THE REPETITIVE AND EXPANDING OCCURRENCE OF A GREEN, BLOOM-FORMING DINOFLAGELLATE (DINOPHYCEAE) ON THE COASTS OF FRANCE

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ABSTRACT - A dinoflagellate has produced green-water events along the Atlantic and English Channel coasts of France since 1982. It differs morphologically from each of the 12 taxa or so of green gymnodinioid dinoflagellates previously known. As some morphological details, as well as their variability, remain to be ascertained, this organism is illustrated and described here under the provisional designation of *Gymnodinium* "sp. 1982". The presence of chlorophyll *b* has been confirmed by HPLC analysis but it could not be ascertained whether true chloroplasts are present, or symbionts. The distribution is coastal and estuarine. The number and intensity of the outbreaks may be related to river runoff and to the amount of preceding rainfall. An encysted stage is described. Some noxious, presumably indirect, effects have been reported.

RÉSUMÉ - Un dinoflagellé du genre *Gymnodinium* mais de coloration verte prolifère sur les côtes françaises de l'Atlantique et de la Manche depuis 1982, principalement en été. Il diffère morphologiquement des quelque 12 espèces de dinoflagellés gymnodinioïdes "verts" connus à ce jour mais, certains détails morphologiques ainsi que la variabilité intraspécifique restant à préciser, cet organisme est ici désigné provisoirement comme *Gymnodinium* "sp. 1982". La présence de chlorophylle *b* a été confirmée par une analyse en HPLC mais la nature des chloroplastes (éventuellement symbiotiques) n'a pu être précisée. La distribution est typiquement côtière et les proliférations semblent corrélées aux apports fluviatiles et à la pluviométrie des mois précédents. Un stade enkysté est décrit, ce qui constitue le second cas connu d'un tel stade dans le vaste genre *Gymnodinium*. Quelques effets nocifs sur la faune marine ont été signalés et sont considérés comme indirects (anoxie).

KEY WORDS : Blooms, dinoflagellates, green waters, *Gymnodinium*, phytoplankton

INTRODUCTION

The biology, ecology and harmful effects of marine plankton algae on the coasts of France were recently reviewed in a multi-authored book (Sournia *et al.*, 1991). This document was completed by the middle of 1990 and considered 4 algae of major concern, i.e.: the dinoflagellates (Dinophyceae) *Alexandrium minutum* Halim emend. Balech, *Dinophysis* Ehrenberg spp. and *Gymnodinium* cf. *nagasakiense* Takayama et Adachi together with the prymnesiophyte genus *Phaeocystis* Lagerheim. Three other microalgae were presented separately because they have been found in France only recently, and can only be said hypothetically or potentially toxic in this country; these are the dinoflagellates, *Gymnodinium spirale* (Bergh) Kofoid et Swezy and *Prorocentrum minimum* (Pavillard) Schiller, and the silicoflagellate (Dictyochophyceae) genus, *Dictyocha* Ehrenberg.

Events during the last two summers of 1990 and 1991 have drawn attention again to a small dinoflagellate, green in colour, belonging to the *Gymnodinium/Gyrodinium* complex and a peculiarity of which is to be green. This organism may have occurred in France for the first time in 1982 (Lassus, 1988), since when its general abundance as well as the extent, the duration and the intensity of its blooms appear to have been increasing. Recently, some harmful effects have been attributed to this dinoflagellate. Another stimulus to the present study was the recent work of Watanabe *et al.* (1987, 1990) which called attention, for the first time, to the existence of green, symbiont-containing gymnodinioids.

MATERIAL AND METHODS

Several bloom events will be reported in this paper. They correspond to different data sets collected independently by various workers (Table I). The techniques used, and particularly their degree of sophistication, thus vary. Only special procedures will be described hereunder.

Fluorescence microscopy: cells fixed with 3 % glutaraldehyde and stained with DAPI (5 μg/ml solution in distilled water) were observed with a Zeiss® Lab 16 microscope equipped for epifluorescence. Two filter combinations were used: (UV) BP 365-11/FT 395/LP 397 and (blue) BP 450-490/FT 510/LP 520.

Electron microscopy: cells fixed with 3 % glutaraldehyde in sodium cacodylate buffer were rinsed and post-fixed with 1 % osmium tetroxyde, then dehydrated and embedded in Epon following conventional methods.

Pigment analysis: extraction was made in 5 ml of 90 % acetone by crushing and stirring the filters with a glass rod. Vials were then stored for 2 hours in the dark at 4°C before analysis. The HPLC system consisted of two pumps (Kontron®, model 414), an injection valve (Altex®model 210), a fluorescence detector (Kontron® spectrofluorometer SPM 25, excitation at 430 nm, emission at 663 nm) and a spectrophotometer (Kontron® Uvikon 722LC, detection at 440 nm). The gradient control and data acquisition were performed by a HPLC computer (Kontron® model 450). The column (100 x 4.6 mm) was filled up with 3 μm ODS Hypersil. Chlorophyll and carotenoid pigments were analysed by reverse-phase ion-pairing HPLC using the method of Knight & Mantoura (1985). The flow rate was 1.8 ml /min and the solvent program was the following: start from 100 % A (80:10:10; methanol: water: ion-pairing reagent) to 100 % B (60: 40; methanol: acetone) in 5 min, and hold in 100 % B for 3 min. Chloropigments were quantified with solutions of purified pigments; chl.

a and *b* were purchased from Sigma®-Chimie, chl. *c* was isolated from a culture of the diatom *Phaeodactylum tricornutum* Bohlin. Carotenoids were identified by comparison of their retention time with those of pigments of well documented species (*P. tricornutum* and the chlorophycean *Dunaliella tertiolecta* Butcher).

THE ORGANISM

The general shape is subglobular (Figs 1: A-F) to (occasionally) elliptical (Fig. 1: G). The hypotheca is equal to or slightly longer than the epitheca. Length 20-24 μm (exceptionally 30 μm, to be confirmed); width 12-16 μm. The antapex is deeply indented by the sulcus (Figs 1: D-G). The cingulum is in a median or very sligthly anterior position; it is displaced by about its own width, i.e. 1/8 the cell length (Figs 1: D-G). The sulcus is deeply impressed and extends from the apex to the antapex with an overall sigmoid path (Fig. 1:G). Chloroplasts are generally green, occasionally yellow-green, either rounded or elliptical, and more or less radially disposed in the cell; there is one pyrenoid per chloroplast. The nucleus is spherical and central (Fig. 1: H), its diameter being 1/3-1/2 of cell width. Numerous mucocysts and trichocysts are present. No stigma was observed.

HPLC analysis revealed the presence of a relatively large amount of chlorophyll *b*; a molecular ratio of chl. *a*/chl. *b* of 2.2 was found. Chlorophyll *c* was virtually absent (< 0.01 ng/l). Traces of chlorophyllid *a* and pheophorbid *a* were also noted. As regards carotenoid pigments, β-carotene, lutein and violaxanthin were present, no peridinin was found and only traces of fucoxanthin were noted.

Cysts were observed in fresh samples as well as in formalin- and in glutaraldehyde-preserved samples (in the latter case, fixation may have induced extra encystment). They are spherical, have a hyaline, double membrane and the dinocaryon remains visible inside (Fig. 1: J). No germination of cysts was observed during a 3-month laboratory incubation.

Negative or doubtful characters include the following. Body scales were shown by transmission electron microscopy to be absent in all the material examined. A "peduncle" (Watanabe *et al.* 1987) or "cytoplasmic projection" (Watanabe *et al.*, 1990) at the crossing of the cingulum and the sulcus was not observed. No apical groove was seen but detailed observation of the apical area by scanning electron microscopy could not be undertaken. Ultrastructural studies failed to ascertain whether the pigment-containing bodies are true chloroplasts, symbionts or symbiotic remnants. Observation by epifluorescence showed overlapping or contiguous chloroplasts (Fig. 1: I) reminiscent of the reticulated chloroplast of *Lepidodinium* Watanabe *et al.* (see below). Fig. 1: I may just reflect the relatively poor resolution of epifluorescence microscopy, however. Lastly, observations at Les-Sables-d'Olonne in 1990 suggest that two size groups occur along the French coasts, one cell type being twice smaller (length 12 μm, width 9-10 μm) than the other in linear dimensions.

From the above characters, this organism differs from all the previously described species of *Gymnodinium* or *Gyrodinium* that could be considered akin at first glance. For each of the species considered, two or several (and not: a single one) features were found to differ. The following "green" dinoflagellates were considered (hereunder alphabetically):

- *Gymnodinium halophilum* Biecheler is variable but always different in shape, the epitheca being generally longer and wider than the hypotheca. It has a peculiar "languette" (tongue, strip) which recalls the peduncle of *Lepidodinium.* The chloroplasts are said to be yellow-brown in the original description (Biecheler, 1952) but yellow-green in Borcakli (1981), hence the mention of this species here. According to both Biecheler and Borcakli, this species blooms in the open water and may also accumulate as deposits on the shore.

- *Gymnodinium herbaceum* Kofoid in Kofoid et Swezy is longer and ovoid with a striated hypotheca. Its nucleus is smaller and located posteriorly.

- *Gymnodinium incertum* E.C. Herdman, a sand-dwelling species, has a short hypotheca, hence a posteriorly located cingulum, and its sulcus reaches neither the apex nor the antapex.

- *Gymnodinium maguelonense* Biecheler is twice as long. The sulcus is straight, the chloroplasts lamellar and the nucleus elliptical.

- *Gymnodinium pyrenoidosum* Horiguchi et Chihara has a rounded antapex, a slightly displaced cingulum, a sulcus restricted to the hypotheca and a single choloroplast.

- *Gymnodinium varians* Maskell is a poorly known species in which the cingulum is not displaced.

- *Gymnodinium viride* Penard (non *G. viride* Schütt nec *G. viride* Lebour), a freshwater species, longer and ellipsoidal in shape, possesses an anterior nucleus.

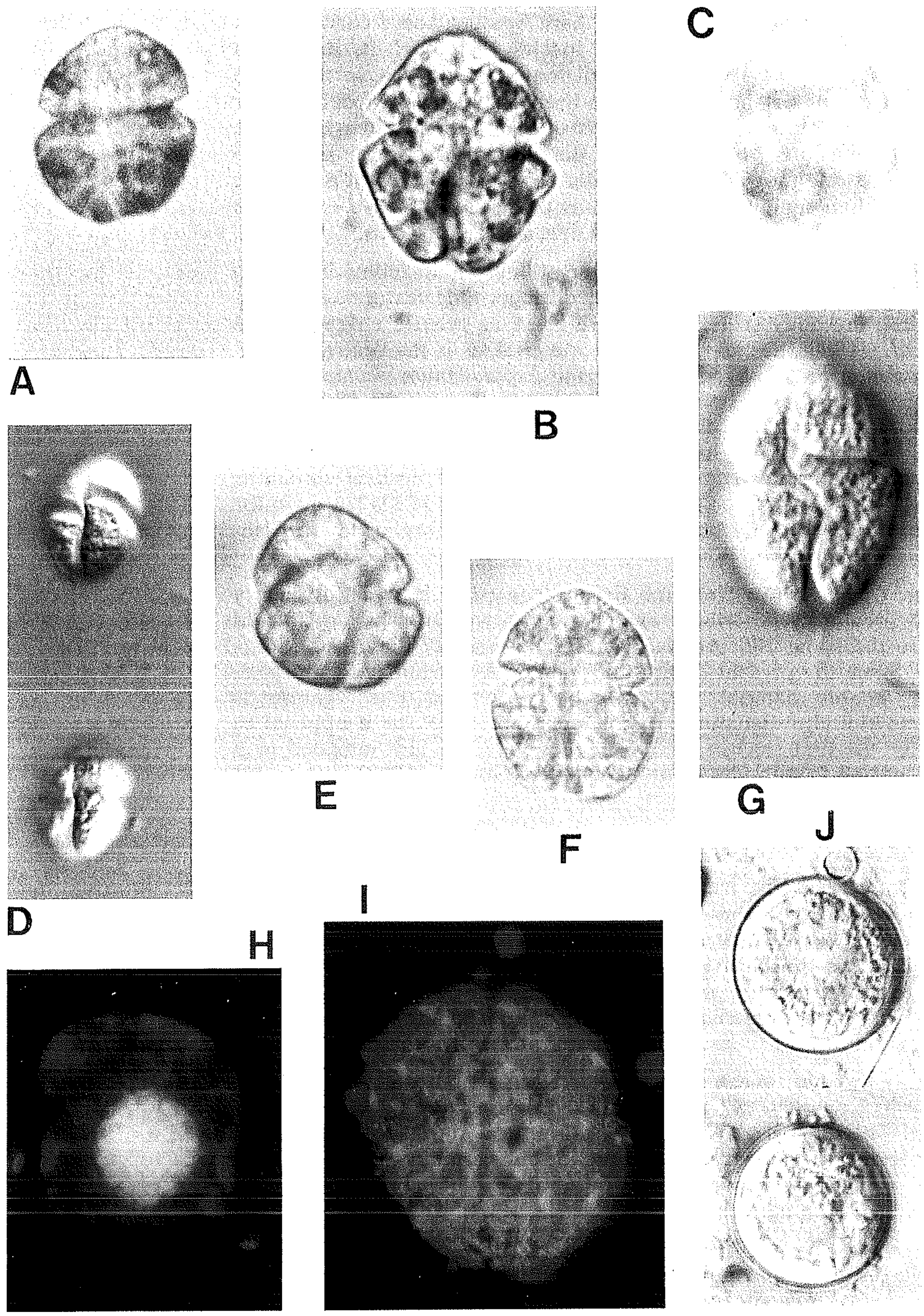
- *Gymnodinium viridescens* Kofoid: the cingulum is not displaced and only a few chloroplasts are present.

- "*Gymnodinium* sp. (Midorishio) (anonymous species)" in Fukuyo *et al.* (1990). A red-tide organism in which the sulcus is straight and described as "sometimes reaching the center of the hypocone" although it appears to reach the antapex (see Fukuyo *et al.*, 1990, p. 56, fig. DE). The chloroplasts are distributed radially and peripherally.

- The several new species of green *Gymnodinium* described by Van Meel (1969) from brackish or coastal waters of Belgium are too poorly described to allow any comparison to be made.

- *Gyrodinium foliaceum* Kofoid et Swezy is longer, the cingulum is much more displaced, the sulcus is straight and the nucleus is posterior.

Figure 1. *Gymnodinium* "sp. 1982" from different localities. (A-G) Living cells: (A, C, E-F) Bay of Vilaine at Assérac, length 22-25 µm (photogr. by M. Bardouil). (B) Les Sables d'Olonne, length 20 µm (photogr. by Ch. Billard). (D) La Brèche d'Hermanville, interference light, length 17-20 µm (photogr. by J. Fresnel). (G) Les Sables d'Olonne, interference light, length 22 µm (photogr. by Ch. Billard). (H) La Brèche d'Hermanville, epifluorescence microcopy (UV excitation) after DAPI staining, showing the nucleus (photogr. by H. Micalef). (I) La Brèche d'Hermanville, epifluorescence microscopy (blue excitation) showing the autofluorescence of chloroplasts (photogr. by H. Micalef). (J) Living cysts from La Brèche d'Hermanville in a laboratory culture, interference light, diameter 19-21 µm (photogr. by Ch. Billard).


A
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Among the common (non green) and bloom-forming dinoflagellates, *Gyrodinium aureolum* Hulburt deserves mention here because some early reports of the present organism have referred to this species. Although its name has been widely used, *G. aureolum* remains an enigmatical organism, in the sense that all authors after Hulburt have obviously been dealing with a different or with several different organisms (Partensky & Sournia, 1986; Partensky *et al.*, 1988; Partensky *in* Sournia *et al.*, 1991). Only the original description is of concern here because of some morphological similarities with the present organism. These are not more than similarities, however, as *G. aureolum* "sensu stricto", in addition to being a yellow-brown dinoflagellate, has a straight sulcus.

Another green and morphologically resembling dinoflagellate is the recently described genus *Lepidodinium*. Several distinguishing features are obvious, however. First, the body scales, which are given as generic characteristics by Watanabe *et al.* (1990), are lacking in our material, as is the ventral peduncle. Then, Watanabe *et al.* (1987, 1990) describe *Lepidodinium viride*, the only species of the genus thus far, as being 22.5-52.5 μm in length, and 18.9-38.3 in width. Its cingulum appears less displaced, as far as this may be objectively measured, and its sulcus is straight. The antapex is almost round unlike the French green dinoflagellate. Last, *L. viride* has been shown to possess symbionts rather than chloroplasts (Watanabe *et al.*, 1990) but the question is left open for our material. Furthermore, *Lepidodinium's* chloroplast-like organelles are isolated to reticulated, thus forming in the latter case a single organelle.

The green *Gymnodinium* from the French coastal waters is thus clearly different from all previously described taxa. However, we are reluctant to add another species to the some 200 previously described ones of the genus (Sournia, 1986, 1990). Since the present description lacks a few details and morphological variabililty in our material remains to be investigated, this organism is given here the provisional designation*Gymnodinium* "sp. 1982", as it appears to have been seen for the first time in 1982. This designation is not intended as a specific name according to the rules of nomenclature (Greuter, 1988).

THE GREEN WATERS

The cases of green water caused by *Gymnodinium* "sp. 1982" are listed in Table I and their locations are shown on Fig. 2. In a dozen cases, identification is tentative since no microscopical examination was possible (Table I); the interpolation in space and time is legitimate, however. All the cases occurred in summer, except two. These took place in October and December, an unusual time of the year for mass occurrence of phytoplankton in the northern hemisphere.

In their totality, these green waters occurred in nearshore or coastal waters, occasionally in harbours. All the affected areas are exposed to significant freshwater inputs. The northern area shown in Fig. 2 is under the influence of river Seine. The upper part of the southern area is subject both to river Vilaine, a relatively small river, and to the northward flowing plume of the river Loire. In the southern area, there is no major river near la Rochelle but a number of small ones.

A majority of green-water phenomena were noticed during 1988 in the Vilaine-Loire area. This may be correlated with the previous, unusually rainy winter. From a graph produced by Maggi *et al.* (in press; data from Station Météorologique de Nantes), one may calculate that during the six months Janu-

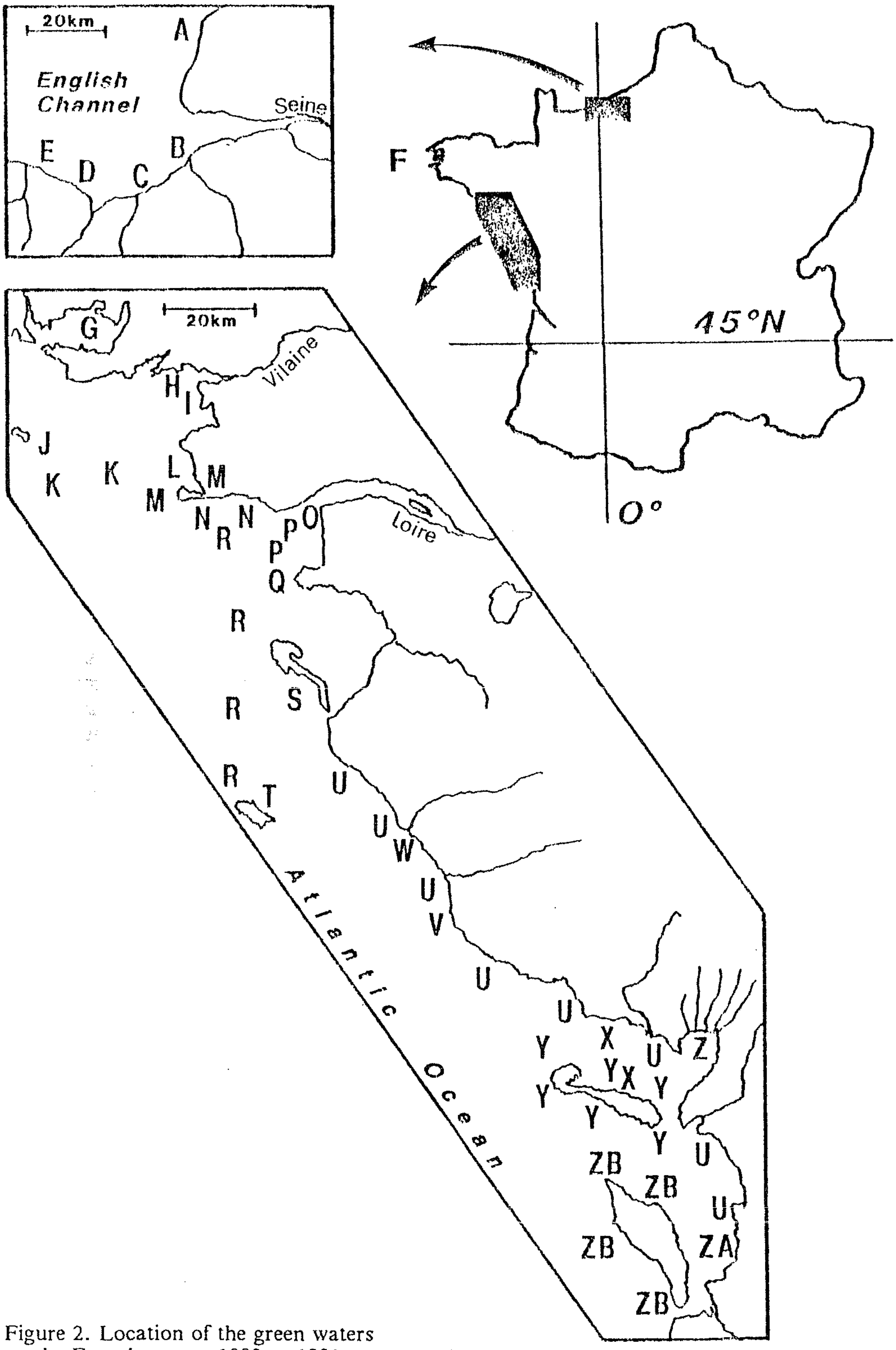

Figure 2. Location of the green waters on the French coasts, 1982 to 1991.

ary to June 1988, the Vilaine-Loire region received nearly twice as much rain (625 mm) than during the corresponding period averaged for 1951-1980 (360 mm). July alone received 86 mm in 1988 but only 48 mm on average in 1951-1980. August, however, was very dry in 1988 (13 mm) compared with the preceding 30 years (mean: 57 mm). Similarly, the events of 1988 on the coasts of Vendée and Charente may be related to an unusual amount of rain during the preceding spring (Soulard, 1990 and unpubl. data).

Gymnodinium "sp. 1982" has not been reported so far on the Mediterranean coast of France.

As is generally the case with "discoloured water", the surface of the sea is primarily concerned because it is readily observed. Vertical sampling in the Bay of Vilaine, however, has revealed heavy concentrations near the bottom during daylight (Maggi *et al.*, in press). During the course of a 24-hour study in the harbour of Antifer ("A" on Fig. 2), the highest concentration of *Gymnodinium* "sp. 1982 " were found in the 0-1 m layer between 20 h and 5 h, while during the remaining part of the 24-hour cycle, the dinoflagellate occupied the whole 0-5 m layer (Lassus *et al.*, 1991). On the other hand, positive reactions to light were observed in the culture vessels in the laboratory. Phototaxis is thus questioned in this organism.

Other mentions of green waters produced by a dinoflagellate in European waters refer to the German Bight in the summer of 1990 (Elbrächter *et al.*, 1991; Lenz *et al.*, 1991) and the Adriatic during the mid 1980's (G. Honsell in Elbrächter *et al.*, 1991; G. Honsell, pers. comm.). In both regions, the organism responsible was "very similar or identical" to *Lepidodinium viride.*

NUISANCES AND POTENTIAL TOXICITY

Mortalities of marine organisms followed some of the *Gymnodinium* "sp. 1982" outbursts. Most of them occurred in August-September 1988 off southern Brittany and between Saint-Jean-de-Monts and Les-Sables-d'Olonne ("W" on Fig. 2). A few others were mentioned in the summer of 1991 off southern Brittany and at Les Sables-d'Olonne ("V" on Fig. 2). Minor damages were tentatively attributed to the dinoflagellate in Normandy in 1990 ("B-E" on Fig. 2). On the whole, mortalities affected mussels, oysters, some smaller molluscs, shrimps, crabs, and smaller crustaceans, depending on places. A lowering of the oxygen content due to decomposition was offered as an explanation.

The green waters are often reported as juicy, mucous or slimy. Phytoplankton deposits may accumulate on various substrates at low tide (Fig. 3, bottom).

Tourists and swimmers complained about the appearance and consistence of the seawater (Fig. 3) and some of them may have suffered from skin irritation. Tests for cutaneous allergy proved to be negative, however. No toxicity nor human intoxication of any kind has so far been reported.

CONCLUSIONS AND FUTURE WORK

The reported outbreaks of *Gymnodinium* "sp. 1982" add another organism to the already long list of bloom-forming phytoplankters which had both remained unknown or unnoticed until recently and for which the distribution has extended in space and time during the course of the last ten years. This supports

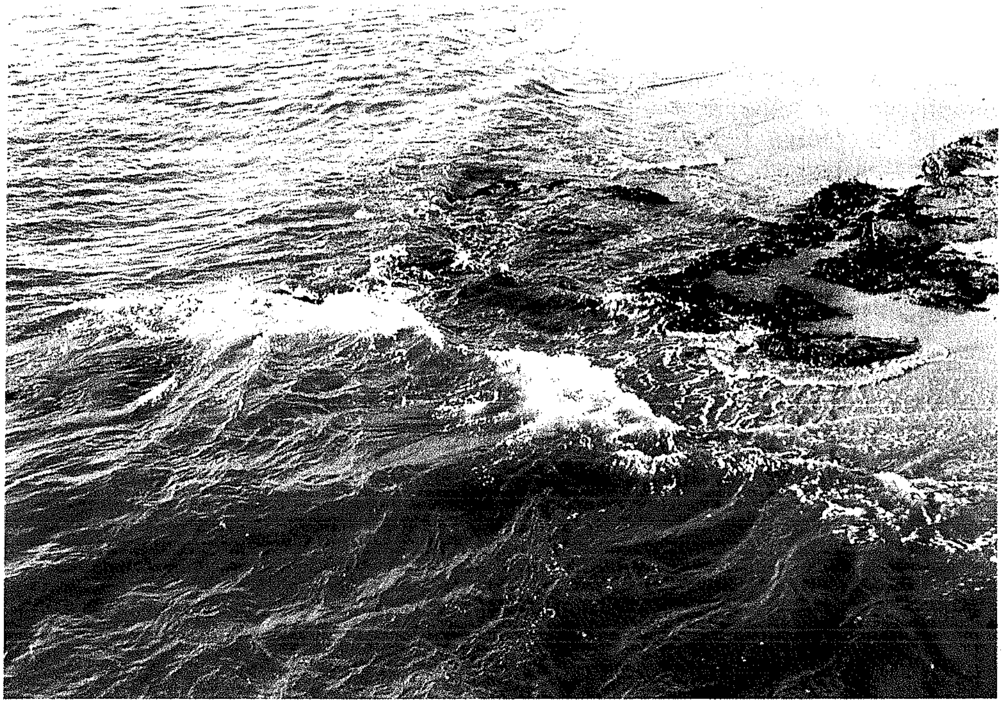

Figure 3. Top: green water at Assérac, near Pen-Bé (Brittany, France), September 1988. Bottom: mucous embedding on a rope at low tide, same place and date. (Photographs by M. Catherine.)

the hypothesis that such events are increasing in extent and frequency (Anderson, 1989; Smayda, 1990; Sournia *et al.*, 1991).

The present dinoflagellate is green, a peculiarity which is not unique among the class Dinophyceae, however, as it is shared by at least a dozen other gymnodinioid species of the genera *Gymnodinium, Gyrodinium* and *Lepidodinium*. It remains to be established whether the photosynthetic pigments of *Gymnodinium* "sp. 1982" are borne by true chloroplasts or by symbionts. The latter hypothesis is suggested by the presence of chlorophyll *b* and the lack of both chl. *c* and peridinin. In any case, the pigment content of *Gymnodinium* "sp. 1982" is totally atypical for a member of the class Dinophyceae and, rather, it reminds closely that of the Chlorophyceae.

Table I - Occurrence of green waters in France, 1982-1991. Indications are as precise as reported in the original, mostly unpublished records. References to published reports (of limited distribution) are given when available. Letters refer to indications on the map (Fig. 2).

A green *Gymnodinium* identified from microscopical observation

1982	September 29 (→ Z) Between La Rochelle and Ile de Ré. After several days of heavy rain. 124 10^6 cell/l. Cells only 10 x 7.6 μm ? (A species different from that described here ?)
1982	Sept. 30 (→ M) In the harbour of Le Croisic. After heavy rains.
1983	August 5 and the days before (→ Y) North and South of Ile de Ré along two, 30-kilometer long patches.
1985	August 9-22 (→ Y-Z) Off La Rochelle, South and North of Ile de Ré. 1.5 - 3.6 10^6 cell/l.
1985	August 28 (→ ZA) Bassin de Marenne-Oléron. 2.6 10^6 cell/l.
1986	September 30 (→ ZB) Around Ile d'Oléron. 7 10^6 cell/l.
1986	October 14 (→ L) Bay of La Turballe. During rainy weather. 3 10^6 cell/l.
1987	end of July (→ S) La Guérinière.
1987	July-August (→ I). Bay of Vilaine. ≤ 1.2 10^6 cell/l.
1988	June (→ Z). Off La Rochelle.
1988	July 30 (→ N) Off La Baule, along a 10-kilometer long patch. 24 10^6 cell/l *Gymnodinium* plus 0.5 10^6 cell/l *Prorocentrum micans*.
1988	August 7-9 (→ L) Bay of La Turballe. 0.5 10^6 cell/l.
1988	August 10 and 18 (→ J) Ile d'Houat. 50-80 10^3 cell/l.
1988	August 11-17 (→ O) Saint-Nazaire. 24-40 10^6 cell/l.
1988	August 13 (→ V) Les Sables d'Olonne. 18.4 10^6 cell/l.
1988	August 16 (→ H) Bay of Vilaine. 0.3 10^6 cell/l.
1988	August 16-17 (→ M) Batz-sur-Mer and Le Croisic. ≤ 32 10^6 cell/l.
1988	August 18 (→ G) Le Tour du Parc and Golfe du Morbihan. 4.4 10^6 cell/l.
1988	mid-August to beginning of October (→ U). A large portion of the coasts of Vendée and Charente between Ile d'Yeu and Ile d'Oléron. ≤ 300 10^6 cell/l.
1988	September 5 (→ H) Bay of Vilaine. 2,4 10^6 cell/l.
1988	September 12 (→ H). Bay of Vilaine. 7.3 10^6 cell/l.
1989	July 17-August 16 (→ H) Bay of Vilaine, intermittently. 2-8 10^6 cell/l.
1989	July 31-August 1 (→ ZA) East of Ile d'Oléron. 0.4-42 10^6 cell/l.
1989	July 28-August 16 (→ L) Near La Turballe, intermittently. 10^6 cell/l.
1989	August 1-28 (→ F) Off Camaret (western Brittany), intermittently. 0.7-37 10^6 cell./l.
1989	August 7-8 (→ T) Ile d'Yeu. 0.7 10^6 cell/l.
1989	September 13 (→ C) Off Cabourg. 130 cell/l.
1990	August 22-September 5 (→ D-E) An intermittent or continuous, 3- kilometer long patch near the mouth of river Orne. 50-600 10^6 cell./l.
1990	August 23 (→ C) Cabourg.
1990	August 24 (→ E) Luc-sur-Mer

1990 August 27 (→ B) Villers-sur-Mer.
1990 August 28 (→ D) Franceville.
1990 August 29-30 (→ E) Luc-sur-Mer.
1990 August 31 (→ D) La Brèche d'Hermanville.
1990 August 29-31 (→ A) Antifer harbour. > 10^6 cell/l. (Lassus *et al.*, 1991).
1991 July 10 (→ V) Les Sables d'Olonne.
1991 September 4-13 (→ W) Between Saint-Jean-de-Monts and Les Sables-d'Olonne.
1991 September 9-12 (→ M) Bay of Le Croisic. 4.3-5.2 10^6 cell/l.

No microscopical identification

1987 August 28 (→ L) Bay of La Turballe.
1988 August 1 and 10-11 (→ N) Near La Baule or near Pornichet.
1988 August 9 (→ Q) Préfailles (near Saint-Gildas).
1988 August 10 (→ Q) Between Chemoulin and Préfailles.
1988 August 12 (→ R) From La Baule to Ile d'Yeu.
1988 August 13 (→ W) Off Saint-Jean-de-Monts.
1988 August 15 (→ MN) Batz-sur-Mer and along the shore of Le Croisic.
1988 August 15 (→ K-L) Ile d'Houat, Belle-Ile, Piriac.
1988 August 24-25 (→ L) Assérac (near Pen-Bé).
1988 September 6-11 (→ L) Assérac.
1988 September 6-7 (→ L) From Le Croisic to Assérac.
1988 September 8 (→ P) From Préfailles to Saint-Brévin.
1988 October 23 (→ L) Assérac.
1988 December 11 (→ L) Assérac.
1991 August 13-22 (→ L) Bay of La Turballe.

Some morphological characters require a more careful examination. These include: (1) the existence or non-existence of a ventral peduncle; (2) the extension of the sulcus onto the epitheca and the presence or absence of an acrobase and an apical groove; and (3) the shape, number and distribution of the chloroplasts or chloroplast-like bodies, with due consideration given to *Lepidodinium* in which a reticulated, single plastid may be found. Until this is done, the French green *Gymnodinium* will be provisionally called *Gymnodinium* "sp. 1982".

Morphological variability should also be the subject of future investigations, in order to ascertain whether a single or several species are present on the French coasts. A specific question is: do the two apparent size-groups represent growth strategies of a single species, as was established by Partensky *et al.* (1988) for *Gymnodinium* cf. *nagasakiense* (= *Gyrodinium* cf. *aureolum*), or two different species ?

The distribution of *Gymnodinium* "sp. 1982" is coastal and appears linked to freshwater runoff. The precise (direct) causes of the occurrences remain totally unknown, however. Data on any future outbreaks should include, as a first step, the following variables: the weather for the preceding months, salinity, nutrient content, turbidity, and an index of stratification.

The present work seems to represent only the second description of a cyst stage in the large genus *Gymnodinium*, the first case being that of *Gymnodinium catenatum* Graham as described by Bravo (1986). Both cysts are morphologically similar but those of *G. catenatum* are finely reticulated (Anderson *et al.*, 1988), a property which has not been looked for in *Gymnodinium* "sp. 1982".

A third species, *G. sanguineum* Hirasaka, has been observed to germinate during sediment incubation, but the cysts themselves have not been observed (Voltolina & Robinson, 1984).

Lastly, should further harmful effects occur, their cause will have to be closely investigated, in particular to determine whether they result only from lowered oxygen concentration as a consequence of bloom decomposition, or whether *Gymnodinium* "sp. 1982" is directly noxious in some way, or even toxic.

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REFERENCES

ANDERSON D.M., JACOBSON D.M., BRAVO I. & WRENN J.H., 1988 - The unique, microreticulate cyst of the naked dinoflagellate *Gymnodinium catenatum*. *J. Phycol.* 24 (2): 255-262.

ANDERSON D.M., 1989 - Toxic algal blooms and red tides: a global perspective. In T. Okaichi *et al.* (Eds), *Red tides. Biology, environmental science, and toxicology*, Elsevier, New York etc., pp. 11-16.

BIECHELER B., 1952 - Recherches sur les Péridiniens. *Bull. biol. France Belg., Suppl.* 36: 149 p.

BORCAKLI M., 1981 - *Péridiniens littoraux de la région de Montpellier.* Thèse 3ème Cycle Univ. Montpellier, 95 p., 11 pl.

BRAVO I., 1986 - Germinación de quistes, cultivo y enquistamiento de *Gymnodinium catenatum* Graham. *Investigacion Pesqu.* 50 (3): 313-321.

ELBRÄCHTER M., HAGMEIER E. & HESSE K.-J., 1991 - Green water caused by a mass occurrence of an unusual dinoflagellate in the German Bight, North Sea (Abstract). 5th Intern. Conf. Toxic Marine Phytoplankton, Newport (Rhode Island), Oct. 28-Nov. 1, 1991.

FUKUYO Y., TAKANO H., CHIHARA, M. & MATSUOKA K. (Edit.), 1990 - *Red tide organisms in Japan. An illustrated taxonomic guide.* Uchida Rokakuho, Tokyo, xv-407 p.

GREUTER W. (Edit.), 1988 - International code of botanical nomenclature, adopted by the 14th international botanical congress, Berlin July-August 1987. Koeltz, Koenigstein, xiv-328 p.

KNIGHT R. & MANTOURA R.F.C., 1985 - Chlorophyll and carotenoid pigments in foraminifera and their symbiotic algae: analysis by high performance liquid chromatography. *Mar. Ecol. Prog. Ser.* 23: 241-249.

LASSUS P., 1988 - Plancton toxique et plancton d'eaux rouges sur les côtes européennes. Ifremer, Brest, 111 p.

LASSUS P., MAGGI P., PRONIEWSKI F., TRUQUET P. & NIZARD G., 1991 - Distribution verticale de *Dinophysis* spp. au cours d'un cycle de 24 heures dans le port d'Antifer (Normandie). Ifremer/DRO 91-04-MR, 25 / 3 p. (Unpubl. Rep.).

LENZ J., HICKEL M., HAGMEIER E., MICHAELIS H., HANSLIK M., HESSE K.-J. & VOSS J., 1991 - *Lepidodinium viride* (*Gymnodinium* Y-100). *In:* ICES WG *"Phytoplankton and the management of their effects"*, FRG country report 1989/90, pp. 99-103 (Unpubl. Rep.).

MAGGI P., LASSUS P., LARRAZABAL M.E., ETIENNE M., PEZERON A., MORNET F. & SOULARD L., 1989 - Facteurs hydroclimatiques et apparitions d'eaux colorées en baie de Vilaine durant l'année 1987. Ifremer, DERO-88.06-MR: 70 p.

MAGGI P., LASSUS P., ETIENNE M., PEZERON A., MORNET F. & SOULARD L. (in press) - Facteurs hydroclimatiques et apparitions d'eaux colorées en baie de Vilaine durant l'année 1988. Ifremer, DERO-89.05-MR: 60 p.

PARTENSKY F. & SOURNIA A., 1986 - Le dinoflagellé *Gyrodinium* cf. *aureolum* dans le plancton de l'Atlantique nord: identification, écologie, toxicité. *Cryptogamie, Algol.* 7 (4): 251-275.

PARTENSKY F., VAULOT D., COUTÉ A. & SOURNIA A., 1988 - Morphological and nuclear analysis of the bloom-forming dinoflagellates *Gyrodinium* cf. *aureolum* and *Gymnodinium nagasakiense*. *J. Phycol.* 24 (3): 408-415.

SMAYDA T.J., 1990 - Novel and nuisance phytoplankton blooms in the sea: evidence for a global epidemic. *In* E. Granéli *et al.* (Edit.), *Toxic marine phytoplankton*, 29-40. Elsevier, New York etc.

SOULARD R., 1990 - Quelques caractéristiques hydrobiologiques du Pertuis Breton en été 1988; tendances à la stratification. *J. Rech. océanogr.* 15 (3-4): 101-105.

SOURNIA A., 1986 - *Atlas du phytoplancton marin, Volume 1: Introduction, Cyanophycées, Dictyochophycées, Dinophycées et Raphidophycées.* Editions du C.N.R.S., Paris, 219 p. incl. 373 figs.

SOURNIA A., 1990 - Catalogue des espèces et taxons infraspécifiques de Dinoflagellés marins actuels publiés depuis la révision de J. Schiller, V: Complément. *Acta Protozoologica* 29 (4) 321-346.

SOURNIA A., BELIN C., BERLAND B., ERARD-LE DENN E., GENTIEN P., GRZEBYK D., LASSUS P., MARCAILLOU-LE BAUT C. & PARTENSKY F., 1991 - *Le phytoplancton nuisible des côtes de France.* Ifremer/CNRS, 154 p.

VAN MEEL L., 1969 - Etudes hydrobiologiques sur les eaux saumâtres en Belgique. 10. Espèces de Protistes rares ou nouvelles pour la côte Belge. *Bull. Inst. r. Sci. natur. Belg.* 45 (10): 1-18, pl. 1-2.

VOLTOLINA D. & ROBINSON M.G., 1984 - Possibility of self seeding of localized blooms of *Gymnodinium sanguineum* Hirasaka. Coastal mar. Sci. Lab., internal mss report, Victoria, BC, 84-1: 6 p. + tables.

WATANABE M.M., TAKEDA Y., SASA T., INOUYE I., SUDA, S., SAWAGUCHI T. & CHIHARA M., 1987 - A green dinoflagellate with chlorophylls *a* and *b*: morphology, fine structure of the chloroplast and chlorophyll composition. *J. Phycol.* 23 (2): 382-389.

WATANABE M.M., SUDA S., INOUYE I., SAWAGUCHI T. & CHIHARA M., 1990 - *Lepidodinium viride* gen. et sp. nov. (Gymnodiniales, Dinophyta), a green dinoflagellate with a chlorophyll A- and B-containing endosymbiont. *J. Phycol.* 26 (4): 741-751.