Notes

The diurnal vertical migrations of *Dinophysis acuminata* in an outdoor tank at Antifer (Normandy, France)

Patrick Lassus [(1)], Frédéric Proniewski [(2)], Cyrille Pigeon [(2)], Laurent Veret [(2)], Loïc Le Déan [(1)], Michèle Bardouil [(1)] and Philippe Truquet [(1)]

[(1)] *IFREMER, rue de l'île d'Yeu, BP 1049, 44037 Nantes Cedex 01, France.*
[(2)] *Laboratoire Municipal du Havre, 5, rue Raymond Guénot, 76000 Le Havre, France.*

Received December 20, 1989; accepted February 23, 1990.

Migrations diurnes de *Dinophysis acuminata* d'une colonne d'eau isolée artificiellement dans le port d'Antifer (Normandie, France).

P. Lassus, F. Proniewski, C. Pigeon, L. Veret, L. Le Déan, M. Bardouil and P. Truquet. *Aquat. Living Resour.*, 1990, 3, 143-145.

Although numerous studies have been published about the vertical migration of dinoflagellates (Blasco, 1978; Brockmann *et al.*, 1977; Hand *et al.*, 1965; Hasle, 1950; Heaney and Eppley, 1981; Kamykowski, 1981; Kamykowski and Zentara, 1977), few data are available on the genus *Dinophysis*. However, a recent study by Durand-Clément *et al.* (1988) reports on the vertical distribution of *Dinophysis* sp. during a 24-hour period in Vilaine Bay (South Brittany, France). It emphasizes the role of light intensity on cell survival and confirms the similarity between *Dinophysis* sp. and other dinoflagellates studied with respect to the migratory cycle: the cells rise toward the surface at dawn, then descend to lower depths at noon because of inhibitory strong light intensities before rising again at the end of the afternoon.

Since several species of these toxic dinoflagellates are widespread in Europe as well as Japan (Kat, 1983; Tangen, 1983; Yasumoto *et al.*, 1984; Lassus *et al.*, 1985; Marcaillou-Le Baut *et al.*, 1985) and no cultures currently allow a better understanding of their behaviour and the factors contributing to their development, *in situ* observations are of particular importance in determining the mechanisms governing proliferation of these species.

The study carried out in Vilaine Bay by Durand-Clément *et al.* indicated neither swimming rates nor the role of temperature and sunshine. Moreover, the measurements made at a fixed point failed to take into account horizontal movements due to tidal currents. Accordingly, it was decided in this present paper to investigate the vertical distribution of *D. acuminata* within the Antifer oil tanker port in Normandy, choosing the month of August 1988 because of the very high cell densities (Paulmier *et al.*, 1985) found there in summer. To avoid interference with advective movements, an isolated water column was studied by means of a tank set up *in situ*, and all species of dinoflagellates present in this environment were recorded.

A reinforced polyethylene cylinder (thickness 50 µm, length 30 m, diameter 1.28 m) was constructed according to the prototype described by Brockmann *et al.* (1974) and used by different authors (Brockmann *et al.*, 1977; Dahl and Brockmann, 1985). Inside the cylinder, 500 cm^3 water samples were obtained every 2 hours at 6 levels (1, 3, 5, 7, 10 and 20 m) using a Masterflex peristaltic pump; a Ponselle heat probe attached on the tip of the pumping tube was used to measure temperature at the time the sample was taken.

The operations of submerging the tank by ship within the port, obtaining the samples and recovering the material were carried out on August 8 and 9,

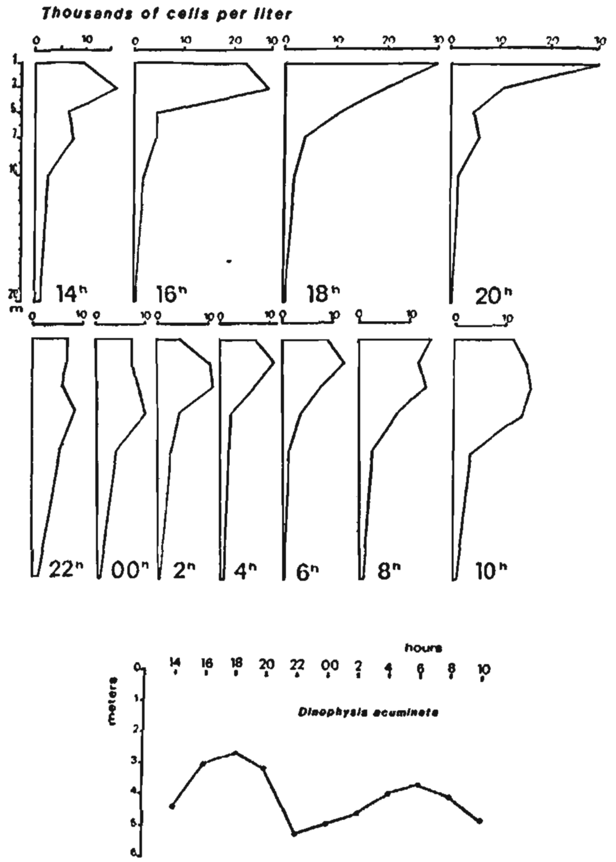

Figure 1. – Vertical distributions of *D. acuminata* densities at Antifer on August 8 and 9, 1988, between 14:00 and 10:00 hours, at 6 sampling levels, and time evolution of barycenter WD.

1988. The samples were subsequently fixed in formol (2%) and examined by inverted microscopy according to the method of Utermöhl (1958), using 10 cm^3 water volumes. To facilitate calculation of ascending and descending swimming rates of the dinoflagellate population, a weighted depth (WD) was estimated every 2 hours as the barycenter of the vertical distribution of cells, that is:

$$WD = \sum(Pk \times Dk)/\sum Dk$$

where Pk and Dk indicate corresponding depth and cell density, and where result (WD) is expressed in meters.

Figure 1 represents the vertical distributions of *D. acuminata* for depths from 1 to 20 m. A typical behaviour may be noted in the migration: a spreading-out at surface levels (1 to 3 m) from 16:00 to 20:00 hours, and a second, ascending migration (02:00 to 06:00 hours), characterized by a low amount of cells, seems to correspond to a subsurface level (5 to 7 m).

Changes in the barycenter of populations over time made it possible to note two typical migratory movements in *D. acuminata* essentially in the 0 to 6 m depth range: the first between 14:00 and 22:00 hours and the second between 02:00 and 10:00 hours. It is in the mid-afternoon that the "active" migration by swimming of cells is greatest: 0.70 $m.h^{-1}$. Likewise, the fastest descending migration occurs between 20:00 and 22:00 hours with 1.11 $m.h^{-1}$. These values are in the range of data reported in the literature (0.7 to 1 $m.h^{-1}$ for *Gonyaulax polyedra* and *Ceratium furca* in Heaney and Eppley (1981); 0.72 to 1.80 $m.h^{-1}$ for other dinoflagellates in Blasco, 1978) as maximal velocities in small temperature gradients.

Analysis of temperature in the depth range concerned by the migration (0 to 10 m) shows a marked temperature gradient (2°C deviation between 1 and 7 m) in the 18:00 to 20:00 hours period. It would thus seem clear that most observed species, but especially *Dinophysis acuminata* and *Prorocentrum triestinum*, accumulated actively in the warm surface layer above the thermocline. The low migration of *D. acuminata* between 02:00 and 06:00 hours would thus have no relation to the temperature gradient.

It should also be noted that the majority of cell divisions observed in *D. acuminata* occurred at 06:00

Table 1. – Number of *D. acuminata* cells in division (cells.l^{-1}) in the experimental tank at the different times and sampling levels (figures between brackets indicate percentages of total *D. acuminata* populations).

Depth (m)	Sampling times (h)										
	14	16	18	20	22	0	2	4	6	8	10
1	0	0	0	0	0	0	0	0	(1.16) 100	0	(0.87) 100
3	0	(0.12) 100	0	0	0	0	0	0	(1.40) 500	0	0
5	0	(0.45) 100	0	0	0	0	(0.18) 100	0	(0.28) 100	(0.31) 200	0
7	0	0	0	0	0	0	0	0	(0.79) 200	(0.84) 400	(0.21) 200
10	0	0	0	0	0	0	0	0	(0.83) 100	0	0
20	0	0	0	0	0	0	0	0	0	0	0

hours, involving only 3% of the counted population (*table* 1). This result, confirmed by other observations in France (7% of the population undergoing division at 08:30 hours in Douarnenez Bay) and Japan (2% divisions at 06:30 hours in Kesennuma Bay—Igarashi, pers. comm.) suggests a relatively slow but synchronous rate of division related to nycthemeral rhythm (first hours of daylight).

Finally, we compared the hydrologic conditions peculiar to the 2 days corresponding to our observations with all of the data collected over 25 days in the same month. In this respect, it is of interest to note that on August 8 and 9 surface salinity was low (between 28 and $30\,g.l^{-1}$), whereas it had been higher the preceeding week (32 to $32.5\,g.l^{-1}$). Likewise, winds were weak, attaining daily mean velocities of less than 5 m/s from August 1 to 9. Concerning temperatures, differences between the surface and the bottom were relatively insignificant until and including August 9. Sunshine was moderate on the 8th (7.5 hours) and rather limited on the 9th (3.2 hours).

Thus, hydrologic conditions corresponded to a period of superficial desalination with a rewarming of the surface layer on August 8, between 16:00 and 20:00 hours. Besides, the number of hours of sunshine was about the same as on the preceeding day, whereas it was reduced by half on August 9. Given the weak wind velocities before and during the period studied, a preponderant role cannot be attributed to this parameter as a cause at the high densities of *D. acuminata* observed at the sampling station in August.

In view of these different factors, *D. acuminata*, exhibits migratory behaviour typical of several dinoflagellates, on the same order as that described by Durand-Clément *et al.* (1987) for *Dinophysis* sp. in Vilaine Bay. However *D. acuminata* migration takes place in two time phases and remains limited to a surface layer (0 to 10 m) without reaching deeper levels (30 m).

The first phase between 16:00 and 18:00 hours, seems characteristic of nearly all species of dinoflagellates observed, that is, of species showing a marked preference for estuaries.

REFERENCES

Blasco D., 1978. Observations on the diel migration of marine dinoflagellates off Baja California coast. *Mar. Biol.*, **46**, 41-47.

Brockmann U. H., K. Eberlein, P. Hosumbek, H. Trageser, E. Maier-Reimer, U. K. Schone, H. D. Junge, 1977. The development of a natural plankton population in an outdoor tank with Nutrient-Poor Sea water. 1. Phytoplankton succession. *Mar. Biol.*, **43**, 1-17.

Brockmann U. H., K. Eberlein, H. D. Junge, H. Trageser, K. J. Trahms, 1974. Einfach Folientanks zur Planktonuntersuchung *in situ*. *Mar. Biol.*, **24**, 163-166.

Dahl E., U. H. Brockmann, 1985. The growth of *Gyrodinium aureolum* Hulburt in *in situ* experimental bags. *In*: Toxic Dinoflagellates, Anderson D. M., A. W. White, D. G. Baden Eds., Elsevier Science Publishing, New York, 233-238.

Durand-Clément M., J. C. Clément, A. Moreau, N. Jeanne, S. Puiseux-Dao, 1988. New ecological and ultrastructural data on the dinoflagellates, *Dinophysis* sp. from the French coast. *Mar. Biol.*, **97**, 37-44.

Hand W. G., P. A. Collard, D. Davenport, 1965. The effect of temperature and salinity change on swimming rate in the dinoflagellates, *Gonyaulax* and *Gyrodinium*, *Biol. Bull.*, **128**, 90-101.

Hasle G. R., 1950. Phototactic vertical migration in marine dinoflagellates. *Oikos*, **2**, 162-175.

Heaney S. I., R. W. Eppley, 1981. Light, temperature and nitrogen as interacting factors affecting diel vertical migration of dinoflagellates in culture. *J. Plankton Res.*, **3**, 331-344.

Kamykowski D., 1981. Laboratory experiments on the diurnal vertical migration of marine Dinoflagellates through Temperatures gradients. *Mar. Biol.*, **62**, 57-64.

Kamykowski D., S. J. Zentara, 1977. The diurnal migration of motile phytoplankton through temperature gradients. *Limnol. Oceanogr.*, **22**, 148-151.

Kat M., 1983. *Dinophysis acuminata* blooms in the Dutch coastal area related to diarrhetic mussel poisoning in the Dutch Waddensea. *Sarsia*, **68**, 81-84.

Krogh P., L. Edler, E. Graneli, V. Nyman, 1985. Outbreak of diarrheic Shellfish poisoning on the west coast of Sweden. *In*: Toxic Dinoflagellates. Anderson D. M., A. W. White Baden D. G. eds., Elsevier Science Publishing, New York, 501-503.

Lassus P., M. Bardouil, I. Truquet, P. Truquet, C. Le Baut, M. J. Pierre, 1985. *Dinophysis acuminata* distribution and toxicity along the Southern Brittany coast (France): correlation with hydrological parameters. *In*: Toxic Dinoflagellates. Anderson A. M., A. W. White Baden D. G. eds., Elsevier Science Publishing, New York, 159-164.

Marcaillou-Le Baut C., D. Lucas, L. Le Dean, 1985. *Dinophysis acuminata* toxin: status of toxicity bioassays in France. *In*: Toxic Dinoflagellates. Anderson D. M., A. W. White, D. G. Baden eds., Elsevier Science Publishing, New York, 485-488.

Paulmier G., J. P. Joly, 1985. Manifestations de *Dinophysis acuminata* sur le littoral normand. *Rev. Trav. Inst. Pêches. marit.*, **47**, 149-157.

Tangen K., 1983. Shellfish poisoning and the occurrence of potentially toxic Dinoflagellates in Norwegian waters. *Sarsia*, **68**, 1-7.

Yasumoto T., M. Murata, Y. Oshima, G. K. Matsumoto, J. Clardy, 1984. Diarrhetic Shellfish Poisoning. *In*: Seafood toxins. Am. Chem. Soc., eds., 207-214.