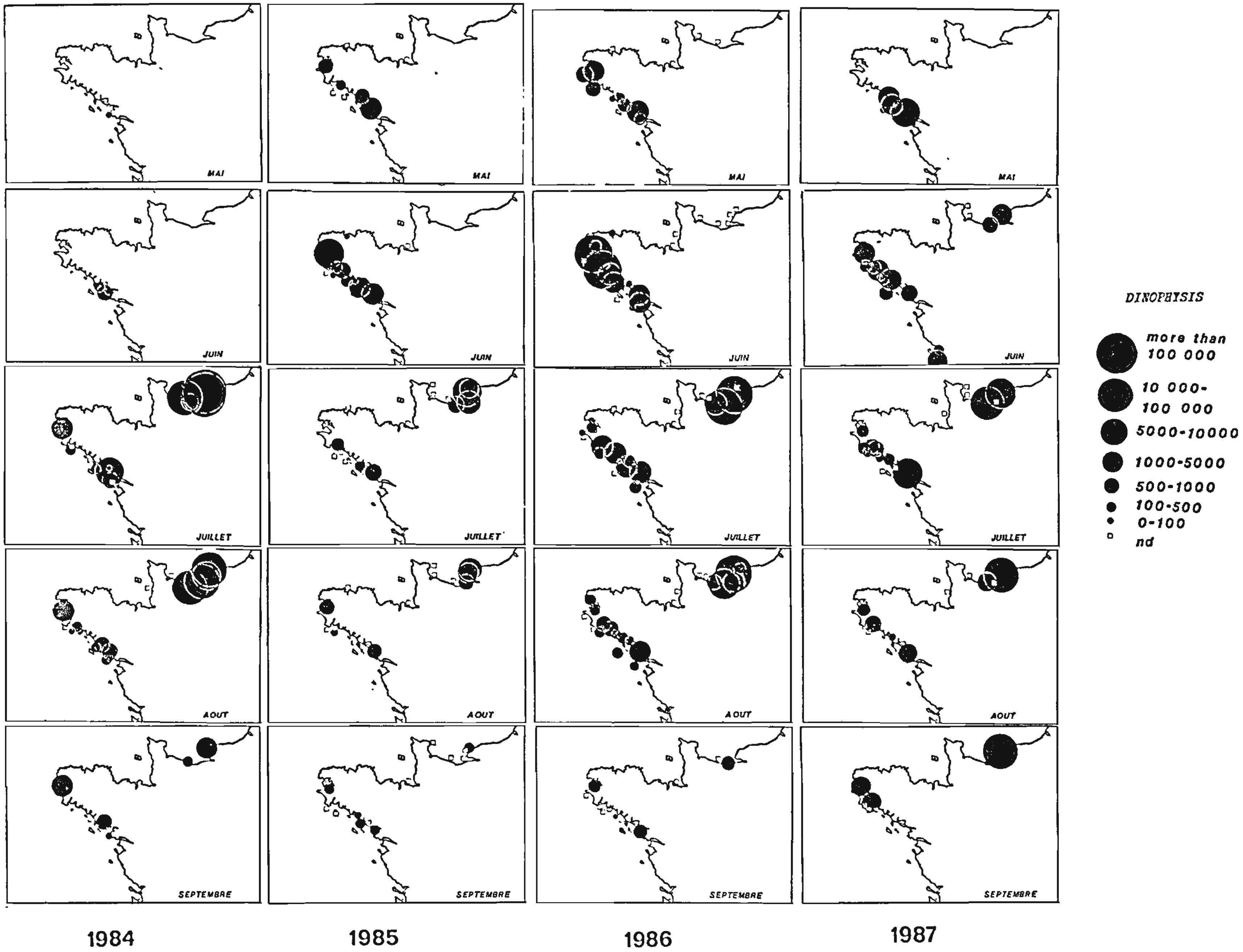

Figure 1. — Monthly distribution of *D. sacculus* and *D. acuminata* along the French coast from 1983 to 1987; for each month, max. surface values of all concentrations (cell/dm^3) have been expressed (nd = none detected).

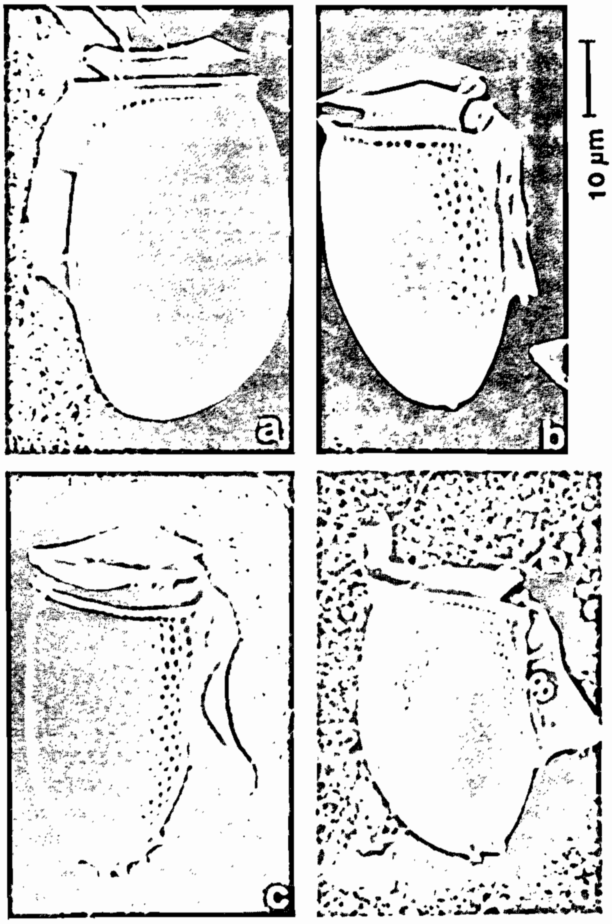

Figure 2. — *Dinophysis* cf *acuminata* from the Normandy coast (Antifer), (*a*): lateral view, (*b*): *Dinophysis sacculus* from Vilaine bay, (*c*): *D. sacculus* from Douarnenez bay collected in 1986, (*d*): *D.* cf. *norvegica* collected in 1987 in Vilaine bay.

where the highest concentrations occurred, and where residual populations were still observed in late summer. On an other hand, in 1987, new areas were contaminated: the Aiguillon bay on the Atlantic coast, and the western Mediterranean coast.

Distribution along the southern Brittany coast

During an oceanographic survey cruise conducted in June 1986, samples of water in the top 10 m layer were analysed for phytoplankton in a study area comprised between Concarneau and île d'Yeu (*fig.* 3). The highest densities were observed down to 3 m depth in a highly stratified area situated in the south of river Loire estuary mouth. Despite thermal stratification was more important than the salinity gradient, significant (99% confidence limits) correlations of 0.66 and 0.57 respectively were found between the log of *Dinophysis* concentrations at 3 and 5 m depths and the difference of sea-water density from the surface down to 10 m depth. In June 1987, the general patterns of *Dinophysis* distribution were different: concentrations were low and patchy, higher in the same stratified area but generally lower than in 1986. The result was that no correlation could be established with sea-water density, and despite a large DSP epidemia in May 1987 in the Aiguillon bay and neighbouring areas of Charentes-Maritimes (about 2000 cases of intoxication), the mean level of shellfish contamination for the whole southern Brittany coast proved to be low in June/July, and did not lead to a severe ban of shellfish marketing.

Vilaine Bay

Apart from the general summer distribution pattern of *Dinophysis* sp. along the southern Brittany coasts, a "critical area" was studied between 1983 and 1987: the Vilaine bay successively suffered from extensive DSP epidemias in mussels in 1978, 1981, 1983 and 1986. *Dinophysis* was described as the toxic agent for the first time in 1983 (Alzieu *et al.*, 1983; Lassus *et al.*, 1985; Le Baut *et al.*, 1985), and sporadic contamination also occurred in 1985 and 1987. This area is typically stratified in summer (Langlois, 1984) and three sub-areas have been delineated by Mer (1986), using the cluster analysis to establish comparisons between the sampling stations, e. g.: an homogeneous area with dominance of Vilaine estuarine waters, an oceanic sub-area in the southern part of the bay, and an intermediate zone (*fig.* 4). The analysis of the data collected in 1983-1984 showed that *Dinophysis* blooms were detected after the decay of diatom discoloured waters (peak in June) but no relation could be established between *Dinophysis* concentrations and temperature/salinity patterns (Lassus *et al.*, 1985). The hypothesis of stimulating factors released after the decay of diatoms was not verified during the 1986 *Dinophysis* bloom, as no diatom discoloured water was observed. In 1985 the *Dinophysis sacculus* vertical distribution pattern revealed a summer maximum concentration layer situated between 3 and 5 m water depth (*table* 1) similarly to the observations made later on in this area, and in offshore waters during the 1986 cruise. Water column stability probably has an effect on *Dinophysis* sub-surface concentrations as the decreasing rates observed in late June 1985 (*fig.* 5) actually coincided with strong west winds. A more comprehensive study of the vertical distribution pattern was conducted between April and September 1986 (*fig.* 6): maximum concentrations were confirmed during the period comprised between June and July. The south part of the bay is first contamined in April, whereas in September the residual populations are confined in the inner area of the bay. It is also interesting to note that the highest *Dinophysis* concentrations (in excess of 5000 cell/dm^3) are often situated close to the bottom in the shallow waters of the bay. In that later case, it can be postulated that such relatively high concentrations result from physical accumulation processes rather than caused by an old

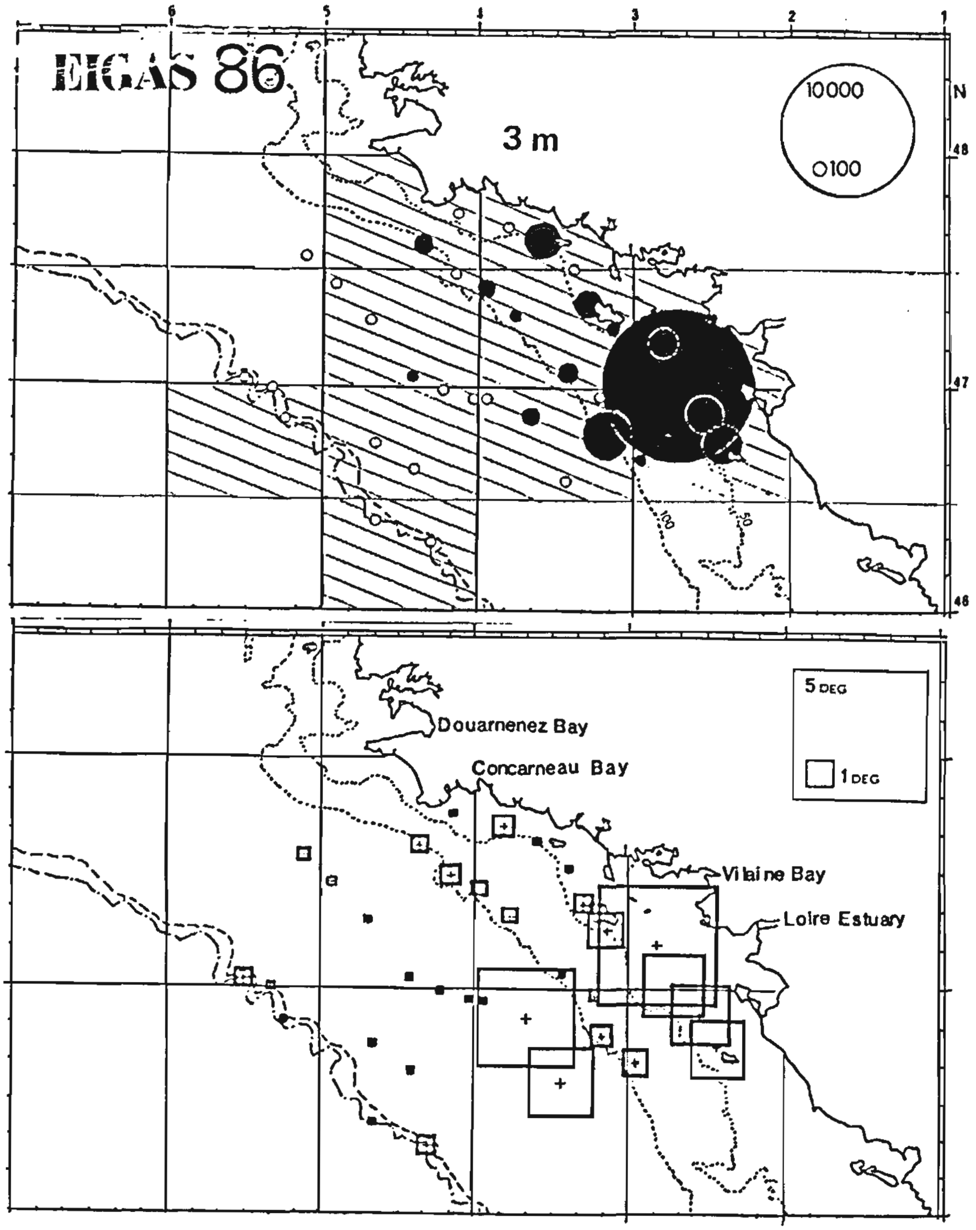

Figure 3. — Upper: *Dinophysis* concentrations (cell/dm^3) in June 1986 (all species counted: *D. sacculus*, *D. rotundata* and *D. skagi*) at 3 m depth off southern Brittany (open circles indicate none detected). Lower: correlated thermal stratification in the same area (the squares are proportional to the temperature difference between the 1 and 10 m layers. The cruise is referred to as Eigas 86.

stage population sinking to the bottom. Such accumulation processes can be partly explained by a cyclonic current system in the inner part of the bay (De Nadaillac and Breton, 1985). From the data collected between 1983 and 1986 no clear evidence could be found as to a possible link either with hydrological parameters, or with biological indicators such as *Prorocentrum micans*. It only appeared that no correlation could be established between log of *Dinophysis* concentrations and temperature, salinity or nitrates, and that a possible negative correlation with phosphates was found in 1983 and 1986, when peak *Dinophysis* blooms were observed. A correlation with *Prorocentrum* blooms was only found in 1983 and, apparently, could not be used as a "predictive parameter" for the next years.

A last point was studied: the influence of water stability (*) on *Dinophysis* concentrations. From data related to the 1983 and 1986 blooms, it appears (*fig.* 7) that the increases in stability index correspond to increasing *Dinophysis* concentrations, sometimes with a short time lag.

(*) Expressed as $E = 10^{-3}\ dS/dZ$, with dS: difference between surface and bottom density, and dZ: depth.

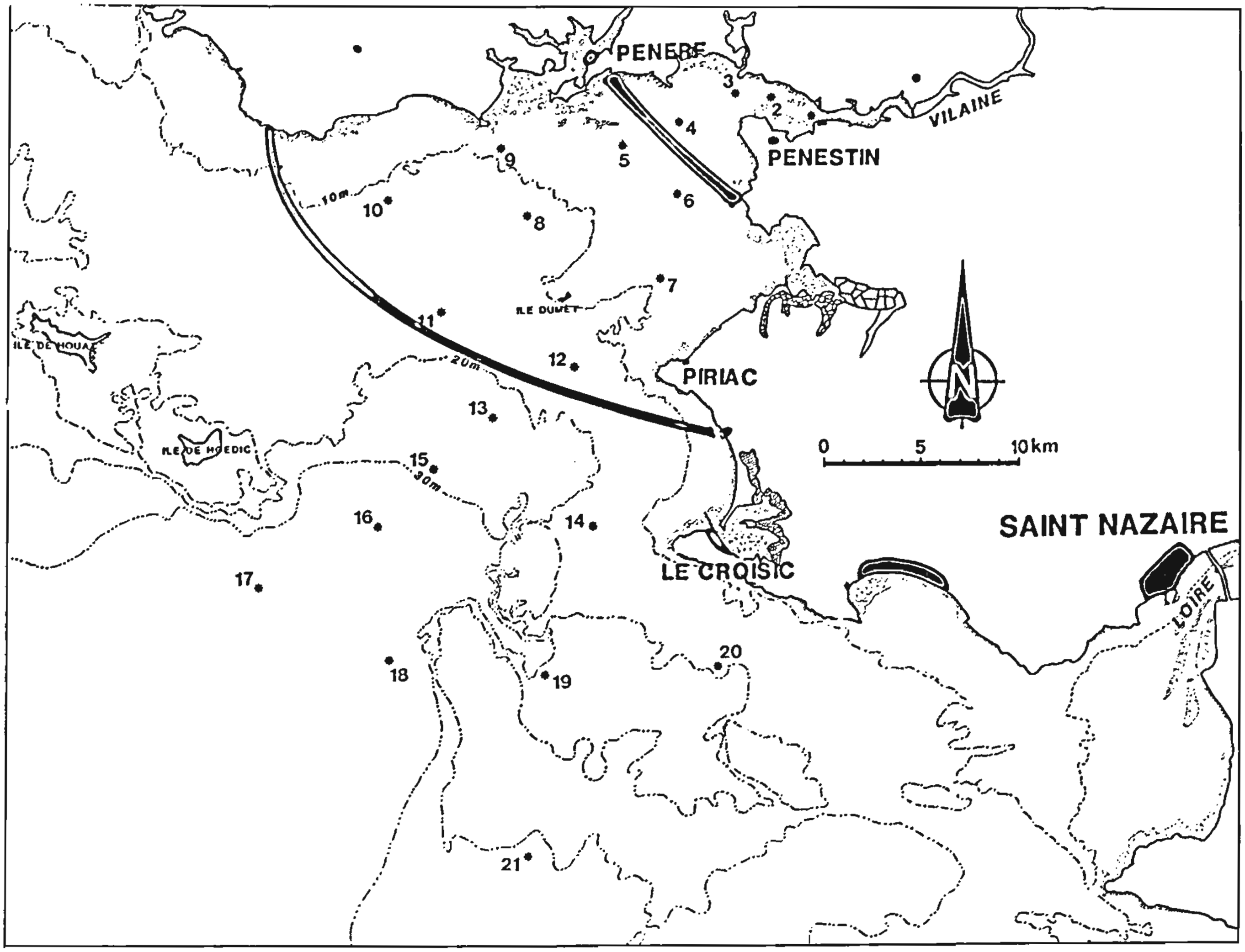

Figure 4. — Vilaine bay, sampling grid and sub areas as determined by Mer (1976) from a cluster analysis of hydrological parameters and chlorophyll at each station. Stations 1-4: estuarine zone; stations 5-12: intermediate zone; stations 13-21: oceanic zone.

Table 1. — Arithmetic mean ($\bar{x}$) of *Dinophysis* concentrations at different depths during summer 1985 for all sampled stations n = number of cell counts, $v\%$ = variation of standard deviation ($S/\bar{x}$).

Depths	n	$\bar{x}$	$v\%$
0 m	36	593	117
1 m	109	605	110
3 m	90	1 239	157
5 m	88	1 063	147
10 m	57	435	179
20 m	24	229	105
30 m	15	104	302

DISCUSSION

Despite the fact several species of toxic *Dinophysis* produce DSP outbreaks almost every year along the French coasts, such bloom events cannot be assimilated to "red tides" or "exceptionnal blooms" as the maximum concentrations seldom exceed 5×10^3 cell/dm^3. This feature, makes that it is not easy to find an hydrological parameter which could be used as a predictive or discriminant factor.

Nevertheless, on the basis of the data collected over the period ranging from 1983 through 1987 during field observations (culture assays of *Dinophysis* revealed unsuccessful, Durand-Clément *et al.*, 1988), several points can be outlined. First, despite the important yearly amount of $N-NO_3$ discharged in certain areas such as the Vilaine bay (11 000 t/year), no evidence of any relationship with summer *Dinophysis* blooms can be demonstrated. Now, the general pattern of *Dinophysis* distribution along the French coasts reveals different seasonal peak values, depending on the dominant species: *D. acuminata* in July along the

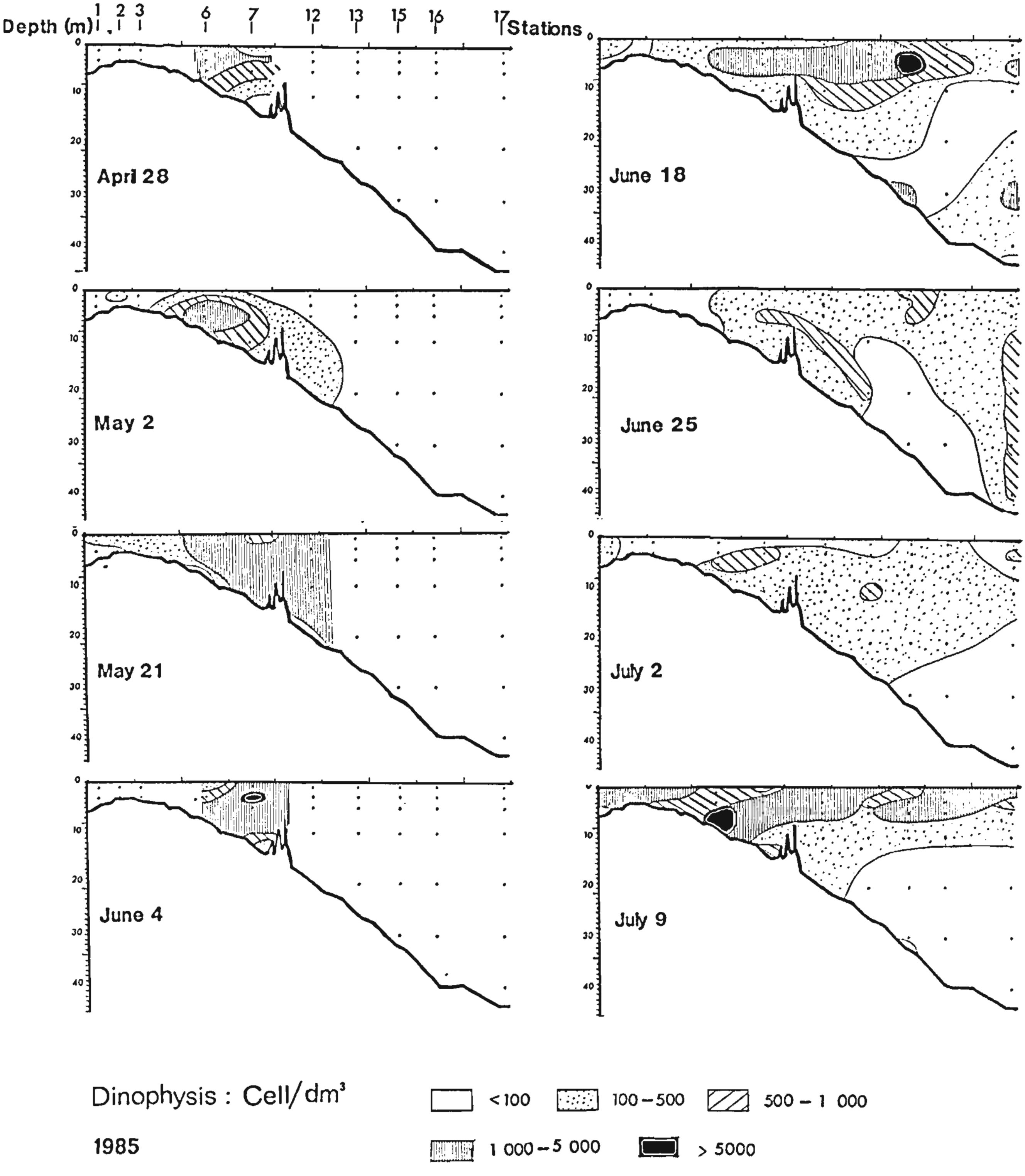

Figure 5. — Vertical distribution of *Dinophysis sacculus* in Vilaine bay in June and July 1985.

Channel coast, *D. sacculus* and other species in June along the Atlantic coasts. If transport of offshore populations by coastal currents to inshore semi-closed systems most probably occurs, no wide dissemination of these species due to oceanic currents can be exploited, as this is the case for *D. fortii* distribution patterns in Japanese waters. As in offshore statified areas, a correlation with the water stability index can

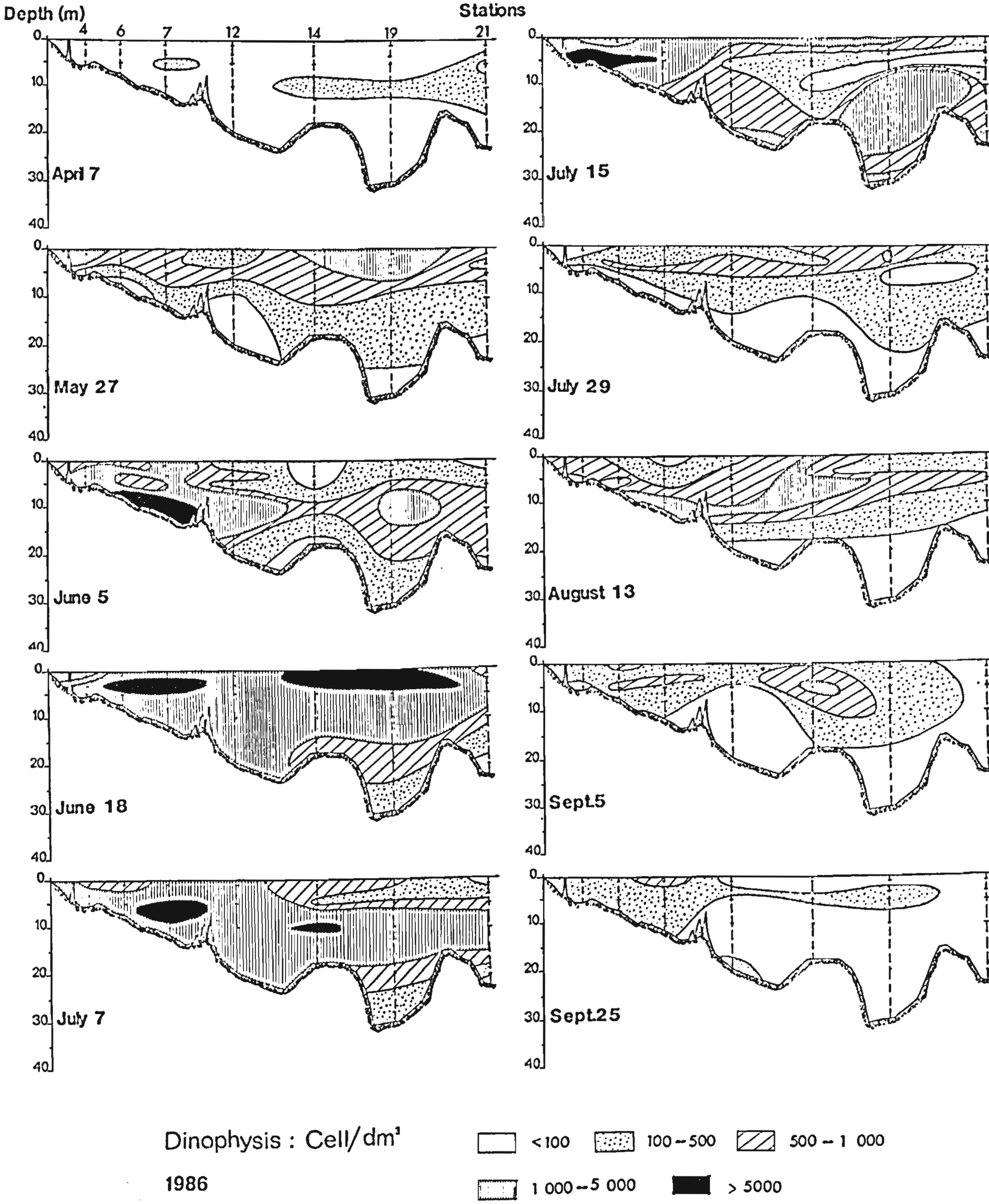

Figure 6. — Vertical distribution of *Dinophysis sacculus* in Vilaine bay from April to September 1986.

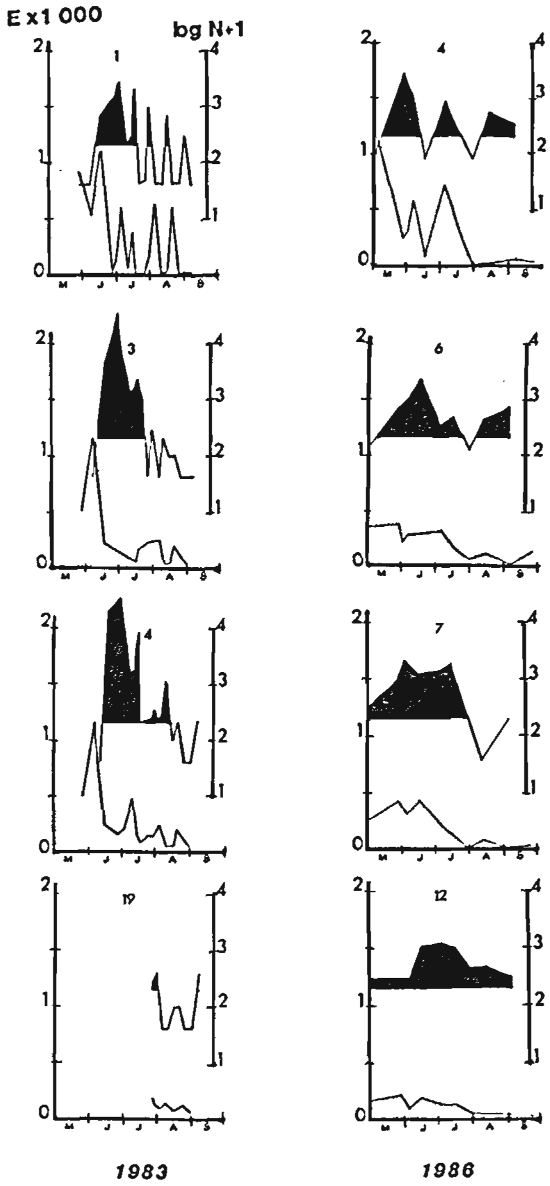

Figure 7. – Comparative evolution of the log of *Dinophysis* concentration and of stability index E (*cf.* text) in Vilaine bay during the summers of 1983 and 1986. Dark areas correspond to cell concentrations exceeding 200 cell/dm^3. Both estuarine (1, 3, 4 in 1983; 4, 6, 7 in 1986) and oceanic (19 in 1983; 12 in 1986) stations are investigated.

be observed in bay systems (*fig.* 7) during the years of highest blooms. It is obvious that if such a factor promotes the physical sub-surface accumulation of *Dinophysis*, other factors most probably behave as "initiating factors".Phosphates are postulated as the limiting factor for phytoplankton production in the Vilaine bay (Clément *et al.*, 1988) an could be related to extensive blooms of *Dinophysis* in such eco-systems, but if summer coastal populations originate from offshore populations, other triggering factors have to be studied in critical stratified areas: the high *Dinophysis* concentrations observed in 1986 in the south part of river Loire estuary mouth for one third constituted of dividing cells. Finally, a possible biological indicator such as *Prorocentum micans* cannot be used as a predictive factor for a continuous monitoring survey.

CONCLUSION

From the hydrological and biological data collected in the Vilaine bay as well as off the coasts of Southern Brittany between 1983 and 1987, it appears that blooms of *Dinophysis* sp. are essentially related to physical offshore processes like thermal stratification and water colum stability, and depend on general coastal current system. Some secondary processes may act as promoting factors in bays and estuaries, but nutrients levels as triggering factors are unprobable. The absence of any significant correlation with simple parameters (temperature, salinity, nitrates) constitutes the real difficulty for developing a predictive model, and further information is needed as to the behaviour of this dinoflagellate: winter crop, migration, effect of grazing by zooplankton.

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