Toxic Phytoplankton Blooms in the Sea
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DO *Dinophysis* spp. COME FROM THE "OPEN SEA" ALONG THE FRENCH ATLANTIC COAST?

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ABSTRACT

A study was conducted with the aim of showing which environmental conditions promote an increase in *Dinophysis* cells in a land-locked embayment with shellfish installations. From May 1989 to September 1991, vertical profiles were taken of temperature, salinity, nutrients and chlorophyll-a, and counts of phytoplankton species composition were made during late spring and summer. In the strait separating this area from the open sea, residual tidal currents are from offshore to nearshore. Significant thermocline (Δ t ≈ 5°C) and stable stratification of the water column were required for *Dinophysis* to exceed 1000 cells L^{-1}. *Dinophysis* spp. were more abundant in the "thermocline layer", scarce below this layer and absent near the bottom. These stratified conditions occurred first in the open sea. Denser *Dinophysis* populations were then carried through the strait from offshore to nearshore waters by tidal currents. Growth of *Dinophysis* occurred in nutrient-impoverished waters after the spring diatom bloom, and was not correlated with the measured nutrient concentrations (nutrient inputs from agricultural and domestic origins appeared not to promote growth directly). The maximum apparent *in situ* growth rate was low, 0.25 division day^{-1}, a rate similar to that of other dinoflagellates. In late spring and early summer, dinoflagellate importance relative to diatoms increased in offshore surface waters, as a result of both cell division and diatom sinking. The importance of the nano- and the pico-size classes also increased relative to the micro-size class. Six *Dinophysis* species have been recorded; *D. sacculus, D. acuminata* and *D. rotundata* were the most abundant.

INTRODUCTION

There is provocative evidence of recent, significant increases in algal biomass and production, as well as changes in community structure and species distribution, in some inshore waters worldwide [1, 17]. In French coastal waters, three dinoflagellates now represent a serious potential nuisance or health hazard [2]. Among them, several species of the genus *Dinophysis* seem to have recently changed from low-density occurrence [5] to cell densities high enough to warrant monitoring in programs related to public health [3]. Moreover, occurrences of *Dinophysis* at noxious levels have spread from Brittany, where they were first recorded in 1983, both northward and southward, as well as into the Mediterranean Sea [4, 12]. *Dinophysis* spp. always occur at low densities (not more than a few thousand cells L^{-1}) even in summer [11]. On the other hand, considerable increases in cell density have been recorded in both offshore and coastal Atlantic waters [13]. In contrast, *D. fortii* populations in Japanese waters first develop offshore and then are introduced by currents into nearshore areas where it renders farmed shellfish toxic [7].

An investigation was thus started in May 1989 on the French Atlantic coast, in the vicinity of La Rochelle, with the aims: (i) to point out what environmental conditions lead to increases in *Dinophysis;* (ii) to investigate whether nutrient input of agricultural origin favours growth; and (iii) to determine where increased cell densities first appear.

STUDY AREA AND METHODS

The area investigated (Fig. 1) is divided into three parts: (i) two land-locked subareas (pertuis Breton; bassin Marennes-Oléron) with important shellfish industries; (ii) an intermediate strait (pertuis d'Antioche); and (iii) the open ocean up to the 100 m isobath. Coastal waters are enriched by agricultural runoff contributed by two rivers. In the strait, tidal currents transfer water from the open sea to the coast, while the displaced water exits through another strait (pertuis de Maumusson) after bathing shellfish installations. The sampling strategy was modified yearly in order to favour spatial distribution and the temporal variations. In May 1989, 24 stations, from the coast to the open sea (-40 m), were visited four times. During May-June 1990, only 9 of the 24 stations were visited eight times, and one station in the strait was monitored continuously for 48 hours. In 1991, from late April to late September, 11 vertical profiles were taken at six stations located from the coast to the open sea (-100 m). In addition, a drogue was deployed just outside the strait and followed for three days, and "METEOSAT" satellite images analyzed to check whether "true" open-sea circulation patterns characterized the most offshore stations. In the continuous vertical profile, temperature, salinity (CTD probe) and irradiance (Licor quanta meter) were recorded before discrete sampling (Niskin bottle) for nutrients, chlorophyll-a and counts of phytoplankton abundance using Utermöhl's method.

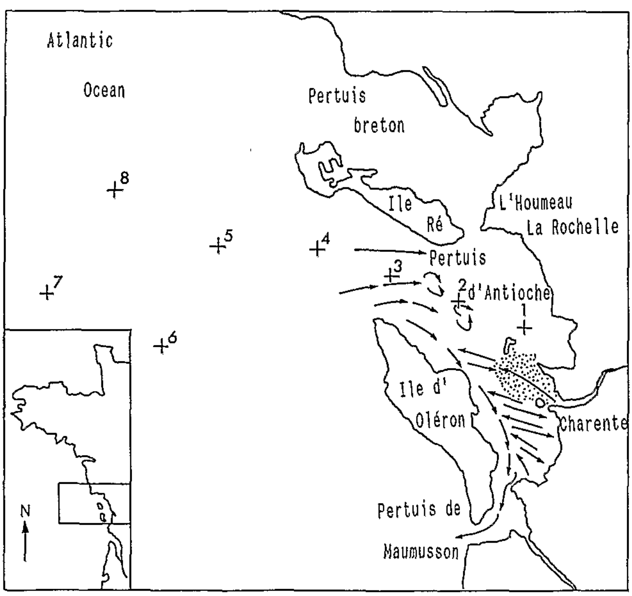

FIG. 1: Study area and sampling stations (+); arrows indicate tidal and residual currents; dotted area, nutrient-rich plume of River Charente.

RESULTS AND DISCUSSION

Highest *Dinophysis* densities were recorded in 1990. Furthermore, over the three-year period the rate of cell increase was always positively related to stable stratification of the water column (Fig. 2). Like many phytoflagellates which accumulate at the thermocline [10, 15, 16], *Dinophysis* spp. were generally more abundant in the water layer limited by the upper and lower values of the thermocline (Fig. 3). They were scarce below this layer and absent near the bottom, as in the case of *D. fortii* observed in Japan [8]. Since the thermal stratification became established first in offshore waters, growth occurred in the open sea before it did in the landlocked areas: again with the same sequence as for *D. fortii* off Japan [7, 9]. Flood-tide currents carried *Dinophysis* cells from offshore to inshore waters, whereas ebb-tide currents advected some cells back out (Figs. 1, 4).

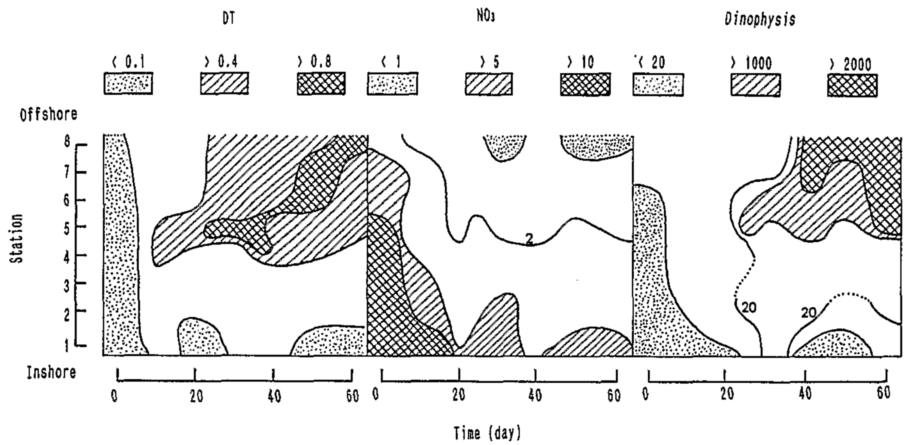

Fig. 2: Temperature gradient (°C m^{-1}) within "thermocline layer", NO_3 concentration (µM) in upper 15 m and *Dinophysis* numbers (cells L^{-1}) from 22 April to 19 June 1990 along nearshore (station 1) to offshore (station 7) gradients.

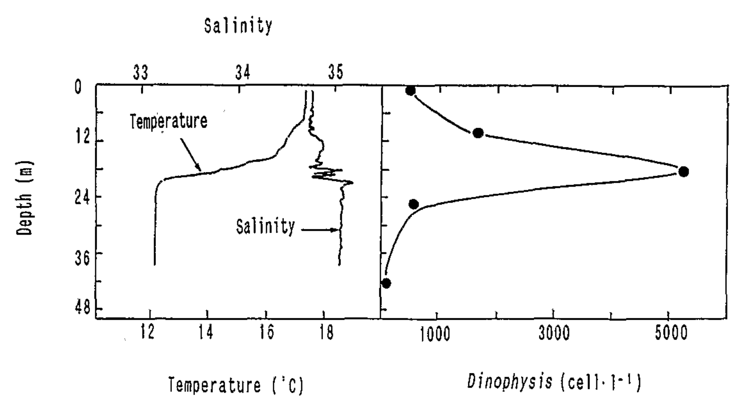

FIG. 3: Variation with depth in temperature, salinity and *Dinophysis* spp. density off the strait of Antioche on 19 June 1990.

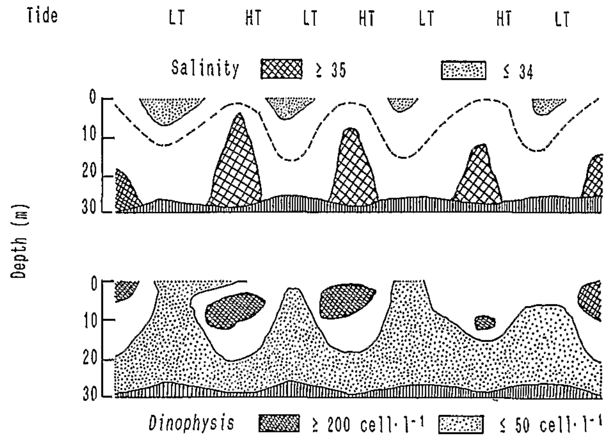

FIG. 4: Evolution, according to tidal salinity cycle, of *Dinophysis* spp. cell density in the "strait of Antioche" on 22-24 May 1990 (48-h continuously monitored station). Flood-tide currents bring high-salinity, offshore water towards the coast; ebb-tide currents return less saline nearshore waters offshore.

Dinophysis spp. growth, which occurred in water nutrient impoverished by previous phytoplankton growth (e.g. NO_3, Fig. 2), was not correlated with any change in nutrient concentrations. Moreover, since no experimental evidence is yet available worldwide, except for *D. rotundata* reported to be phagotrophic [6], it remains unknown whether growth of *Dinophysis* spp. is related to uptake of organic or inorganic nutrients. It is clear from our data (Fig. 2) that nutrient input from agricultural and domestic origins does not directly favor inshore *Dinophysis* growth. Since increased cell densities of *Dinophysis* cf. *acuminata* in the Seine plume, however, parallel increased nitrate concentrations [14], an indirect stimulation accompanying inorganic nutrient enrichment is a possibility.

Dinophysis spp. growth was slow, 0.25 net division day^{-1} during its fastest growth period (Fig. 5), similar to that of other dinoflagellates. During late spring and summer, the importance of dinoflagellates relative to diatoms increased, finally representing 80% of the microphytoplankton in the upper 15 m in offshore waters. This increased relative importance resulted both from their growth and the sedimentation of diatoms; the maximum chlorophyll-a content was recorded deeper as the season progressed. Both the nano- (<20 µm) and picophytoplankton (<3 µm) size classes relative to the micro-size class also increased in the upper layer, finally representing 80% and 40% of total chlorophyll-a content, respectively (Fig. 5). Six *Dinophysis* species were recorded, none of which was present in all samples (detection limit: 7 cells L^{-1}). *D. sacculus* and *D. acuminata* were the most abundant and frequent species, *D. rotundata* occurred similarly, but at markedly lower densities, and *D. acuta*, *D. tripos* and *D. caudata* were scarce and episodic.

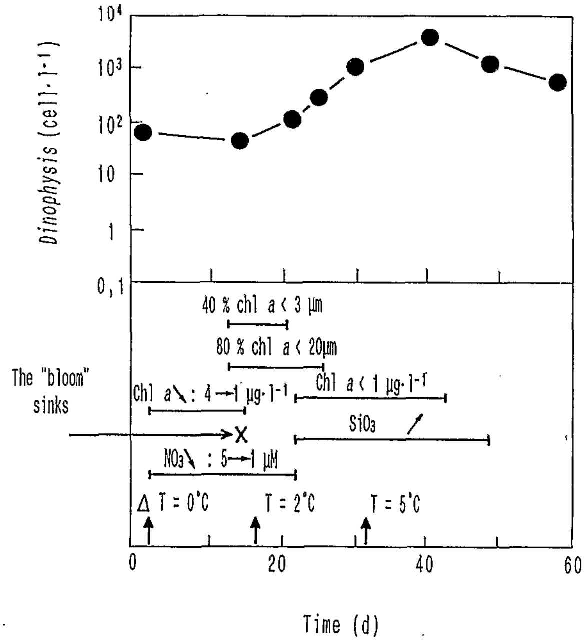

FIG. 5: Summary of changes in main environmental conditions related to *Dinophysis* spp. growth in coastal waters off La Rochelle in 1990. Ordinate value: T_0 = 20 April; T_{60} = 20 June. *Dinophysis* growth started when thermal stratification had established, Spring-diatom bloom had ended, the cells were sinking (chlorophyll-*a* maximum deep), the nutrient reservoir was greatly impoverished, and relative importance of <3 µm and <20 µm size fractions was increasing. Apparent *in situ* growth rate was 0.25 division d^{-1}.

CONCLUSION

Within the "Bay of Biscay" system, the area investigated is but a small component. To the extent that satellite images and discrete measurements (temperature, chlorophyll-a) confirm that farthest offshore stations were truly located in offshore waters and representative of them, it is clear that *Dinophysis* comes from the open sea in this part of the French Atlantic coast. It is also clear that nutrients from land origin do not promote *Dinophysis* growth.

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REFERENCES

1. D.M. Anderson in: Red Tides: Biology, Environmental Science, and Toxicology, T. Okaichi, D.M. Anderson and T. Nemoto, eds. (Elsevier, New York, 1989), pp. 11-16.

2. C. Belin, J.-P. Berthomé and P. Lassus, Hydroécol. Appl. 1/2, 3-17 (1989).
3. J.P. Berthome and P. Lassus in: Actes du colloque pluridisciplinaire franco-japonais océanographie, Les aménagements côtiers et la gestion du littoral, Marseille 16-21 septembre 1985, H.J. Ceccaldi and G. Champalbert, eds. (Coll. fr-japon. Océanogr., Marseille 2, 1987), pp. 37-50.
4. J.P. Berthomé, C. Belin, P. Lassus and C. Le Baut, Equinoxe 6, 10-17 (1986).
5. J.R. Grall, Trav. Stat. biol. Roscoff 23, 19-22 (1976).
6. P.J. Hansen, Mar. Ecol. Prog. Ser. 69, 201-204 (1991).
7. T. Igarashi in: Biology and Ecology of Shellfish Poisoning Plankton, Y. Fukuyo, ed., Bull. Jap. Assoc. Sci. Fish 56, 71-81 (1985).
8. T. Igarashi, Bull. Tohoku Reg. Fish. Res. Lab. 48, 137-144 (1986).
9. J. Iwasaki, Bull. Tohoku Reg. Fish. Res. Lab. 48, 125-136 (1986).
10. K.J. Jones and R.J. Gowen, Estuar. Coast Shell Sci. 30, 557-567 (1990).
11. P. Lassus and C. Marcaillou-Le Baut in: Nuisances et intoxications causées en France par le phytoplankton et les "efflorescences" marines, A. Sournia *et al.*, eds. (1991), pp. 11-16.
12. P. Lassus, C. Marcaillou-Le Baut and P. Maggi, Rapp. P.-v. Réun. Cons. int. Explore. mer, 187, 84-82 (1987).
13. P. Lassus, P. Truquet, L. Le Dean and M. Bardouil, Rapport IFREMER-DERO/89-08-MR, 69 pp. (1989).
14. P. Lassus F. Proniewski, P. Maggi, P. Truquet and M. Bardouil in: Toxic Phytoplankton Blooms In the Sea, T. Smayda and Y. Shimizu, eds. (Elsevier, New York, 1992).
15. R. Margalef, Oceanologica Acta 1, 493-509 (1978).
16. R. Raine, T. McMahon, J. O'Mahony, M. Moloney and C. Roden, Estuar. Ecotoxicology, pp. 19-28 (1990).
17. T.J. Smayda in: Toxic Marine Phytoplankton, E. Granéli et al., eds. (Elsevier, New York, 1990) pp. 29-40.