

A MULTI-SPECIES MICROALGAE BLOOM IN BAHIA DE LA PAZ, GULF OF CALIFORNIA, MEXICO (JUNE 2008)

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ABSTRACT. Red tide patches were observed in Bahía de La Paz in June 17 and 18 of 2008. According to temperature and wind data this bloom occurred under upwelling-like conditions. Examination of the red tide samples showed the ciliate *Myrionecta rubra* and the naked dinoflagellates *Gyrodinium instriatum* and *Katodinium glaucum* as the main species responsible for this bloom. Total density (microalgae and ciliate) at the sampling stations was similar on both days, varying from 4607×10^3 cells L^{-1} to 4976×10^3 cells L^{-1} on the first day, and from 4172×10^3 cells L^{-1} to 5024×10^3 cells L^{-1} on the second day. Phytoplankton biomass (chlorophyll *a*) observed during the first day of the bloom was 1.5 mg m^{-3} . Dinoflagellates and diatoms were the most numerically important phytoplankton groups. The phytoplankton community showed a high species richness, particularly heterotrophic dinoflagellates and ebridians. The ecological importance of the heterotrophic component of naked dinoflagellates and the ebridians for this bay is discussed.

Keywords: Bloom, *Myrionecta rubra*, *Gyrodinium instriatum*, *Katodinium glaucum*, heterotrophic dinoflagellates, ebridians, silicoflagellates, Gulf of California.

Florecimiento multiespecífico de microalgas en la Bahía de La Paz, Golfo de California, México (Junio, 2008)

RESUMEN. Durante los días 17 y 18 de junio de 2008, se observó una marea roja en la Bahía de La Paz. De acuerdo con los datos de temperatura y de vientos, este florecimiento ocurrió bajo condiciones muy similares a las de una surgencia. El examen de las muestras de marea roja revelaron que el ciliado *Myrionecta rubra* y los dinoflagelados desnudos *Gyrodinium instriatum* y *Katodinium glaucum* fueron las principales especies responsables de esta proliferación. La densidad total (microalgas y ciliado) fue similar en ambos días, variando de 4607×10^3 céls L^{-1} a 4976×10^3 céls L^{-1} durante el primero y entre 4172×10^3 céls L^{-1} y 5024×10^3 céls L^{-1} el segundo día, respectivamente. La biomasa fitoplanctónica (clorofila *a*) medida durante el primer día del florecimiento fue de 1.5 mg m^{-3} . Los dinoflagelados y las diatomeas fueron los dos grupos del fitoplancton numéricamente más importantes. Se observó una comunidad fitoplanctónica con una alta riqueza de especies, particularmente de dinoflagelados y ebridos heterotróficos. Se discute la importancia del componente heterotrófico de los dinoflagelados desnudos y ebridos.

Palabras clave: Florecimiento, *Myrionecta rubra*, *Gyrodinium instriatum*, *Katodinium glaucum*, dinoflagelados heterótrofos, ebridos, silicoflagelados, Golfo de California.

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INTRODUCTION

Over the last 30 years, an apparent increase of harmful algae blooms (HAB) have been recorded in coastal waters around the world. In Mexico, an important number of HAB have also been recorded during the same period. Microalgae blooms are frequent and periodic throughout the year in Bahía de La Paz, in the

southwestern Gulf of California. Frequent blooms have been occurred in this bay since 1984 and more than 40 blooms have been registered with 25 bloom-forming taxa identified (Gárate-Lizárraga *et al.*, 2001, 2006; Gárate-Lizárraga & Muñetón-Gómez, 2008). Frequently new blooming species are recorded; this study is not an exception. Bloom-forming species belong to different phytoplankton

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groups: dinoflagellates, diatoms, raphidophytes, cyanobacteria, and ciliates (*Myrionecta rubra*). This ciliate and naked dinoflagellates such as *Noctiluca scintillans* and *Cochlodinium polykrikoides* are the main species forming blooms in this bay. Generally, a single species is dominant in Bahía de La Paz blooms (Gárate-Lizárraga *et al.*, 2001; 2006; Gárate-Lizárraga & Muñetón-Gómez, 2008). However, in this study we describe a two-day multi-species bloom that occurred in this bay. This prompted the analysis of the hydrographic characteristics, which could initiate this type of bloom. Our hypothesis, thus, indicate that upwelling conditions would be detected by both hydrological and biological (indicator species) ways and that *M. rubra* and *N. scintillans* were the main species responsible for the bloom.

MATERIALS AND METHODS

Bahía de La Paz is the largest coastal water body on the west side of the Gulf of California. It has a constant exchange of water with the gulf through two (northern and southern) mouths (Gómez-Valdés *et al.*, 2003). The main northern mouth of the bay is wide and with a depth of 300 m, while the southern mouth is straight and shallow, associated with a shallow channel of about 20 m deep, and the coastal lagoon (Ensenada de La Paz) which is connected to Bahía de La Paz by a narrow inlet (1.2 km wide and 4 km long), with an average depth of 7 m. On June 17-18 2008 red tide patches were detected in Bahía de La Paz (Station 17; samples A, B, C and D; 24°10.7'N, 110°22.09'W; Station 18; sample A, B, C and D; 24°11.1'N, 110°21.90'W: Fig. 1). Four samples were taken each day with a plastic bucket and fixed with non acid Lugol (Hasle, 1978). Numbers 17 and 18 in Figure 1 indicate the date when samples were taken. Other sub-samples were taken for live phytoplankton observations. Sea surface temperature was recorded. Ciliate and phytoplankton abundance were estimated and species were identified in Uthermöhl sedimentation chambers under an inverted (Zeiss) microscope (Uthermöhl, 1958).

Live samples of the red tide were used for the identification of naked dinoflagellates. Taxonomic determination was done using the following specialized literature: Kofoid & Swezy (1921), Lebour (1925), Schiller (1933, 1937),

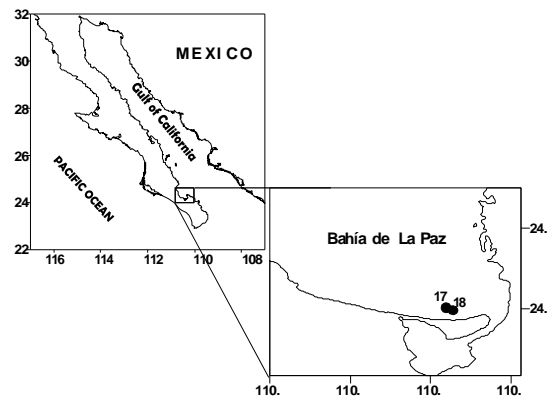


Figure 1. Location of the bloom sampled during 17-18 June 2008 in Bahía de La Paz, Mexico.

Hulburt (1957), Dodge (1982), Murray & Schrader (1983), Elbrächter (1979), Fukuyo *et al.* (1990), Hansen & Larsen (1992), Steidinger & Tangen (1997), Throndsen (1997), and Avancini *et al.* (2006). A SONY Cyber-shot camera (8.1 MP) was used for photographic record given in figures 5 to 68.

In order to know environmental conditions before and after the bloom, wind data (speed and direction) from 2008 were obtained from the automated meteorological station at CIBNOR, ~25 km west of the bloom area (<http://www.cibnor.mx/meteo>). The temperature and chlorophyll *a* data in hdf format, from 2008 images with 4 km resolution, were recorded by the MODIS satellite (www.oceancolor.gsfc.nasa.gov). Daily images of sea surface temperature (SST) were used. The chlorophyll *a* data represent three day composites, with a 4 km resolution, and are limited to the region of Bahía de La Paz.

RESULTS AND DISCUSSION

SST ranged from 18 °C at the beginning of February to 31 °C at the beginning of October (Fig. 2). From June 2th until 20th a marked drop of SST was observed, probably due to changes in the direction and speed of wind. During June, winds came from southeast with average intensity values of 2.7 m s⁻¹ (Fig. 3). Chlorophyll *a* average values were about 2.0 mg m⁻³ during the bloom (Fig. 2). A higher peak with values up to 8.0 mg m⁻³ was observed in January. Another peak was detected before the bloom (~4.0 mg m⁻³) and a small peak of phytoplankton biomass (2.1 mg m⁻³) was observed after the bloom (Fig. 2). The bloom occurred under upwelling-like condi-

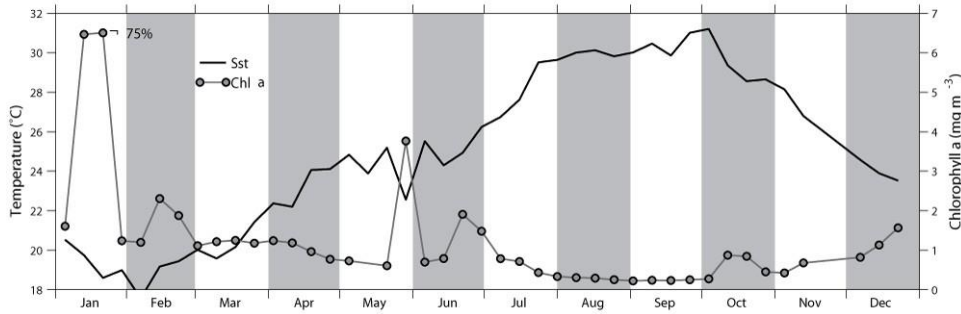


Figure 2. Sea surface temperature (Sst) and chlorophyll a variation during 2008 in Bahía de La Paz, obtained from MODIS-OCEAN satellite database.

tions characteristic of this season (water temperature ~24 °C) (Fig. 2) (López-Cortés *et al.*, 2006), confirming part of our hypothesis. Water temperature were lower than typical temperatures (26 °C –28 °C) registered for this month (De Silva-Dávila & Palomares-García, 2002); however, similar low water temperatures (21 °C –24 °C) have been recorded during this month in this area under similar meteorological conditions (López-Cortés *et al.*, 2006; Gárate-Lizárraga *et al.*, 2007).

Upwellings are common events during late autumn to early spring (Roden & Grooves, 1959). However, a short period of upwelling-like conditions has been reported at the end of spring related to SE winds (López-Cortés *et al.*, 2006; Gárate-Lizárraga *et al.*, 2007; this study). Blooms in Bahía de La Paz during this season (May-June) are regulated by upwelling currents that bring nutrient-enriched water and probably re-suspend dinoflagellate cysts to the surface.

A total of 70 microalgae species and a ciliate (*M. rubra*) were identified in the red tide samples. Dinoflagellates were by far the most important group in abundance and species richness (44 taxa), followed by diatoms (19), silicoflagellates (5), and 2 ebridians (Table 1). The total density (phytoplankton and ciliate) at the sampling stations was similar on both days, varying from $4607 \times 10^3 \text{ cells L}^{-1}$ to $4976 \times 10^3 \text{ cells L}^{-1}$ on the first day, and from $4172 \times 10^3 \text{ cells L}^{-1}$ to $5024 \times 10^3 \text{ cells L}^{-1}$ on the second day (Fig. 4A). Dinoflagellates abundance varied from $1239 \times 10^3 \text{ cells L}^{-1}$ to $1716 \times 10^3 \text{ cells L}^{-1}$ during the first day. An important increase in dinoflagellate abundance was observed in the second day reaching densities from $3979 \times 10^3 \text{ cells L}^{-1}$ to $4706 \times 10^3 \text{ cells L}^{-1}$ (Fig. 4A). Siliceous plankton such as diatoms, silicoflagellates, ebridians, and the dinoflagellate *Actiniscus pentasterias* (Figs. 37-38) were present with abundances from $47 \times 10^3 \text{ cells L}^{-1}$ to $110 \times 10^3 \text{ cells L}^{-1}$ (Fig. 4A). Diatoms were less abundant than dinoflagellates by several orders of magnitude. Abundance of diatoms

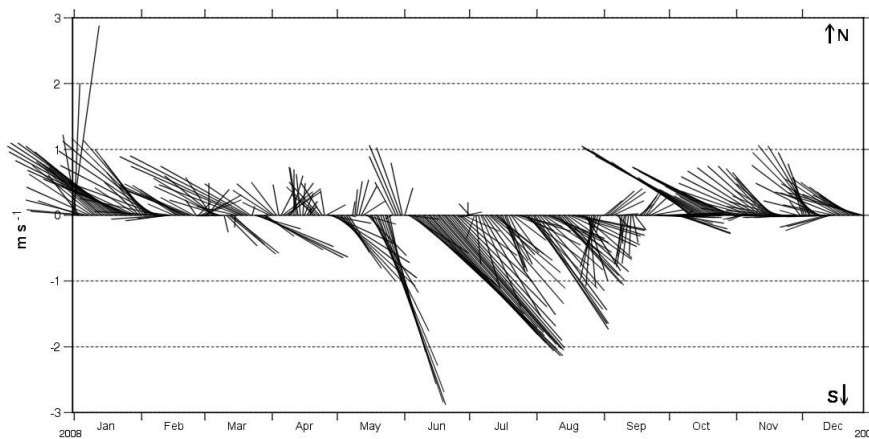


Figure 3. Wind speed recorded by a 9 m sensor during 2008 in Bahía de La Paz, obtained from MODIS-OCEAN satellite database.

Table 1. Abundance ($\times 10^3$ cells L^{-1}) of microalgae species and the ciliate *Myrionecta rubra* found in Bahía de La Paz during a two-day bloom in June 2008. A=Autotrophic, M= Mixotrophic, H= Heterotrophic.

	Throphic state	Samples 17/06/08				Samples 18/06/08			
		A	B	C	D	A	B	C	D
CILIATES									
<i>Myrionecta rubra</i>	M	3420	2850	3100	3400	160	89	120	190
DINOFLLAGELLATES									
<i>Actiniscus pentasterias</i>	H	1	0	0	1	1	0	0	1
<i>Amphidinium acutissimum</i>	H	0	0	0	0	1	2	0	1
<i>Blepharocysta splendor-maris</i>	H	0	0	1	2	0	0	2	3
<i>Brachidinium capitatum</i>	A	0	0	0	0	0	0	2	2
<i>Ceratium azoricum</i>	M	1	0	0	0	0	0	0	0
<i>Ceratium furca</i>	M	4	3	4	0	3	5	1	4
<i>balechii</i>	M	1	0	1	1	2	1	0	0
<i>Cochlodinium polykrikoides</i>	M	12	14	8	6	16	22	12	32
<i>fulvescens</i>	M	4	6	6	2	8	8	4	6
<i>helix</i>	M	0	0	0	0	0	0	4	2
<i>Dinophysis acuminata</i>	M	0	0	0	1	0	0	0	3
<i>Gonyaulax polygramma</i>	M	0	0	0	0	0	0	1	2
<i>Gymnodinium catenatum</i>	M	4	32	14	2	36	12	18	28
<i>Gyrodinium dominans</i>	A	16	12	8	14	42	79	68	26
<i>Gyrodinium instriatum</i>	H	4	6	6	2	2	5	7	2
<i>Gyrodinium falcatum</i>	A	980	833	702	780	3100	3420	3100	3680
<i>Gyrodinium fissoides</i>	H	0	0	0	0	0	0	2	1
<i>Gyrodinium fusiformis</i>	H	0	0	0	0	0	0	2	0
<i>Gyrodinium spp.</i>	H	8	6	4	8	2	9	1	0
<i>Gyrodinium spirale</i>	H	4	6	5	5	0	4	4	40
<i>Gyrodinium submarinum</i>	H	1	4	3	0	27	2	2	30
<i>Karenia mikimotoi</i>	A	1	2	1	0	0	0	0	1
<i>Katodinium glaucum</i>	H	10	12	8	8	17	13	14	20
<i>Kofooidinium velleloides</i>	H	414	750	620	370	620	560	690	714
<i>Lingulodinium polyedra</i>	H	0	0	0	1	0	1	0	0
<i>Metaphalacroma skogsbergi</i>	H	2	0	0	1	0	0	0	0
<i>Pheopolykrikos hartmannii</i>	H	0	0	0	0	1	1	0	1
<i>Polykrikos kofooidii</i>	H	1	6	3	5	35	21	10	20
<i>Polykrikos schwartzii</i>	H	4	4	3	6	0	0	0	0
<i>Prorocentrum lima</i>	A	11	9	6	8	31	14	0	24
<i>Prorocentrum micans</i>	A	0	0	0	2	0	0	1	1
<i>Protoperidinium claudicans</i>	H	1	1	1	2	0	0	0	0
<i>Protoperidinium compressum</i>	H	4	1	1	4	4	60	4	2
<i>Protoperidinium murrayii</i>	H	0	0	0	0	0	0	2	2
<i>Protoperidinium oblongum</i>	H	2	1	0	2	3	5	3	6
		0	0	0	0	0	2	1	0

Table 1. Continued. A=Autotrophic, M= Mixotrophic, H= Heterotrophic.

	Throphic state	Samples 17/06/08				Samples 18/06/08			
		A	B	C	D	A	B	C	D
DINOFLAGELLATES (cont.)									
<i>Protoperdinium</i> spp. <i>Pyrocystis</i>	H	4	4	5	3	2	4	4	2
<i>fusiformis</i> <i>Spatulodinium</i>	H	0	0	1	0	0	0	2	1
<i>pseudonociluca</i> <i>Torodinium</i>	H	0	0	0	0	0	0	2	1
<i>robustum</i>	H	0	2	2	1	6	40	20	45
<i>Warnowia violescens</i>	H	1	1	1	0	0	0	0	1
<i>Warnowia polyphemus</i>	H	1	1	1	2	0	0	2	1
<i>Warnowia pouchetii</i>	H	2	0	0	0	2	0	1	1
DIATOMS									
<i>Achnanthes longipes</i> var. <i>brevipes</i>	A	0	0	0	0	0	0	0	1
<i>Azpeitia nodulifera</i> <i>Asteromphalus</i>	A	1	1	0	0	0	0	0	0
<i>heptactis</i> <i>Asteromphalus</i>	A	8	4	0	6	18	20	14	24
<i>flabellatus</i> <i>Dactyliosolen</i>	A	1	1	1	3	0	0	0	0
<i>fragilissimus</i> <i>Fragilariopsis</i>	A	0	0	4	2	0	0	0	0
<i>doliolus</i> <i>Hemiaulus sinensis</i>	A	0	0	0	0	4	0	0	4
<i>Hemidiscus cuneiformis</i>	A	2	0	2	2	10	8	2	8
<i>Leptocylindrus danicus</i>	A	2	1	1	1	0	0	0	1
<i>Licmophora</i> sp. (on copepod caparace)	A	8	4	2	6	0	12	8	12
<i>Mastogloia</i> sp.	A	0	0	0	0	8	0	1	2
<i>Planktoniella sol</i>	A	0	0	0	0	1	0	0	0
<i>Podocystis adriatica</i>	A	2	0	2	1	1	1	1	1
<i>Proboscia alata</i>	A	0	0	0	0	0	3	0	1
<i>Pseudo-nitzschia</i> spp.	A	2	2	2	0	1	1	1	1
<i>Rhizosolenia hyalina</i>	A	6	5	60	4	11	14	12	8
<i>Thalassiosira</i> spp.	A	20	17	12	24	24	17	6	23
<i>Striatella unipunctata</i>	A	3	12	2	4	1	2	12	28
Non identified diatom	A	0	0	0	0	0	0	2	2
SILICOFLAGELLATES	A	0	0	0	1	0	0	0	0
<i>Dictyocha californica</i>									
<i>Dictyocha fibula</i>	A	0	0	0	2	4	0	1	2
<i>Dictyocha fibula</i> var. <i>robusta</i>	A	0	0	0	2	0	0	0	2
<i>Dictyocha octonaria</i>	H	1	1	1	1	0	0	3	3
<i>Dictyocha pentagona</i>	H	1	0	1	0	1	0	1	1
EBRIDIANs	H	0	0	0	1	0	1	0	2
<i>Ebria tripartita</i>									
<i>Hermesinum adriaticum</i>	H	1	1	2	1	0	0	0	0
TOTAL ABUNDANCE	H	0	0	2	1	0	0	2	2
		4976	4615	4607	4701	4205	4458	4172	5042

varied from 42×10^3 cells L^{-1} to 94×10^3 cells L^{-1} being similar on both sampling days. The

abundance of silicoflagellates and ebridians was lower than 10×10^3 cells L^{-1} .

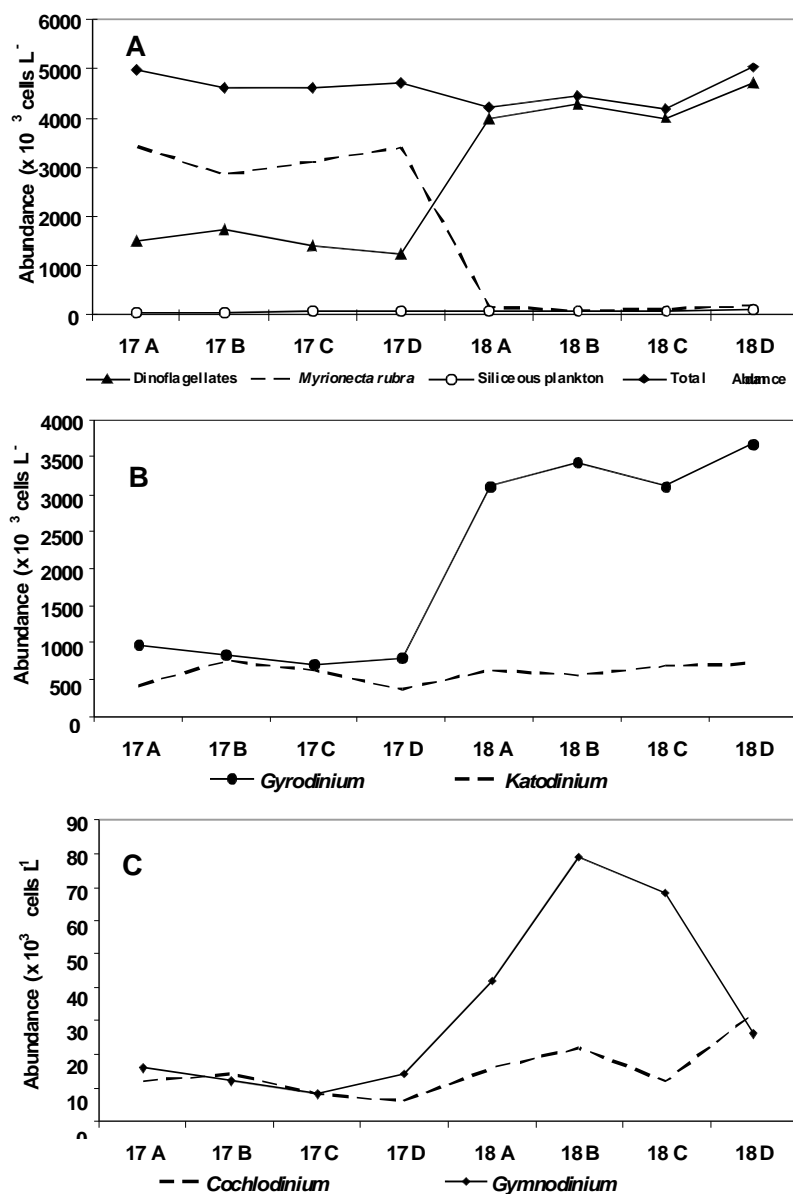


Figure 4. Variation in species abundance in the samples collected during 17 (A, B, C and D) and 18 (A, B, C and D) June 2008 in Bahía de La Paz, B.C.S., Mexico: (A) Main plankton groups; (B) Cell densities of the two main abundant dinoflagellates species; (C) Cell densities of toxic dinoflagellates species.

Confirming another part of our hypothesis, the analysis of qualitative and quantitative aspects of red tide samples revealed that the ciliate *Myrionecta rubra* (Fig. 5) and the two naked dinoflagellates *Katodinium glaucum* (Figs. 6-7) and *Gyrodinium instriatum* (Figs. 8-9) were the main species responsible for this bloom (Table 1). Highest abundances of *M. rubra* were recorded during the first day (3420×10^3 cells L⁻¹), followed by *G. instriatum* (980×10^3 cells L⁻¹), and *K. glaucum* (750×10^3 cells L⁻¹) (Fig. 4B). A shift in the dominant species occu-

red during the second day with highest abundance in *G. instriatum* (3680×10^3 cells L⁻¹), *K. glaucum* (714×10^3 cells L⁻¹), and *M. rubra* (160×10^3 cells L⁻¹) (Fig. 4B). Blooms of *M. rubra* are frequently observed in Bahía de La Paz and in the Gulf of California during winter-spring, particularly after upwelling-like events (Gárate-Lizárraga *et al.*, 2001; 2002; 2006; López-Cortés *et al.*, 2006; 2008). Blooms of this species are very important in terms of the fertility of the coastal zone. Ciliates, including *M. rubra*, are ingested by a va-

riety of zooplankton (copepods) and shellfish (Lindholm, 1985; Sanders & Wickham, 1993; Irigoien *et al.*, 2003), so it is probable that autotrophic and mixotrophic ciliates make an important contribution to coastal food webs.

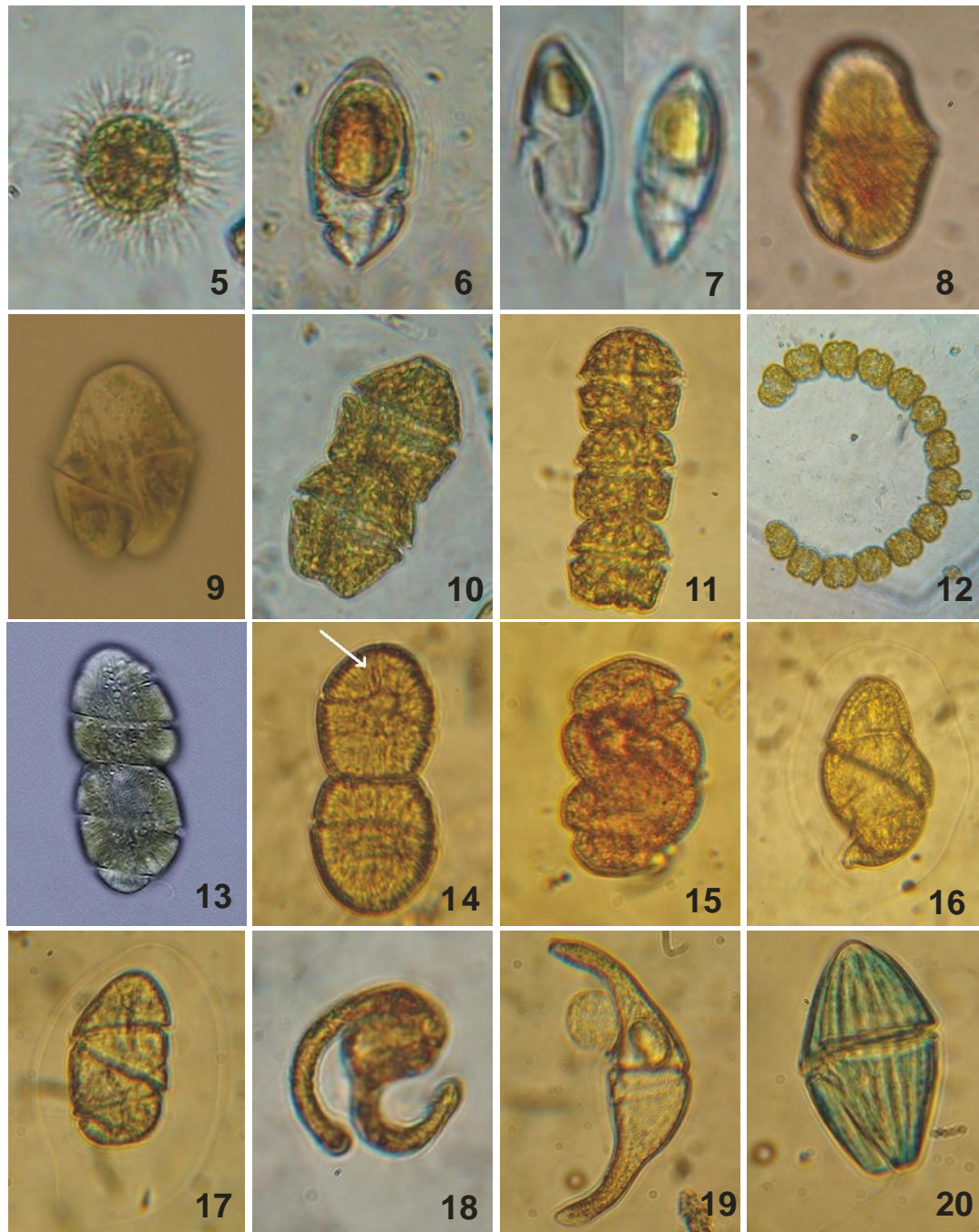
Gyrodinium instriatum is an autotrophic solitary species. Previous blooms of *G. instriatum* have occurred in this bay at the end of summer, reaching high abundances (1.2×10^6 cells L^{-1}) and they have been linked to the breakdown of the thermocline, the nutrient enrichment of water column and the possible transport of cysts to surface (Gárate-Lizárraga unpublished data). *K. glaucum* is a heterotrophic solitary species, however two cell chains were found. This is an easily recognizable species in fresh and Lugol fixed samples. No blooms of *K. glaucum* have previously been reported for the Gulf of California.

A total of 28 species of naked dinoflagellates were found in this study. Two toxic species *Gymnodinium catenatum* (Figs. 10-12) and *Cochlodinium polykrikoides* (Fig. 13) which commonly bloom in Bahía de La Paz were numerically abundant (Gárate-Lizárraga *et al.*, 2004; 2008a, b). The paralytic toxin producer *G. catenatum* (Fig. 4C) reached abundance values of 79×10^3 cells L^{-1} whereas the ichthyotoxic *C. polykrikoides* reached abundance values of 32×10^3 cells L^{-1} (Fig. 4C). Besides *C. polykrikoides*, another three species of *Cochlodinium* were recorded; *Cochlodinium fulvescens* (Fig. 14), *Cochlodinium helix* (Figs. 15-16), and *Cochlodinium* sp. 1 (Fig. 17). *C. fulvescens* was simultaneously reported for the first time by Morquecho & Alonso-Rodríguez (2008) and Gárate-Lizárraga *et al.* (2008a) in Bahía de Mazatlán and Bahía de La Paz, respectively. Abundance of *C. fulvescens* varied from 2×10^3 cells L^{-1} to 8×10^3 cells L^{-1} , whereas *C. polykrikoides* reached abundance values up to 30×10^3 cells L^{-1} . Solitary, two and rarely four-cell chains of *C. fulvescens* were observed in samples; two-cell chains were dominant. Since these two species co-occurred in Gulf of California it is possible that *C. fulvescens* has previously been confused in the routine counting with *C. polykrikoides*. However in our study area it is the first time that *C. fulvescens* is found. Although there is a similarity between these two species, they are easily distinguished by several morphological characteristics, namely cell size, shape of chloroplasts and the position of a narrow sulcus si-

tuated on the cell surface. The sulcus of *C. fulvescens* is located at the intermediate position of the cingulum in the dorsal side, whereas that of *C. polykrikoides* is situated immediately beneath the cingulum (Iwataki *et al.*, 2007).

Many naked dinoflagellates found during this study have been scarcely recorded such as *Brachidinium capitatum* (Figs. 39-40), *Gyrodinium fusiformis* (Fig. 24), *G. spirale* (Figs. 25-26), *Torodinium robustum* (Fig. 42), *Warnowia violescens* (Fig. 32). Some of them are new records for the Gulf of California such as *Amphidinium acutissimum*, *Spatulodinium pseudonoctiluca* (Figs. 35-36), and *Karenia mikimotoi* (not illustrated). Other species like *Cochlodinium helix* (Figs. 15-16), *Gyrodinium dominans* (Figs. 22-23), *G. fissoides* (Fig. 21), *G. submarinum* (Fig. 27), *Warnowia polyphemus* (Fig. 33), and *W. pouchetii* (Fig. 34), are new record for the Mexican Pacific. Some species like *Polykrikos schwartzii* (Figs. 28-29) and *Pheopolykrikos hartmannii* (Figs. 30-31) have been previously reported like cyst stage in Bahía Concepción, Gulf of California (Morquecho-Escamilla & Lechuga-Devéze, 2003). In this study we report for the first time the vegetative stage of *P. schwartzii* and *P. hartmannii* for Bahía de La Paz. Naked dinoflagellates are normally deformed or destroyed with traditional preservation solutions used in phytoplankton sampling. Identification of these dinoflagellate species was possible because of the observation of live phytoplankton. Even during the analysis of fresh samples the identification of dinoflagellates was difficult because they swim quickly and some times they explode under the microscope light. In many cases, that is the reason why no good photographs were obtained and no images of the species are shown in this work.

On the other hand, naked dinoflagellates have a great variation in size and form which difficult their identification. Such is the case of *Gyrodinium dominans*, which varied greatly in size (Length 18 μm - 47 μm and width 10 μm - 22 μm) and form. *G. dominans* surface cells have continuous striations; the number is the same on epicone and hypocone, between 7 and 10 across ventral face (Fig. 22). No chloroplasts were observed. A green color cytoplasm was observed in most of the specimens. All characters above mentioned agree with those described for *G. dominans* by Hulburt (1957) and Fukuyo *et al.* (1990). When cells are dividing the

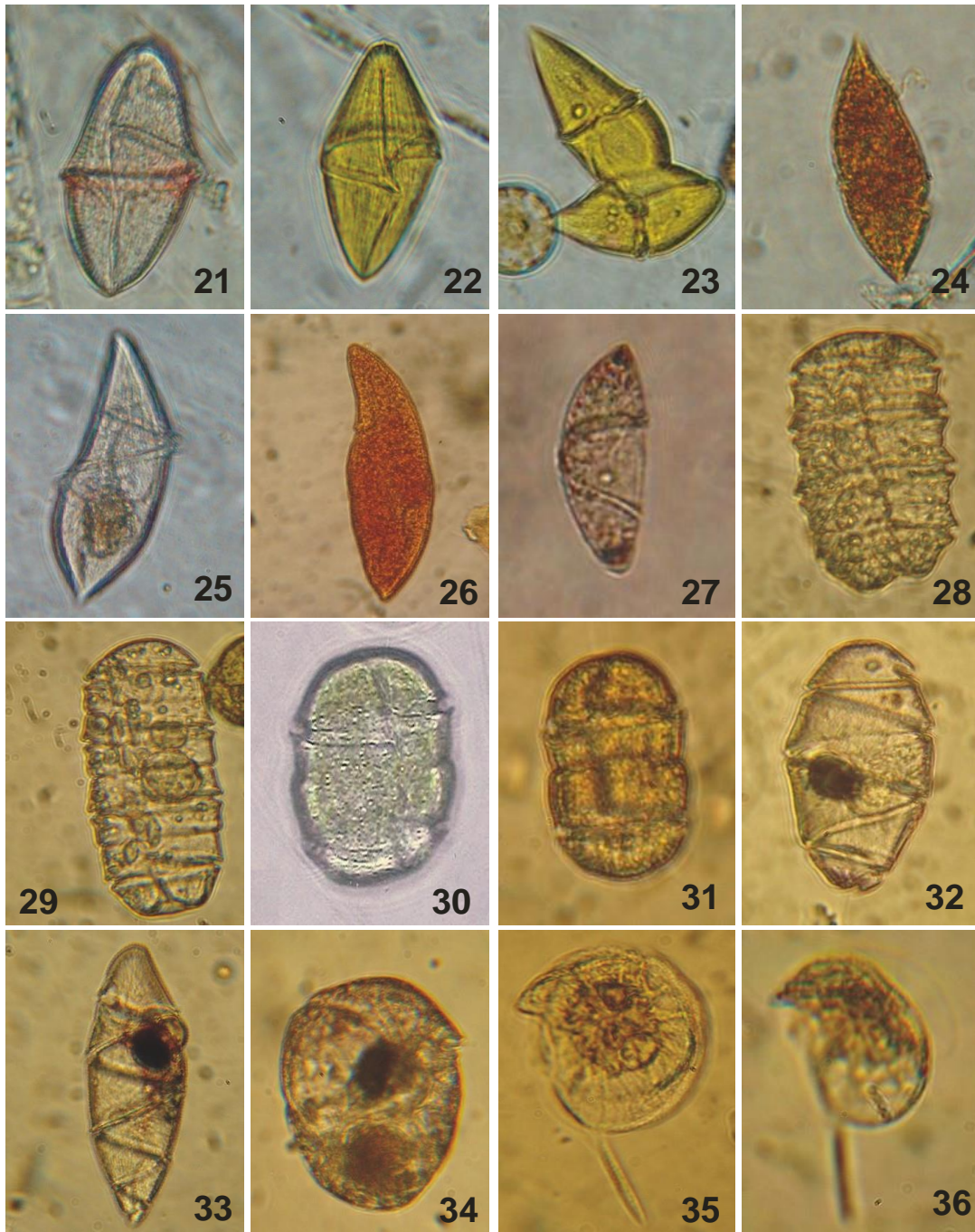


Figures. (5) *Myrionecta rubra*, (6-7) *Katodinium glaucum*, (8-9) *Gyrodinium instriatum*, (10-11-12) *Gymnodinium catenatum*, (13) *Cochlodinium polykrikoides*, (14) *Cochlodinium fulvescens*, (15-16) *Cochlodinium helix*, (17) *Cochlodinium* sp. 1, (18-19) *Gyrodinium falcatum*, (20) *Gymnodinium coeruleum*. The species of figure 15 is Lugol's fixed. Arrow in Figure 14 indicate the reddish orange pigmented

epicone is very conic contrasting with a very round hypocone (Fig. 23).

Five species of silicoflagellates were identified in this period with abundance values lower

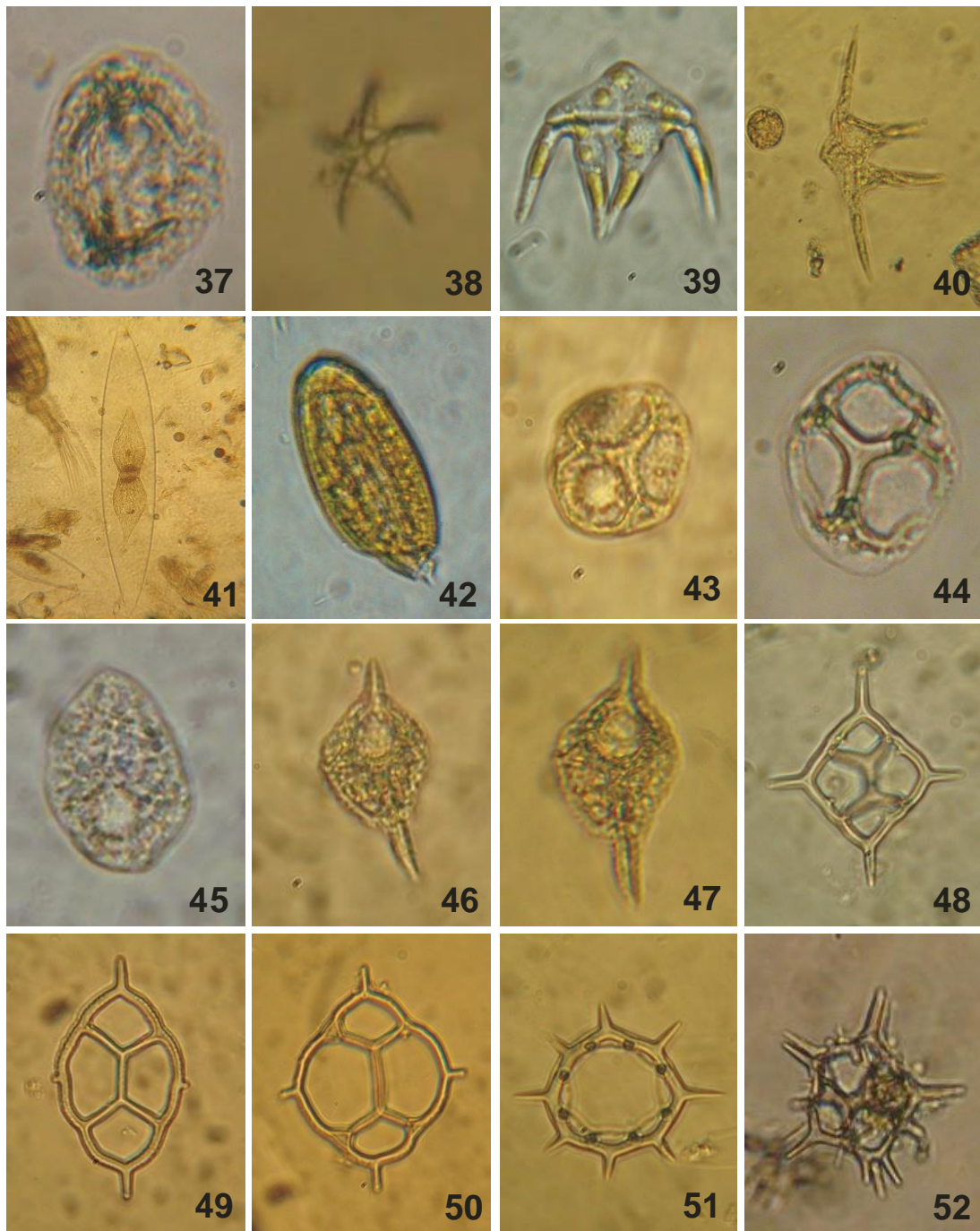
than 6×10^3 cells L^{-1} (Figs. 48-52). Few records of silicoflagellates exist for Bahía de La Paz (Gárate-Lizárraga *et al.*, 2006; Gárate-Lizárraga & Muñetón-Gómez, 2008). During the



Figures. (21) *Gyrodinium fissoides*, (22-23) *Gyrodinium dominans*, (24) *Gyrodinium fusiformis*, (25-26) *Gyrodinium spirale*, (27) *Gyrodinium submarinum*, (28-29) *Polykrikos schwartzii*, (30-31) *Pheopolykrikos hartmannii*, (32) *Warnowia violescens*, (33) *Warnowia polyphemus*, (34) *Warnowia pouchetii*, (35-36) *Spatulodinium pseudonoclituca*. The species of figures 24 and 26 are Lugol's fixed.

occurrence of a red tide of *Noctiluca scintillans* in February 2008 in Bahía de La Paz, the silicoflagellate species *Dictyocha octonaria* (Fig. 51) reached an abundance of 500×10^3 cells

L^{-1} (Gárate-Lizárraga, unpublished data). *D. pulchra* was considered to be indicative of upwelling and high productivity for the Gulf of Ca-

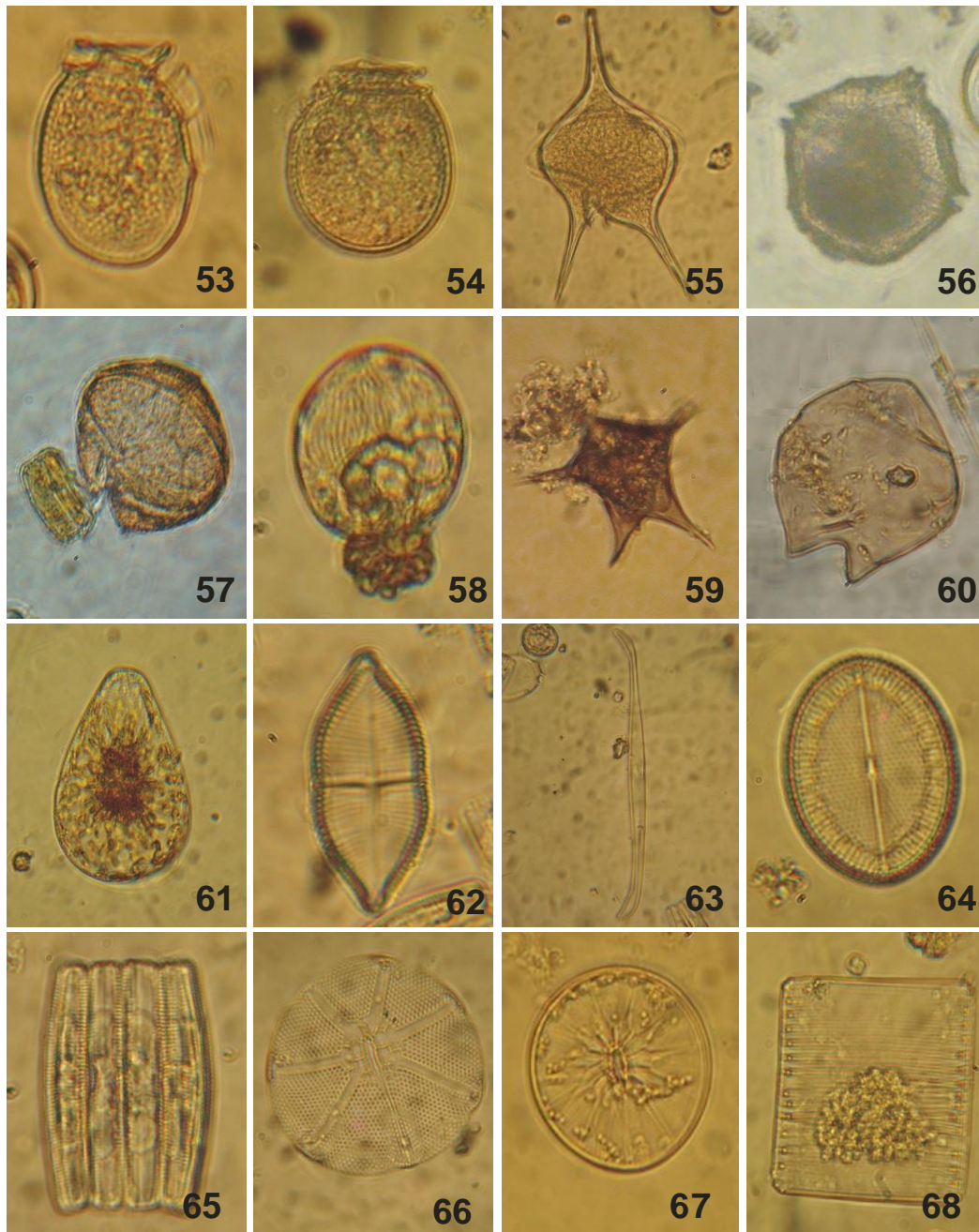


Figures. (37-38) *Actiniscus pentasterias*, (39-40) *Brachidinium capitatum*, (41) *Pyrocistys fusiformis*, (42) *Torodinium robustum*, (43-44-45) *Ebria tripartita*, (46-47) *Hermesinum adriaticum*, (48) *Dictyocha fibula*, (49) *Dictyocha californica*, (50) *Dictyocha fibula* var. *robusta*, (51) *Dictyocha octonaria*, (52) *Dictyocha pentagona*. The species of figures 40 and 41 are Lugol's fixed.

lifornia (Murray, 1982; Barron *et al.*, 2003) agreeing with our results.

The ebridians *Ebria tripartita* (Figs. 43-44-45) and *Hermesinum adriaticum* (Figs. 46-47) are

heterotrophic species and also the first findings for the Gulf of California. Abundance of these species were low (1×10^3 cells L^{-1} to 2×10^3 cells L^{-1}). *E. tripartita* has been previously



Figures. (53) *Dinophysis acuminata*, (54) *Metaphalacroma skogsbergii*, (55) *Protoperidinium murrayi* (56) *Lingulodinium polyedra*, (57) *Protoperidinium* sp. feeding on the diatom *Thalassiosira* sp., (58) *Blepharocysta splendor-maris* feeding on a dinoflagellate, (59) *Protoperidinium compressum* cyst, (60) *Protoperidinium oblongum* cyst, (61) *Podocystis adriatica*, (62) *Achnanthes longipes* var. *brevipes*, (63) Not identified pennate diatom, (64) *Mastogloia* sp., (65) *Fragilariopsis doliolus*, (66) *Asteromphalus heptactis*, (67) *Asteromphalus flabellatus*, (68) *Striatella unipunctata*. The species of figures 55 and 56 are Lugol's fixed.

recorded once in Bahía Magdalena-Almejas lagoon system (Gárate-Lizárraga & Verdugo-Díaz, 2001) and scarcely observed in a few previous samples from Bahía de La Paz (Gá-

rate-Lizárraga, unpublished data). Nevertheless, *Hermesinum adriaticum* is recorded for the first time in this study for the Gulf of California as well as for the Pacific Mexican coasts.

The unusual combination of morphological characters found in ebruids has resulted in a long and muddled taxonomic history. They have been classified as dinoflagellates and silicoflagellates, however at present they are within the Cercozoa (Hoppenrath & Leander, 2006). Ebruids are characterized by having two unequal flagella inserted subapically, a nucleus with permanently condensed chromosomes during interphase, naked cells with no external cell wall and an internal, solid, siliceous skeleton composed of branching or fenestrated rods, which is the best synapomorphy for the group (Hargraves, 2002). Ebruids are of ecological interest since they are herbivorous grazers that occasionally can reach high cell concentrations (Hargraves & Miller, 1974). *Ebria tripartita* has been reported to occur in cold to warm temperate regions and *Hermesinum adriaticum* in warmer waters (Hoppenrath & Leander, 2006); however in Bahía de La Paz they seem to occur in late spring under upwelling-like conditions.

The observation of live samples gave us an opportunity to observe several species of heterotrophic naked dinoflagellates that are otherwise destroyed with traditional preservation solutions or armored species, such as *Protoperidinium* spp. seen feeding on the centric diatom *Thalassiosira* sp. (Fig. 57); *Blepharocysta splendor-maris* seen feeding on *G. instriatum* (Fig. 58) and *Polykrikos* spp. on small dinoflagellates species. Some *Polykrikos* cells were adhered to big *Coscinodiscus* cells. Trophic state of all species found in this study is summarized in table 1. Members of *Protoperidinium*, the largest heterotrophic genus within the peridinioid dinoflagellates acquire their food by means of a pallium (Fig. 57), a pseudopod that enables it to digest algae of its own size (Hansen & Calado, 1999).

Other genera of naked heterotrophic dinoflagellates such as *Gyrodinium*, *Polykrikos*, *Pheopolykrikos*, and *Warnowia* were observed during the examination of live phytoplankton samples. Heterotrophic dinoflagellates have been reported as especially important in the spring, late summer and autumn with mean biomasses representing 15 %, 21 % and 69 %, respectively, of the phytoplankton biomass (Hansen, 1991). In this study, naked dinoflagellates comprised about 60 % of total dinoflagellates abundance and *Katodinium glaucum* comprised from 8 % to 16 % of total dinoflage-

llate biomass. Weston *et al.* (2008) reported that during spring blooms a high number of heterotrophic dinoflagellates, particularly *Katodinium glaucum* and *Gyrodinium spirale* potentially grazed the phytoplankton bloom. The importance of the heterotrophic component of marine dinoflagellates has not been reported previously for any area of the Gulf of California. These findings once again demonstrate the importance of collecting live phytoplankton samples in order to have a closer approximation of the phytoplankton community and to observe species otherwise ignored in traditional phytoplankton monitoring.

The multi-species bloom occurred under upwelling-like conditions characteristic of this season, accompanied by low water temperatures (~24 °C) and southeasterly winds with intensities as high as 2.7 m s⁻¹. Variations in the wind regime due to changes in the position and strength of high and low pressure systems cause short-term variability in upwelling-downwelling cycles within each season (Hickey, 1998). In essence, blooms in Bahía de La Paz during this season (May-June) are caused by upwelling currents that bring nutrient-enriched water and probably re-suspend dinoflagellate cysts to the surface. Germination of cysts and blooms of phytoplankton can be promoted by higher levels of nitrates and phosphates (Anderson & Keafer, 1985). In our samples, some dinoflagellate cysts of *Polykrikos* sp., (see Gárate-Lizárraga *et al.*, 2008a) *Protoperidinium compressum* (Fig. 59), *Protoperidinium oblongum* (Fig. 60), and *Lingulodinium polyedra* (Fig. 56) were found. Some species such as *C. polykrikoides*, *G. instriatum*, *G. catenatum*, *G. polygramma*, *P. hartmannii*, *P. kofoidii*, and *P. schwartzii* are cyst-forming dinoflagellates (Fukuyo *et al.*, 2000). The presence of cysts and cyst-forming dinoflagellates could be related to the upwelling that occurred in the week prior to and during the bloom. On the other hand, the presence of several rare tycho-planktonic or epibiontic diatoms like *Podocystis adriatica* (Fig. 61), *Achnanthes longipes* var. *brevipes* (Fig. 62), *Licmophora* sp., and *Mastogloia* sp. (Fig. 64), in surface water layer samples could be also an indicator of upwelled water. This study reveals the importance of considering the heterotrophic component of the phytoplankton community; further research should be done to understand the com-

plex trophic interactions in the plankton community.

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