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Grazing of heterotrophic dinoflagellate *Noctiluca scintillans* (Mcartney) Kofoid on *Gymnodinium catenatum* Graham

Rosalba Alonso Rodríguez,* José Luis Ochoa,** Manuel Uribe Alcocer***

ABSTRACT. A dinoflagellate bloom (“red tide” event) dominated by the toxic *Gymnodinium catenatum* Graham (Gymnodiniales, Dinophyceae; 99.7%) and the noxious *Noctiluca scintillans* (Mcartney) Kofoid (Noctilucaceae, Dinophyceae; 0.3%) was observed in Bahía de Mazatlán Bay, México, on 24-26 January 2000. Photographic and microscopic analysis of samples during such an event, allowed us to collect evidence of a marked particularity of grazing of *G. catenatum* by *N. scintillans* cells, suggesting a mechanism of “biocontrol” between these species that may contribute to attenuate a potentially toxic phenomenon under natural conditions.

Key words: Biocontrol, *Gymnodinium catenatum*, grazing, *Noctiluca scintillans*, red tides.

RESUMEN. Un evento de proliferación de dinoflagelados (“marea roja”) dominado por el dinoflagelado tóxico *Gymnodinium catenatum* Graham (Gymnodiniales, Dinophyceae; 99.7%) y el dinoflagelado nocivo *Noctiluca scintillans* (Mcartney) Kofoid (Noctilucaceae, Dinophyceae; 0.3%) fue observado en la Bahía de Mazatlán, Sin., México, del 24 al 26 de enero del 2000. El análisis fotográfico y microscópico de muestras obtenidas durante el evento nos permitió documentar una marcada depredación de *N. scintillans* sobre *G. catenatum*, lo que sugiere un mecanismo de “biocontrol” entre estas especies que puede contribuir a atenuar un fenómeno potencialmente tóxico en condiciones naturales.

Palabras clave: Biocontrol, depredación, *Gymnodinium catenatum*, “mareas rojas”, *Noctiluca scintillans*.

INTRODUCTION

Mazatlan Bay in Mexico is an open, eutrophic and subtropical coastal embayment, located on the Southeast Gulf of California (Fig. 1). In the summer, it is influenced by tropical waters, and in the winter by sporadic NW dominant winds that induce upwelling.¹ Red tides are common in Mazatlan Bay at the end of the winter and the beginning of the spring. Harmful dinoflagellates, such as *Gymnodinium catenatum* Graham and *Noctiluca scintillans* (Mcartney) Kofoid, have been reported occurring separately in the area in various red tide episodes in the last two decades.^{3,17} However, the red tide event observed on January 24-26, 2000, dominated by the coexistence of these two species and perceived as a brownish to dark purple color pigmentation patch, with a high viscosity in the water column, was unusual in terms of duration and composition. Increase in sea water viscosity is frequently associated with phytoplankton blooms.⁹ Both, *G. catenatum* and *N. scintillans*, are capable of producing exopolymers that may be

partly responsible for the noxious effect of such events.^{10,12,22} The fish, for example, would have to use more O₂ in the action of pumping water than the amount they could extract from the pumped water, thus dying because of O₂ deficiency.⁹ Also, if the polymers stick to the epithelia of the gill lamellae, thus narrowing the pores, an increase in flow resistance can be anticipated and, therefore, the diffusion of O₂ and other substances results affected.; in addition, mucus secretion by the fish, as a defense mechanism against macromolecular adhesion, would itself increase flow resistance of the viscous water, even further jeopardizing the fish survival.⁹

G. catenatum is a chain-forming dinoflagellate, usually with 8-16 and up to 64 cells, and notorious for its association with Paralytic Shellfish Poisoning (PSP) events worldwide. Its distribution includes cold-temperate, warm-temperate and tropical regions.^{2,6} The optimal conditions for *G. catenatum* growth vary for each strain, making the temperature a determinant variable in the biogeography of the different ecotypes, and in the creation of the optimal environmental window for its seasonal blooms.⁷ Such blooms coincide with upwelling-downwelling sequences within a short-time scale, and recurrence relies on its capacity to produce cysts when the water column conditions are unfavorable.^{7,23} *N. scintillans*, on the other hand, is a heterotrophic, large (up to 1,000 µm), obloid, and luminescent dinoflagellate, also frequently involved in red tide events.⁴ It is considered non-toxic but is responsible for fish and benthic fauna mortalities associated with anoxia and ex-

* Universidad Politécnica de Sinaloa. Paseo de Niños Héroes # 1413 Esq. Constitución, Centro Histórico, Mazatlán, Sinaloa, C.P. 82000.

** Graduate Program. Centro de Investigaciones Biológicas del Noroeste S. C. Apdo. Postal 128 La Paz, B.C.S., México, C.P. 23000.

*** Unidad Académica de Ecología Marina. Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México.

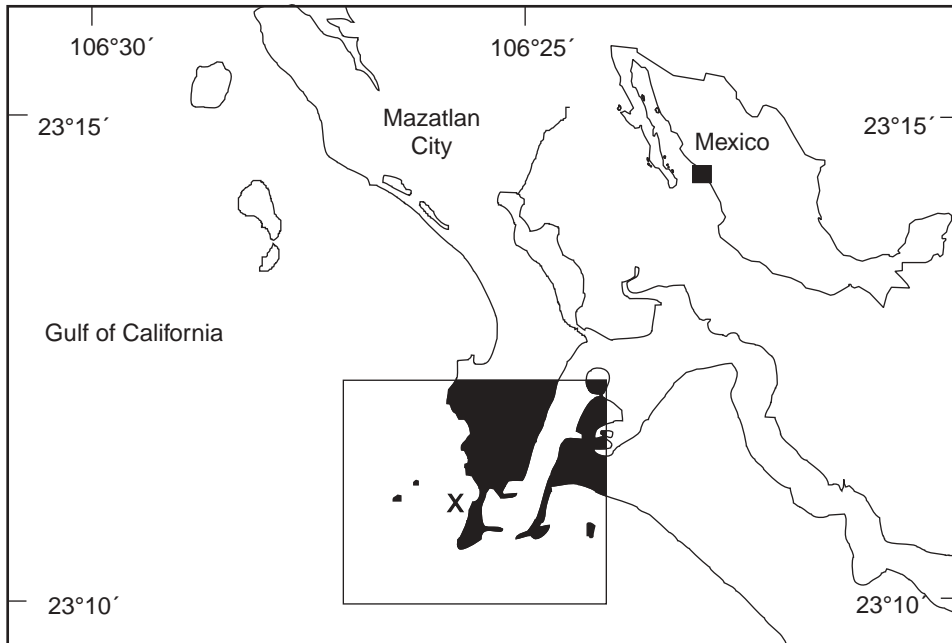


Figure 1. Location of study area and collection site.

creted ammonia produced by this organism.^{5,25} Environmental factors, such as temperature and salinity, determine the extension and intensity of *N. scintillans* blooms, being 21-24°C, and salinities between 21-25 ppt, optimum for growth.¹⁴ At the end of a *N. scintillans* bloom, the large amounts of ammonia concentrated inside the cells promotes their accumulation at the sea surface, thus making them visible as a red tide phenomenon.^{4,18} *N. scintillans* blooms are frequently observed in all major upwelling regions and their sudden decline is related to endogenous circannual rhythms, triggered by light-dark changes and predation by adult copepods and medusae. Temperature, light, wind, and currents, appear to determine the seasonal appearance of *N. scintillans* worldwide.²⁴

In an attempt to characterize the event registered in Mazatlán Bay on January 24-26, 2000, we determine the prevailing hydrological conditions, the composition, and the cell density of the bloom to conclude that, in spite of its low abundance, the preying activity of *N. scintillans* appeared to be the main factor controlling the development of a potentially harmful *G. catenatum* bloom.

MATERIALS AND METHODS

Meteorological and hydrological conditions, such as ambient temperature variation, wind strength and direction, and upwelling index, were determined as recommended by Lluch-Cota.¹³ Surface water samples were collected with a van Dorn sampling bottle and examined by optical microscopy, at 200X and 400X, thus allowing identification of the

most abundant species. Various aliquots were fixed with an acid solution (Lugol 1:100) and stored in 500-ml plastic bottles in darkness for counting. Cell abundances were estimated in a Sedgwick-Rafter chamber (at 40X and 100X), and the cell diameter measured using a scale included in the ocular. Photographs of fixed material were taken with a compound microscope (Mod. ICCA, Leyca, Heerbrugg, Switzerland) using an achromatic light source, a drawing tube, a digital camera (Mod. DMLB, Leyca, Heerbrugg, Switzerland), and an IM1000 software (Leyca, Heerbrugg, Switzerland). Biovolume ratio (*N. scintillans* vs *G. catenatum*), was determined as suggested by Hillenbrand et al.⁸

RESULTS

The conditions prevailing in Mazatlan Bay on January 24-26, 2000 (Fig. 2), showed an ambient average temperature at the sampling site of 19.3°C, with a maximum of 25°C and a minimum of 13°C, at the surface and bottom of the water column, respectively. Wind strength and direction was 1.4 m/sec, NNW, and the low upwelling index estimated (CUI, Coastal Upwelling Index) indicated the situation of a calm conditions day in the area of study. Day length on such a date, provided 10 h of solar incidental light, and was the second highest irradiation of that month. The densities of the most abundant species, *G. catenatum* and *N. scintillans* were 1,300 cells ml⁻¹ (S = 409.06), and 4 cells ml⁻¹ (S = 0.57), respectively. *G. catenatum* cell size distribution was bimodal with specimens measuring between 20-35 μm and 25-40 μm in diameter, while *N. scin-*

tillans cells were 10 times larger (220-500 μm in diameter). With these data, the biovolume ratio of *G. catenatum* vs *N. scintillans* was approximately 1: 10,000.

Photographs in Figure 3c-e indicate the grazing activity of *N. scintillans* on *G. catenatum* during such an event. Unfortunately,

its sudden appearance and briefness, did not allow to record the process of the active feeding of *N. scintillans* over *G. catenatum*, nor to determine the rate of ingestion *in situ*. We presume that the predation of *G. catenatum* by *N. scintillans* contributed to ending the bloom within a short interval.

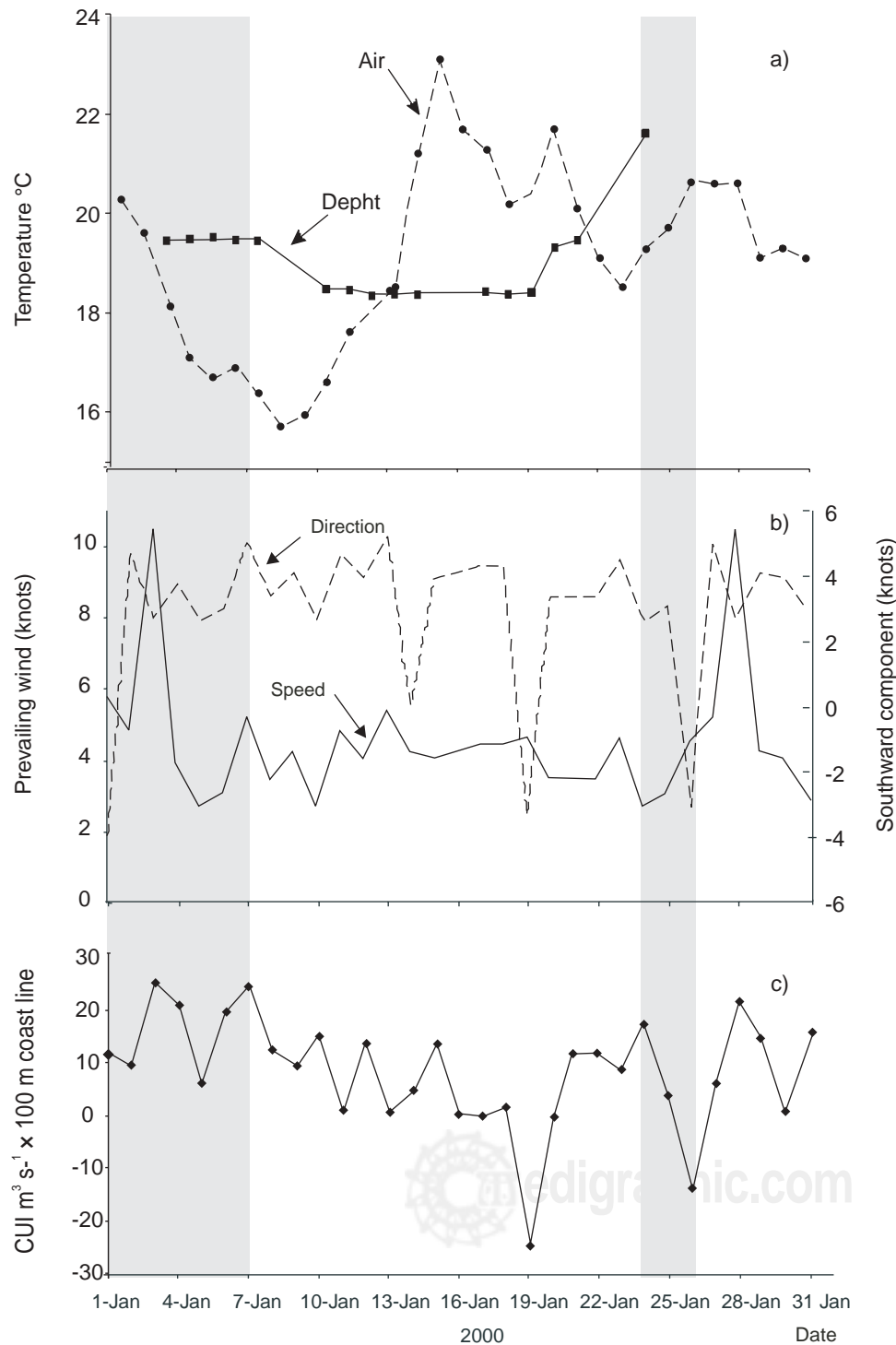


Figure 2. Meteorological and Oceanographic conditions in Mazatlan Bay on January, 2000. (a) Depth temperature; (b) Prevailing wind (speed) and northward component (direction); (c) Coastal Upwelling Index $\text{CUI} \text{ m}^3 \text{ s}^{-1} 100 \text{ m}$. Dashed zone corresponds to red tide events.

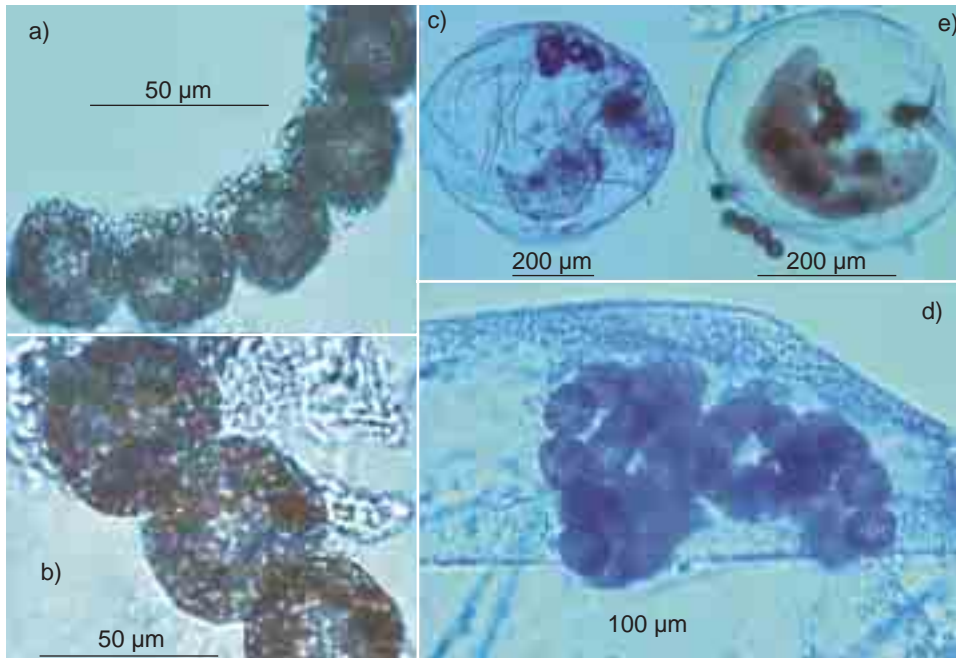


Figure 3. Grazing of *Noctiluca scintillans* on *Gymnodinium catenatum*. (a) A single chain of small *Gymnodinium catenatum* cells (25-30 µm width); (b) A single chain of large *G. catenatum* cells (35-40 µm width); (c) *G. catenatum* cells inside the cytoplasm of *Noctiluca scintillans*; (d) Zoom *G. catenatum* inside *N. scintillans* cytoplasm; (e) *N. scintillans* vacuoles filled with brown amorphous material and *G. catenatum* cells inside and outside the cell.

DISCUSSION

Opposed to previous beliefs that consider *N. scintillans* surface patches as a sign of a decaying population,²⁴ the observation of the red tide event registered in Mazatlán Bay on January 2000, revealed a very active population preying on a simultaneous bloom of *G. catenatum* in terms of feeding. The constant and fast swimming of *G. catenatum* provoked frequent and numerous encounters with *N. scintillans* cells, which then engulfed the chains rapidly. We were able to observe intact brilliant *G. catenatum* chains moving, though rather slowly, inside *N. scintillans* cells. The polyphageous behaviour of *N. scintillans* is well known, however this is the first photographic documentation of its grazing on a *G. catenatum* bloom. The implications of their coexistence could be of much relevance in controlling toxic and noxious red tide events. For example, when compared to *Polykrikos kofoidii* Chatom, which has been tested preying on *G. catenatum* under experimental conditions,¹⁶ *N. scintillans* is capable of engulfing a considerably higher number of *G. catenatum* cells (Fig. 3c-e). Such difference could be due not only to its bigger size (50 µm for *P. kofoidii* versus 200-500 µm for *N. scintillans*), but also to its food preference. About 43% of sampled *N. scintillans* cells in our case showed chains, bodies, or *G. catenatum* cell remains in their cytoplasm. The majority of the chains (84%) consisted of 4 cell units and, therefore, *G. catenatum* ingestion by *N. scintillans* cannot be assumed a mere accident but the result of an intense

feeding activity. In fact, Nakamura et al.¹⁹ have described the grazing of *Chatonella antiqua* Hada by *Gyrodinium dominans* Hulburt at a rate of 3.6-4.8 cells d⁻¹, and Matsuyama et al.¹⁶ found that *P. kofoidii* preys on *G. catenatum* at a rate of 2.7 to 16.2 cells d⁻¹ (an average of 6.3 *G. catenatum* cells d⁻¹). These values, although low, could be meaningful in determining the cessation of a bloom. In our case, despite the larger *G. catenatum* biomass, and compared against *P. kofoidii* preying on a *G. catenatum* bloom,^{11,15,16,21} *N. scintillans* appears capable of inducing the decline of *G. catenatum* population more rapidly, probably as a result of a higher feeding activity or because its capacity of engulfing various cells, and even complete dinoflagellate chains, at one time. This observation rises the question of whether *N. scintillans*, in a moderate concentration, could help to prevent or control the noxious effects of other toxic bloomers. In order to verify such an assumption, the rate of feeding (No. of cells ingested/day) should be evaluated *ex situ*.²⁰ We are in the process of testing such hypothesis.

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Correspondence to:

José Luis Ochoa

Centro de Investigaciones
Biológicas del Noroeste S. C.
Apdo. Postal 128
23000 La Paz, B.C.S., México.
Tel. +(52) 612-123-8484, ext. 3806
E-mail: jlochoa@cibnor.mx