

## DINOFLAGELLATES IN SHRIMP CULTURE PONDS UNDER TYPICAL PRODUCTION CONDITIONS

### Dinoflagelados en estanques de cultivo de camarón bajo condiciones típicas de producción

**RESUMEN.** Durante el cultivo del camarón se busca que las diatomeas sean el fitoplancton preponderante; sin embargo, frecuentemente surgen florecimientos algales nocivos, *v.gr.*, de dinoflagelados. Nuestro objetivo fue identificar los taxa de dinoflagelados presentes y aquellos potencialmente nocivos bajo condiciones típicas de producción en una granja camaronera. Para ello se tomaron muestras mensuales (junio-octubre de 2003) de fondo (microfitobentos) y de superficie (arrastres). Se identificaron 46 taxa de dinoflagelados; los más frecuentes fueron *Proto-peridinium cf. pacificum*, *Scrippsiella trochoidea*, *Prorocentrum minimum*, taxa formadores de florecimientos nocivos; asimismo, se identificaron taxa potencialmente tóxicos (*Prorocentrum rathymum*, *P. micans*, *Dinophysis caudata*, *D. tripos*). En ningún caso hubo problemas en los estanques. Los dinoflagelados fueron menos abundantes al final del ciclo de cultivo del camarón.

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Although the role of phytoplankton in maintaining water quality of shrimp culture ponds is generally accepted, the consequences of its confinement and manipulation are largely unknown in terms of its structure, *i.e.*, floristics, species diversity, and dominance. Thus, the changes in phytoplankton structure that could lead to the onset of harmful algal blooms (HAB) are still uncertain.

Typical physicochemical conditions in shrimp culture ponds depend largely on artificial fertilization, whose purpose is to promote diatom and phytoflagellate proliferation, because a high proportion of diatoms in phytoplankton favors shrimp growth (Gárate-Lizárraga *et al.*, 2009). Nevertheless, adding fertilizers also promotes blooming of harmful non-toxic or toxic species (Delgado *et al.*, 1996; Gárate-Lizárraga *et al.*, 2004). These conditions and typical (desirable) phytoplankton in an adequate abundance have been described on the basis of spatial and temporal variations in species diversity of diatom assemblages found in culture ponds of a shrimp farm during a 24-week (June-October 2003) production cycle in the State of Sinaloa, Mexico (Acevedo-González, 2007). Here, we record the co-occurring dinoflagellate species under the same overall conditions, and identify the potentially harmful non-toxic and toxic species.

This study was carried out in shrimp ponds of the farm Marea Alta Comercial, near the Teacapán-Agua Brava lagoon system in Sinaloa, where intensive production of white shrimp (*Litopenaeus vannamei*) is practiced. Here, during a typical production cycle (June-October 2003) in six selected ponds and in the water supply channel monthly net phytoplankton (60 µm) samples were collected from the surface by doing ten minute tows. Bottom microalgae samples were collected directly along the pond margins using 250 mL plastic jars. All samples were preserved with 4% formaldehyde.

To identify dinoflagellates, fresh preparations were mounted. Samples with excessive organic matter were previously sieved (Matsuoka & Fukuyo, 2000). Sodium hypochlorite and methylene blue were added to observe plate ornamentation. Samples were examined in sedimentation chambers (Hasle, 1978) under an Olympus CK2 inverted phase contrast microscope. Taxonomic identification was done following Balech (1988), Licea-Durán *et al.* (1995), Sournia (1967), Taylor (1976), and Steidinger and Tangen (1997). Taxa propor-

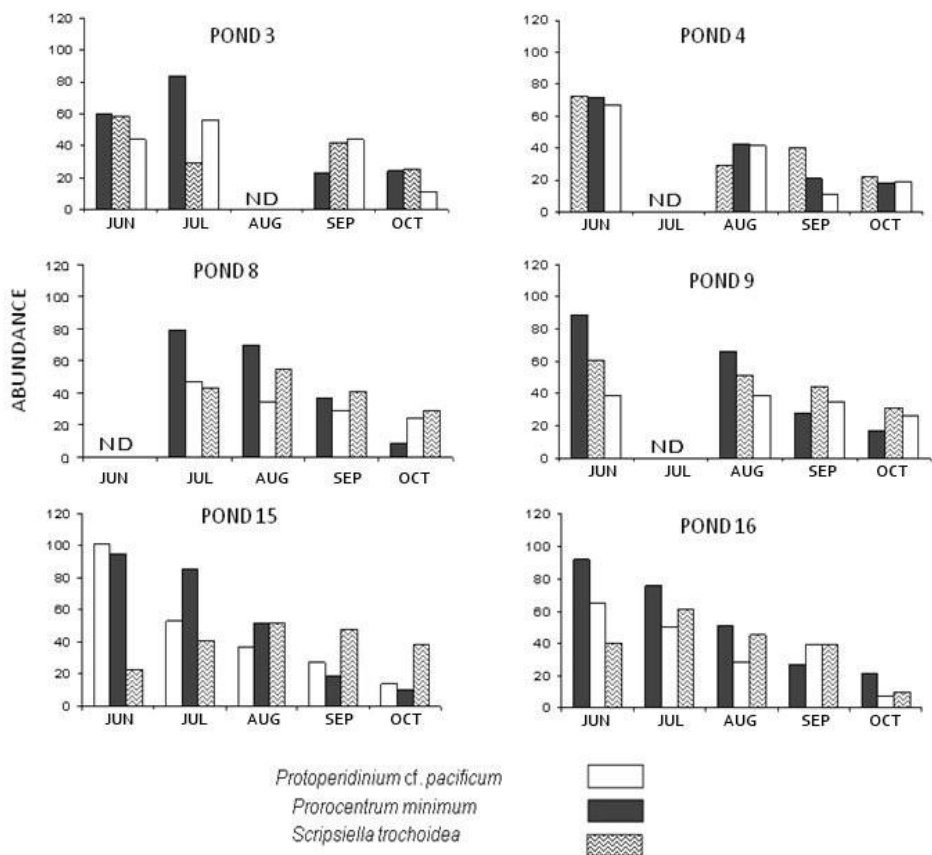
tions were estimated on the basis of N = 250 for each sample, and their time variations were recorded. Finally, potentially harmful and toxic species were identified.

**Bottom samples** contained a total of 46 dinoflagellate taxa included in 16 genera (Table 1). Those comprising 48% of the species were *Ceratium* (16) and *Protoberidinium* (5). The more abundant were *Prorocentrum*, *Scrippsiella*, and *Protoberidinium*, adding >70% to the total abundance. Dominant taxa occurred during June and July, while higher species richness occurred in August along with a decrease in the abundance of the dominant taxa. During September and October dinoflagellate abundances were the lowest (Fig. 1) although species richness varied little.

**Net samples** yielded 40 taxa within 14 genera. Those with higher species richness

were *Ceratium* (14) and *Prorocentrum* (6) with 50% of the species. The dominant *Prorocentrum*, *Protoberidinium*, and *Scrippsiella* accounted for >83% of the total abundance which decreased towards the end of the production cycle. Dominant taxa remained the same as in the bottom samples plus the less abundant *Prorocentrum micans*. In contrast, *Protoberidinium cf. pacificum* occurred more frequently in all the ponds particularly during August. Except for this species, the supply channel showed low abundances in July and August. By September, *P. micans* had become the most abundant taxon.

Although the abundance of dinoflagellate taxa varied somewhat alternatively in both substrata, the lowest abundances occurred towards the end of the sampling period, which corresponds with the highest diversity values estimated for the diatom assemblages in the



**Figure 1.** Monthly variation of the most abundant dinoflagellate taxa (relative abundance) in the culture ponds of Marea Alta during a typical production cycle in June-October 2003.

Table 1. Dinoflagellate taxa collected in the culture ponds of the Marea Alta shrimp farm, Sinaloa, Mexico in June-October 2003.

Taxon	References
<b>Thecate dinoflagellates</b>	
1 <i>Alexandrium</i> sp.	Balech (1988)
2 <i>Blepharocysta splendor-maris</i> Ehrenberg	Balech (1988)
3 <i>Ceratium balechii</i> Meave del Castillo <i>et al.</i>	Meave del Castillo <i>et al.</i> (2003)
4 <i>Ceratium belone</i> Cleve	Licea-Durán <i>et al.</i> (1995)
5 <i>Ceratium breve</i> var. <i>paralellum</i> (Schmidt) Jörgensen	Licea-Durán <i>et al.</i> (1995)
6 <i>Ceratium candelabrum</i> var. <i>candelabrum</i> Sournia	Licea-Durán <i>et al.</i> (1995)
7 <i>Ceratium deflexum</i> (Kofoid) Jörgensen	Licea-Durán <i>et al.</i> (1995)
8 <i>Ceratium falcatum</i> (Kofoid) Jörgensen	Licea-Durán <i>et al.</i> (1995)
9 <i>Ceratium furca</i> (Ehrenberg) Claparède et Lachmann	Balech (1988)
10 <i>Ceratium furca</i> var. <i>furca</i> Sournia	Licea-Durán <i>et al.</i> (1995)
11 <i>Ceratium fusus</i> (Ehrenberg) Dujardin	Sournia (1967)
12 <i>Ceratium kofoidii</i> Jörgensen	Licea-Durán <i>et al.</i> (1995)
13 <i>Ceratium lunula</i> (Schimper ex Karsten) Jörgensen	Licea-Durán <i>et al.</i> (1995)
14 <i>Ceratium macroceros</i> (Ehrenberg) Vanhöffen	Balech (1988)
15 <i>Ceratium massiliense</i> (Gourret) Jörgensen	Balech (1988)
16 <i>Ceratium trichoceros</i> (Ehrenberg) Kofoid	Licea-Durán <i>et al.</i> (1995)
17 <i>Ceratium tripos</i> var. <i>atlanticum</i> (Ostenfeld) Paulsen	Licea-Durán <i>et al.</i> (1995)
18 <i>Ceratium tripos</i> var. <i>pulchellum</i> (Schröder) López ex Sournia	Licea-Durán <i>et al.</i> (1995)
19 <i>Dinophysis caudata</i> Seville-Kent	Licea-Durán <i>et al.</i> (1995)
20 <i>Dinophysis</i> sp.	Balech (1988)
21 <i>Dinophysis tripos</i> Gourret	Licea-Durán <i>et al.</i> (1995)
22 <i>Dinophysis rudgei</i> Murray & Whitting	Balech (1988)
23 <i>Gonyaulax polygramma</i> Stein	Licea-Durán <i>et al.</i> (1995)
24 <i>Gonyaulax spinifera</i> (Claparède et Lachmann) Diesing	Licea-Durán <i>et al.</i> (1995)

same ponds (Acevedo-González, 2007). We also observed that *S. trochoidea* and *P. minimum* were among the most abundant in the same season as in Cortés-Altamirano and Licea-Durán (1999), albeit they recorded the highest diatom diversity towards the end of summer.

Microphytoplankton characteristics (floristics and diversity) vary according to seasons but not in shrimp culture ponds where a dominance of diatoms is mostly desired and should be maintained throughout the production cycle. However, this is impossible due to water recycling and artificial fertilization practices, which alter species composition of phytoplankton in the ponds. Hence, two microphytoplankton assemblages were recorded in the ponds of the Marea Alta shrimp farm at the beginning of the production cycle (June-July). They showed low species richness and diversity related to artificial fertilization (Acevedo-González, 2007), resembling eutrophication processes in the natural environment (Alonso-Rodríguez *et al.*, 2000), and higher

abundance of dinoflagellates in the ponds both in net and bottom samples. Diatom assemblages increased their species richness and diversity values ( $H'$ ) twofold in most ponds from June to September-October (Siqueiros-Beltrones & Acevedo-González, 2010). In this process, dominant diatom abundances decreased sharply and equitability increased, while dinoflagellates decreased their abundances tenfold, down to a few specimens in October. On the other hand, August (start of the rainy period) seems to be a transitional phase when the highest species richness of dinoflagellates was observed, which agrees with an increase in the common diatom taxa and a decrease in the most dominant ones.

Several dominant dinoflagellate taxa recorded in this study are accountable for HAB in other shrimp culture ponds (Table 2). Gárate-Lizárraga *et al.* (2006) indicate that these types of blooms are common throughout several shrimp ponds being operated in Baja California Sur, Mexico. Species responsible for such blooms are *Nephroselmis* sp., *Scrippsi-*

Table 1. Continued

Taxon	References
<b>Thecate dinoflagellates</b>	
25 <i>Goniodoma polyedricus</i> (Pouchet) Drugg & Loeblich	Balech (1988)
26 <i>Heterocapsa</i> sp.	Balech (1988)
27 <i>Ornithocercus magnificus</i> Stein	Licea-Durán <i>et al.</i> (1995)
28 <i>Ornithocercus</i> sp.	Balech (1988)
29 <i>Oxyphysis oxytoxoides</i> Kofoid	Licea-Durán <i>et al.</i> (1995)
30 <i>Peridinium quinquecorne</i> Abé	Balech (1988)
31 <i>Prorocentrum compressum</i> (Bailey) Abé ex Dodge	Licea-Durán <i>et al.</i> (1995)
32 <i>Prorocentrum gracile</i> Schütt <i>Prorocentrum</i>	Licea-Durán <i>et al.</i> (1995)
33 <i>micans</i> Ehrenberg <i>Prorocentrum minimum</i>	Licea-Durán <i>et al.</i> (1995)
34 (Pavillard) J. Schiller <i>Prorocentrum</i>	Licea-Durán <i>et al.</i> (1995)
35 <i>rhathymum</i> Loeblich III <i>et al. Podolampas</i>	Balech (1988)
36 <i>palmipes</i> Stein	Licea-Durán <i>et al.</i> (1995)
37 <i>Protoperidinium conicum</i> (Gran) Balech	Licea-Durán <i>et al.</i> (1995)
38 <i>Protoperidinium elegans</i> (Cleve) Balech	Licea-Durán <i>et al.</i> (1995)
39 <i>Protoperidinium grande</i> (Kofoid) Balech	Balech, 1988
40 <i>Protoperidinium cf. pacificum</i> (Kofoid & Michener) F.J.R. Taylor & Balech ex Balech	Balech, 1988
41 <i>Protoperidinium pellucidum</i> (Bergh) Balech	Licea-Durán <i>et al.</i> (1995)
42 <i>Pyrophacus steinii</i> (Schiller) Wall & Dale	Licea-Durán <i>et al.</i> (1995)
43 <i>Scrippsiella trochoidea</i> (Stein) Loeblich III	Licea-Durán <i>et al.</i> (1995)
<b>Naked dinoflagellates</b>	
44 <i>Gymnodinium catenatum</i> Graham	Licea-Durán <i>et al.</i> (1995)
45 <i>Cochlodinium polykrikoides</i> Margalef	Gárate-Lizárraga <i>et al.</i> (2004)
46 <i>Noctiluca scintillans</i> (Macartney) Kofoid & Swezy	Licea-Durán <i>et al.</i> (1995)

*Ila trochoidea*, *Prorocentrum minimum*, and *Heterocapsa triquetra*, which are likely favored by the high concentrations of artificial nutrients commonly poured into the ponds, especially in summer. On the other hand, a red tide caused by *Ceratium balechii*, *Pseudo-nitzschia* spp. and *Gymnodinium catenatum* (Cortés-Altamirano & Alonso-Rodríguez, 1997) was blamed for a massive mortality of white shrimp nauplii in laboratories of southern Sinaloa in 1997.

Supposedly, the hydrosoluble toxin made its way through the water filter considering that no cells were found in the water pumped from the sea. Meanwhile, another case of massive mortality of shrimp nauplii and adults in February-March coincided with a series of red tides involving *G. catenatum* off the coast of Sinaloa (Gárate-Lizárraga *et al.*, 2002).

The Teacapán-Agua Brava lagoon system shows a high primary productivity

**Table 2.** Harmful dinoflagellates found in culture ponds of Marea Alta Comercial shrimp farm (Sinaloa) in June-October 2003, and their potential effects.

<i>Prorocentrum rhathymum</i>	Hemolytic toxin producer	Nakajima <i>et al.</i> (1997)
<i>Prorocentrum micans</i>	Blooms may cause mortality of fish by oxygen depletion	Horstman (1981)
<i>Dinophysis caudata</i>	Okadaic acid producer; involved in diarrhetic toxin production (DSP)	Fukuyo <i>et al.</i> (1990)
<i>Dinophysis tripos</i>	Produces DTX-1 diophysitoxin involved in DSP	Lee <i>et al.</i> (1989)
<i>Prorocentrum minimum</i>	Certain strains excrete substances toxic to <i>Artemia</i> nauplii. Associated to fish and bivalve mortality; DSP	Grzebyk <i>et al.</i> (1997)
<i>Noctiluca scintillans</i>	Produces concentrated ammonia	Fukuyo, Y. & Y.T. Ishimaru. (1986)
<i>Gymnodinium catenatum</i>	PSP toxin producer; forms red tides	Hernández-Orozco & Gárate-Lizárraga (2006) Gárate-Lizárraga <i>et al.</i> (2004)
<i>Cochlodinium polykrikoides</i>	Ichthyotoxic (hemolytic), ROS Toxin producer	



