The Intergovernmental Oceanographic Commission of UNESCO *October 2003*

HARMFUL ALGAE NEWS

An IOC Newsletter on toxic algae and algal blooms

http://ioc.unesco.org/hab/news.htm

No. 24

• Kenya

A cyano-anomaly? Cyanobacterial toxins as contributors to Lesser Flamingo mass deaths.

Microscopic analysis, over 70 years ago, of the stomach contents of the Lesser Flamingo, *Phoeniconaias minor*, confirmed what is apparent from the birds' ecology, feeding habits and bill structure: they feed on cyanobacteria [1]. The massive populations, at times over a million, of Lesser Flamingo at Kenya's Rift Valley saline, alkaline lakes, receive nutrients and energy from the local blooms of cyanobacteria, mainly *Arthrospira* spp. (formerly termed *Spirulina*). Although flamingos also feed on diatoms and invertebrates, e.g. brine shrimp, it is thought that the cyanobacteria can serve as the sole food of *P. minor.*

Over the past decade, episodic mass mortalities of Lesser Flamingos have occurred at the lakes [2]. The locations involved, including Lakes Nakuru, Bogoria

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• Mexico

First record of *Fibrocapsa* cf. *japonica* in Matanchen Bay, Nayarit, Mexican Pacific coast.

Abstract

In the present study, significative HAB'S bloom was confirmed in Matanchén Bay during Febrary 2003. The Raphidophice *Fibrocapsa* cf. *japonica*, Toriumi *et* Takano 1973 (=*Chatonella japonica*) has dominated (97%) red tide event occurring lately in coastal waters of Nayarit state, with high cell concentration of 4-6 millions of cells per liter of water. The duration of this bloom could not be determined exactly due to limiting sampling. There have been no reports of fish kills or human intoxication in the locality. This study represents the first survey on the distribution of *Fibrocapsa* cf. *japonica* in the Mexican Pacific coast. The finding adds Raphidophyceans to the list of harmful algal blooms and toxin producers in Mexico.

Key words: Fibrocapsa cf. *japonica*, Raphydophyte, Harmful algal bloom (=HAB) blooms, Nayarit State, Pacific Mexico.

Introduction

Routine phytoplankton monitoring in Matanchén Bay has revealed the presence of several discolorations on February 2003, however the duration of this bloom could not be determined exactly from beginning to lasting due to limiting samples. The discoloration was concentred in the middle of the bay near to Aticama village and Arrollo de La Palma turning seawater reddish-brown appearance. Matanchén Bay extends from 21° 25' 24" and 21° 30' 40" latitude N and 105° 12' 00" and 105° 15' 00" longitude W, a little below the Tropic of Cancer. The rain precipitations are in the order of 1000 to 1500 mm per year with climate warm and sub-humid with rains in summer. This Bay of Mexico is under the influence of fresh water particularly from San Cristóbal estuary in the north, Sauta River, Arroyo De La Palma and Santa Cruz River (Fig. 1).

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The publication of Harmful Algae News is sponsored by the Botanical Institute University of Copenhagen, and the Spanish Institute of Oceanography, Vigo.

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and Elmenteita, are important national wildlife and tourism resources. They are also subjected to increasing human pressures as receiving waters for anthropogenic diffuse and point pollution. Multiple factors are thought to be involved in the mass die-offs, including septicemia, avian tuberculosis, pesticides and heavy metals. Environmental analyses, feeding and body burden estimates have indicated that heavy metals would not have been sufficient alone to account for the deaths.

Analyses of flamingo carcass livers and cyanobacterial samples from Lakes Bogoria and Nakuru were carried out at both the Leibniz Institute for Freshwater Ecology and Inland Fisheries in Berlin, in the framework of the BIOLOG (Biodiversity and Global Change) programme of the German Federal Ministry of Education and Research and at the University of Dundee with support from the UK Natural Environment Research Council. Both groups of investigators found cyanobacterial toxins in dead flamingo livers: two hepatotoxins (microcystin-LR and –RR) and the neurotoxin, anatoxin-a, at estimated harmful concentrations [3]. The total extractable microcystin concentrations in the bird livers were 0.21 to 0.93 µg microcystin-LR equivalents, and that of anatoxin-a, 1.06 to 5.82 µg per g fresh weight. These toxin concentrations may have been sufficient alone to have caused the bird deaths, that of anatoxin-a being consistent with observations of staggering and convulsions in the flamingos before death and with opisthotonus, post-mortem.

Our investigations indicate that the microcystins and anatoxin-a should be included among the major agents contributing to the bird deaths. The only known sources of these toxins are cyanobacteria and it follows that the exposure of the flamingos to the toxins is largely via their diet. Further research with materials from Lake Bogoria Lesser Flamingos has identified the hepato- and neurotoxins in bird stomach and intestine contents and faecal pellets [4].

Shifts in cyanobacterial bloom composition, towards toxigenic genera, perhaps due to human intervention, could present the birds with an additional poisoning hazard. This may have occurred at Lake Nakuru, where the plankton population changed from one dominated by *Arthrospira* to one dominated by *Anabaenopsis* and *Anabaena* spp. [3]. The latter two genera include microcystin-producing species/strains and anatoxin-a can be produced by *Anabaena* spp. In addition, the birds may be exposed to cyanobacterial toxins other than via their primary food. At Lake Bogoria, the Lesser Flamingos drink in the vicinity of hot springs on the lake margin, where salinity is lower. The cyanobacterial mats around the hot springs include genera with toxigenic members (*Oscillatoria*, *Phormidium*; [4]) and it is possible that the flamingos may be exposed to the toxins via incidental ingestion of detached cyanobacterial mat biomass and/or drinking from the water nearby.

Mass die-offs of Lesser Flamingos do not appear to have been recorded during earlier decades of intensive study at these lakes [1, 5, 6], suggesting that the mass mortalities of the 1990s are relatively modern phenomena [2]. The extent to which increasing modern pressures from visitor numbers upon the breeding colonies, and pollution input from industry and agriculture interact with microbial threats to bird health, is a complex problem. The production of cyanobacterial toxins in the lakes and their presence in birds, dying after displaying typical signs of intoxication, indicate that their primary food can present benefits and costs. The characteristics of the toxigenic cyanobacteria in the lakes, and their regulation, require investigation to further understand the multiple influences upon the health and population dynamics of the Lesser Flamingo.

References

1. Jenkin, P.M., 1929. Nature 124: 574.
2. Bennun, L. & O. Nasirva, 2000. Ostrich 71: 220 -226.
3. Ballot, A., *et al*., 2002. *In*: Abstracts, Xth International Conference on Harmful Algae, Oct. 21-25, St. Pete Beach, Florida, p. 20.
4. Krienitz, L., *et al*., 2002. FEMS Microbiology Ecology. 1437: 1-8.
5. Jenkin, P.M., 1957. Philosophical Transactions of the Royal Society of London B, 240: 401-493.
6. Brown, L.H., 1975. *In*: Flamingos. Kear, J. & N. Duplaix-Hall (eds.), T & AD Poyser, Berkhamsted, UK, pp. 38-48.

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• International

X HAB Model Group

At the tenth international conference on harmful algal blooms (HABs) at St. Pete Beach, Florida a special session on MODELS AND MYTHS was convened by J.J. Walsh on 23 October 2002. This workshop addressed the status of ecological modeling of HABs, from simple concepts of one dimensional processes that must be considered in any process model to three dimensional computer homomorphs of the "real world", where circulation models drive those of plankton competition. Ted Smayda presented an insightful introduction on "Models we should build". Present "Models we have built" on the Bay of Biscaye, Gulf of Maine, and the West Florida shelf were then discussed by Patrick Gentien, Dennis McGillicuddy, Bob Weisberg, and John Walsh. Topics varied from actual model results to future constraints in modeling HABs, i.e., initial conditions, data assimilation algorithms, sampling networks, and validation methods. These oral presentations will be part of the written proceedings of the conference.

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Surface phytoplankton samples was taken from central bay region of Matanchén Bay on February 21 and 23, 2003. The samples were stored in a 250 ml plastic bottle, and then preserved with Lugol-acetate solution. Live whole specimens were analyzed using light microscope from which photographic records were made. Phytoplankton abundance was determinate by the standard Utermohl technique [1], and algal quantification, was made with 100x magnifications in aliquots of 10 ml using a 1 mm^2 scale Wipple disc with double cross pattern of 100 µm. Temperature was registered with a 0.1°C precision bucket thermometer and salinity was analyzed with a 1 psu precision refractometer.

Sampling results from identification and phytoplankton abundance during the bloom (Table 1) indicate 97% of total dominance of *F.* cf. *japonica* from over all community, although was associated with 27 species those represent only 3%. The identification of *F.* cf. *japonica* was based on morphological examination *in vivo* specimens which shape was spherical (possibly cyst stage) to ovoid. The vegetative cells showed their two characteristic flagella emerging from an anterior gullet and the mucosysts in posterior region consistent with the description of Loeblich III & Fine (1977) and Hara (1990) [2,3]. Another evident characteristic was the number and organization of chloroplasts (Fig. 2) and the spherical cell size of 15 µm, whereas in ovoid cells was 15-22 µm long and 15-17 µm wide. Living cells were fragile and difficult to preserve changing the body shape immediately, they can die in few minutes under light microscope. In addition this alga can be somewhat pleomorphic (it can have varied shapes).

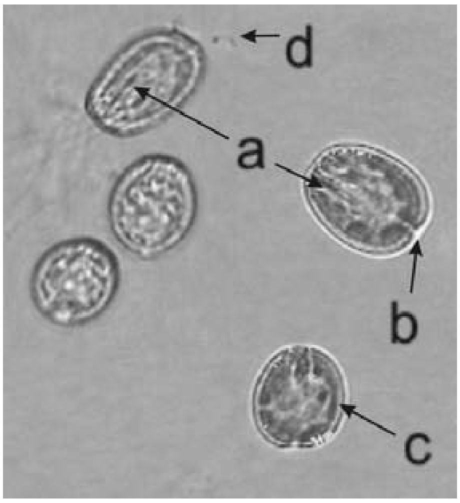

Fig. 2. Images of Fibrocapsa cf. japonica observed in living conditions. a)mucocysts b)gullet, c)chloroplasts arrangement d)flagella.

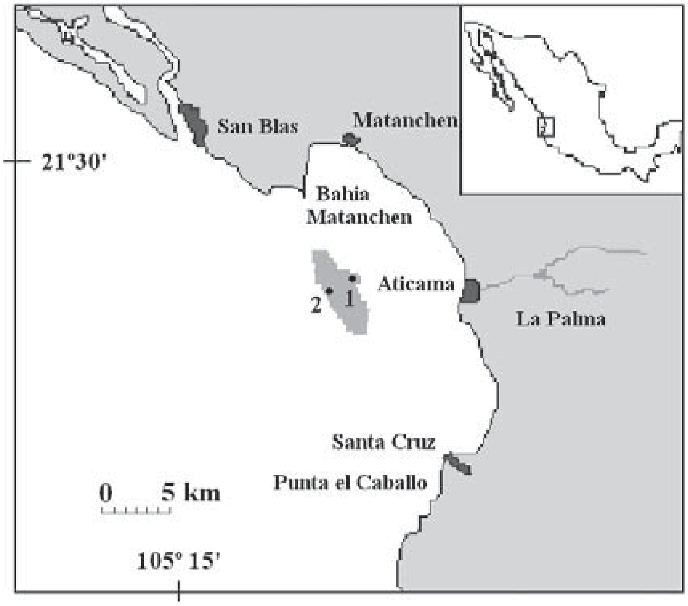

Fig.1. Map showing the study area of Matanchen Bay in Nayarit State México with location of sampling station and presence of discoloration.

There have been no reports of fish kills or human intoxication in the locality although high proliferation of this specie in marine water may cause serious issues in fish industry and local aquaculture. No harmful algal bloom events have been recorded in coastal Nayarit State [4,5]. This occurrence is the first identification and published record of *Fibrocapsa* cf. *japonica* in Mexican Pacific littoral extending their distribution to warm temperature regions. Although this specie has been detected in Point Loma San Diego California Bay [2] correspond to USA (32° latitude N), so similar than those of Japan (30°-35° latitude N) where reach large numbers. Here we found it, in warm and more temperature water >26°C and >34 psu salinity. Hence it is reasonable to assume the presence as an invader specie traslocated by their resting cysts now adapting in this region, or also as new specie. However, to prove it is necessary to know the cellular ultraestructure in electronic microscopy and compare with known species.

Toxic Raphidophyceae have been documented from other geographical regions of the word: coastal waters of Japan, Australia, New Zealand, Brazil, north-western Europe, California and Florida but, is in Seto Inland Japan where the populations showed devastating effects on mariculture [6]. Date no reported indicate fish mortality in Baja California Sur (Mexico) due Raphidophyceae in Todos Santos municipality of La Paz on July 22, 1999. So far, a few years ago flagellate resembling Chatonella sp. were recorded in water samples from Cabo San Lucas zone (Lat. 22° 30' N, Long. 110° 30' W) on march 1996 without blooming [7].

Toxicity PSP analysis by bioassay and chromatographic techniques was carried on by the Center for Biological Research (CIBNOR) with negative results, and conclude that the testing were not able to detect the presence of toxins. Recently in 2001 have been also reported fish kills in same geographical area of Nayarit State due Raphydophyceae assuming *Chattonella* cf. *antiqua* (Sierra-Beltrán, pers. comm.). Furthermore, a researcher from a red tide working group who usually visit this area, has been recognized the specie but in very low abundance (Gómez Aguirre, pers. comm.). The presence of these species in Nayarit State is particularly significant since they are known as NSP producers or brevetoxins-like compounds (named fibrocapsin) and to be the cause of fish kills [8].

It's clearly dominated the culture of this microalge and in unfavorable environmental condition induce cyst or non-motile spherical cells, very common feature in our samples. The precise mechanism behind the ichtyotoxic effects of the Raphidopyceae is still under debate and could be a combination of the different toxins. Furthermore, recent studies demonstrated that this microorganism flagellate is one of the reactive oxygen species (ROS), which generates superoxide O-(/)2 and hydrogen peroxide H_2O_2 under normal condition and may causes severe damage to fish [9]. Their results suggest that the generation of reactive oxygen species (ROS) is a common feature of this alga. There are no specific thresholds or critical values for the number of cell that pose a health risk. The abundance reported here occurred with cell numbers reaching 4 to 6 million cells L^{-1} and should be considered as higher cell concentrations, hence is necessary to determine toxicity of the organism under consideration. This survey on the alga *Fibrocapsa* cf. *japonica* indicate that currently environmental conditions are conductive to exceptional *Fibrocaspsa* cf. *japonica* bloom formation.

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Table 1.- Microalgal abundances form Matanchén Bay bloom.

species	Feb-21-03 cels.ml^{-1}	%	Feb-23-03 cels.ml^{-1}	%
Fibrocapsa japonica	4,751	97.13	6230	97.66
Thalassionema nitzschioides	3.1	0.06	141	2.21
Coscinodiscus granii	0.4	0.01	0.3	0
Nitzschia closterium	73.1	1.49	0.7	0.01
Gyrosigma sp.	0.3	0.01	0.3	0
Pseudonitzschia sp.	0	0	1.4	0.02
Amphora sp.	0	0	0.1	0
Chaetoceros sp.	0	0	0.5	0.01
Navicula sp.	0.2	0	0.2	0
Thalassiosira sp.	0.2	0	0.8	0.01
Proboscia alata	0	0	0.1	0
Skeletonema costatum	0	0	2.1	0.03
Biddulphia mobiliensis	0	0	0.1	0
Leptocylindrus danicus	0.5	0.01	0	0
Detonula pumila	0.1	0	0	0
Protoperidinium nanum	51.6	1.05	0	0
Scrippsiella trocoidea	4.8	0.10	0.4	0.01
Peridinales	2.3	0.05	0.2	0
Ceratium falcatum	0	0	0.1	0
Prorocentrum gracilis	0	0	0.2	0
Gonyaulax spinifera	0.8	0.02	0	0
Dinophysis rotundatum	0	0	0.1	0
Gyrodinium sp	2	0.04	0	0
Silicoflagellate	0.3	0.01	0	0
Ciliate:*Mesodinium rubrum*	0.1	0	0.1	0
Euglenophyte	0	0	0.2	0
Cianophyceae	0.8	0.02	0.4	0.01
total	4,892	100	6379.3	100.00

Due to its high toxicity and periodic appearance, is essential for Nayarit local goberment increase scientific investigation of the autoecology of *Fibrocapsa* cf. *japonica* (or new specie) to minimize further impacts and damage on fisheries, aquaculture and healty ecosystems.

Acknowledgements

The authors would like to tank M.C. Sergio Gustavo Castillo Vargasmachuca and coleagues from Facultad de Ingenieria Pesquera de la Universidad Autónoma de Nayarit, México for providing the phytoplankton sample and chemical data. We are specially grateful to Arturo Sierra Beltrán from CIBNOR for his support and suggestion in this study.

References

1. Hasle, G.R., 1978. *In*: Sournia, A. (ed.) Phytoplankton Manual, UNESCO, Paris, Francia, pp. 191-196
2. Loeblich III, A.R. & K.E. Fine, 1977. Proc. Biol. Soc. Wash. 90 (2): 388-399.
3. Yoshiaki, H., 1990. *In*: Fukuyo *et al*. (eds.), Red Tide in Japan- An illustrated Taxonomic Guide-. Uchida Rukakuho, Tokio, Japón, pp. 344-345.
4. Cortés-Altamirano, R. *et al*., 1996. *In*: Yasumoto, T; *et al.* (eds.), Harmful and toxic algal blooms. Intergovernmental Oceanographic Commision of UNESCO, pp. 101-104.
5. Gómez-Aguirre, S., 1998. Anales Inst. Biol. Univ. Nac. Autón. México, Ser. Zool. 69 (1): 13-22.
6. Hallegraeff, G.M., 2002. *In*: Aquaculturists' Guide to Harmful Australian Microalgae. School of Plant Science, University of Tasmania, Hobart, Tasmania, Australia. 136 pp.
7. Ochoa, J.L., *et al*., 1997. Hidrobiología 352: 195-200.
8. Onoue, Y. & K. Nozawa,1989. *In*: Okaichi T., *et al*. (eds.). Red Tides: Biology, Environmental Science and Toxicology, Elsevier, New York, pp. 371-374.
9. Oda, T., *et al*., 1997. Contest and Abstracts off latest Issue of Bioscience, Biotechnology and Biochemistry, 61 (10): 1658 pp. *In*: Proceedings X COLACMAR, San José, Costa Rica. 22-26/ septiembre/2003.

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• USA

ECOHAB PNW, A New West Coast, USA, Multidisciplinary Program

ECOHAB PNW is a new project whose goal is to study the physiology, toxicology, ecology and oceanography of toxic *Pseudo-nitzschia* species off the Pacific coast of Washington (WA) and British Columbia (BC). The project is funded jointly by the Division of Ocean Sciences NSF and by NOAA's Coastal Ocean Program. Recent studies suggest that the seasonal Juan de Fuca eddy, a nutrient rich retentive feature off the WA-BC coast, serves as a "bioreactor" for the growth of phytoplankton, including diatoms of the genus *Pseudo-nitzschia* (Fig.1). Specific study objectives are: 1) To determine the physical/biological/chemical factors that make the Juan de Fuca eddy region more viable for growth and sustenance of toxic *Pseudo-nitzschia* than the nearshore upwelling zone; 2) To determine the combination of environmental factors that regulate the production, accumulation, and/or release of domoic acid (DA) from *Pseudo-nitzschia* cells in the field; and 3)

To determine possible transport pathways between DA initiation sites and shellfish beds on the nearby coast. A summary of results leading to the formation of this new program and a description of the research plans are given below. The ECOHAB PNW team welcomes collaboration with other interested scientists. For more detailed information about our program please visit our website at http://www.ecohabpnw.org.

Background

While DA poisoning was first recognized in an outbreak on Prince Edward Island, Canada [1], most of the known toxic events since that time have occurred on the U.S. west coast. DA was first implicated in the illness and death of brown pelicans and Brandt's cormorants in Monterey Bay, California in 1991 [2]. About one month following the toxic bloom in California, levels of DA above the regulatory limit of 20 mg/g shellfish tissue were found in the edible parts of razor clams (*Siliqua patula*) and Dungeness crabs (*Cancer magister*) on the Washington coast [3]. In 1998, impacts of DA to the health of marine life and to the fisheries economy were documented in several regions along the west coast. In particular, California sea lions (*Zalophus californianus*) in central California were severely affected by DA poisoning [4] and high levels of toxin in razor clams in Oregon and Washington resulted in beach closures for more than a year and a half [5].

Beach and harvest closures resulting from the toxigenic *Pseudo-nitzschia* blooms have a severe economic impact on both coastal economies and on tribal communities. In 1991, the closure of Washington State beaches to recreational and commercial shellfish harvesting resulted in a $15-20 million revenue loss to local fishing communities [6]. The commercial Dungeness crab industry on which Washington's Quileute tribe depends for employment lost 50% of their income in 1998 due to harvest closures. The entire razor clam harvest of the Quinault tribe, on which they depend for both subsistence and commercial revenue, was also lost in the fall of 1998 [7]. Razor clam beaches have again been closed this winter and spring (2003) and devastating economic impacts have resulted in an estimated $10 million loss to the recreational razor clam industry alone. With sufficient warning, tribal fishers could seek alternative buyers for eviscerated crab, and shellfish managers might have longer lead times to schedule closures. Moreover, mitigation strategies to reverse or moderate cell toxicity may soon be available [8].

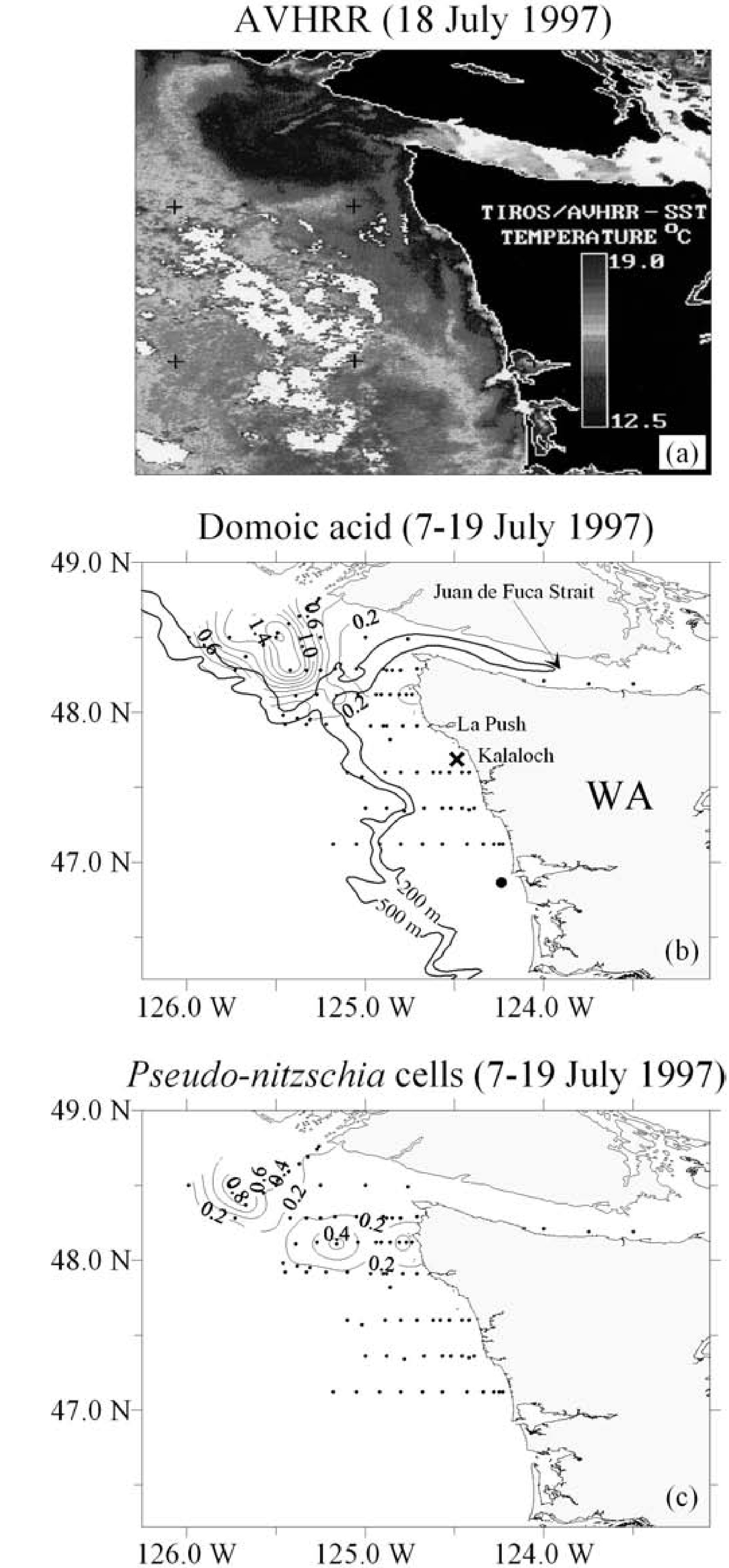

Fig. 1. Satellite-derived sea surface temperature, particulate DA (mg/L) and total Pseudo-nitzschia *cell numbers (10^6 cells/L) in surface seawater in July 1997 (Trainer et al., 2002). Dots represent all sampling stations where DA measurements and* Pseudo-nitzschia *cell counts were made. Spatial patterns show a coincidence of colder temperature, higher DA and greater numbers of* Pseudo-nitzschia *cells offshore of Juan de Fuca strait. The colder offshore water is indicative of the Juan de Fuca eddy. Colder water next to the Washington coast is indicative of local upwelling at the coast.*

Both the species of *Pseudo-nitzschia* (including *P. multiseries*, *P. australis*, and *P. pseudodelicatissima*) and the relative levels of toxicity [4, 9, 10, 11, 12] vary in time and space along the west coast of North America. Moreover, it is not uncommon for potentially toxic *Pseudo-nitzschia* cells to be present without detectable DA [8, 11]. The environmental regulation of DA production by *Pseudo-nitzschia* has not been determined in field populations due primarily to the ephemeral nature of these toxic events. Based on laboratory studies of unialgal cultures (primarily *P. multiseries*), two predominant triggers for the production of DA have been suggested: 1) the degree of cellular stress based on Si and P availability [13, 14, 15], and 2) the effects of micronutrient (Fe, Cu) conditions [8, 16].

A survey of DA along the entire U.S. west coast continental shelf in summer 1998 [11] suggests a strong relationship between DA concentration and mesoscale topographic features. Off northern California where large coastal promontories and hence rapid offshore transport occur, DA levels are low. However, at more retentive sites along the coast, such as offshore of the Strait of Juan de Fuca, over Heceta/Stonewall Bank in Oregon, offshore of Monterey Bay (inshore of the Farallone Islands) and near the Santa Barbara Channel, DA levels are higher. Recent studies suggest that the seasonal Juan de Fuca eddy is an initiation site for toxic blooms of *Pseudo-nitzschia* that impact shellfish on beaches along the Washington coast. Measurements made during cruises and beach sampling of seawater and shellfish are all consistent with the possibility that during some years DA from this eddy appears to move southward in prolonged upwelling events and then onshore during the first major storm of the fall season, where it results in high levels of DA in razor clams on coastal beaches [5].

Study Strategy

To test our hypotheses on the origin of toxic blooms, multidisciplinary field surveys and drifter deployments will be performed in the region of the Juan de Fuca eddy and the nearshore coastal upwelling region (Fig. 2). The temporal context for observed variability as well as seasonal changes will be provided by an array of moored sensors measuring PAR and *in vivo* fluorescence, currents, winds, temperature, conductivity as well as time-dependent water samplers (preserved plankton and DA) deployed in both eddy and coastal environments as well as in the mouth of the strait. Results from the field studies will be used to configure and test numerical physical and biophysical models to determine bio/chem/physical conditions conducive to bloom and/or toxin production as well as transport pathways of *Pseudo-nitzschia* or toxic *Pseudo-nitzschi*a to the coast.

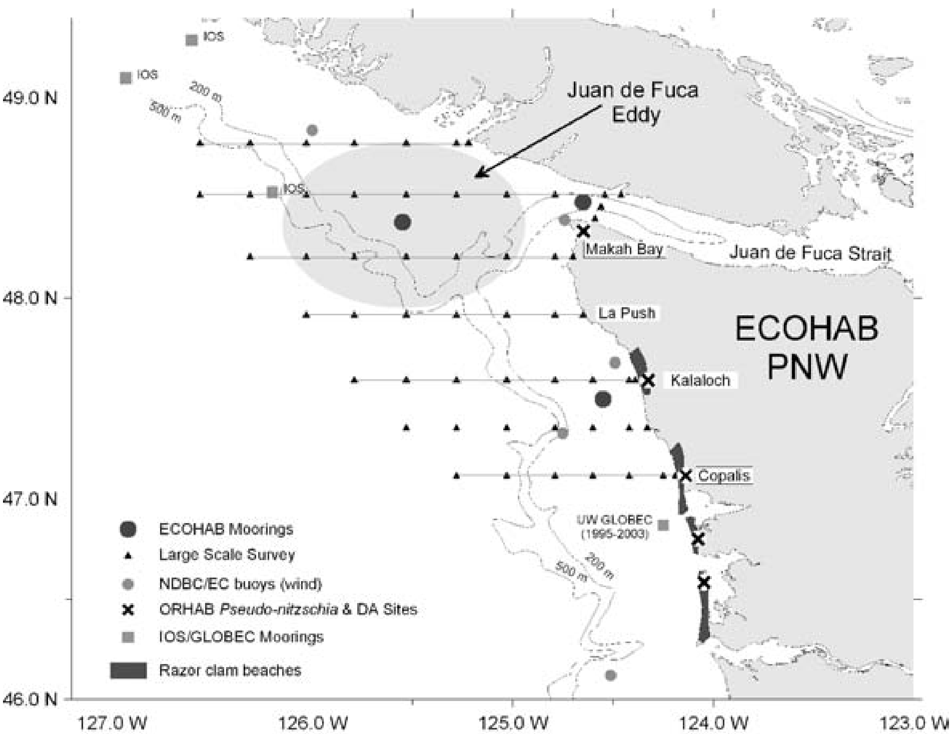

Fig. 2. Schematic large scale survey and locations of three interdisciplinary moored arrays. Locations of existing moorings, wind measurement buoys, razor clam beaches, and ORHAB sampling sites are also shown. The approximate location of the Juan de Fuca eddy is drawn as a lightly shaded area. Institute of Ocean Sciences (IOS) moorings are instrumented with current, salinity and temperature sensors at 3-4 depths between about 25 m and the bottom. ECOHAB PNW moorings will be instrumented with T, S, ADCP profilers and other current meters, time-dependent water samplers, PAR, wind and fluorescence.

The backbone of this project will be 6 three week cruises scheduled in July and September of 2003, 2004 and 2005. The length of the cruises was selected to ensure that a variety of growth regimes, including both upwelling and relaxation or downwelling, will be studied. *In situ* process studies will be made both in the eddy and coastal upwelling regimes as well as following aging water from each of these areas. Coastal *Pseudo-nitzschia* and DA data from the ORHAB (Olympic Region Harmful Algal Bloom) program and related state monitoring programs will be used to determine when and where toxic *Pseudo-nitzschia* arrive along the Washington coast resulting in toxification of razor clams. The field sampling plan, moored sensor arrays at key locations and drifter deployments will allow us to:

- Contrast characteristics of the nutrient-rich eddy with nutrient-rich nearshore upwelling areas. We will determine whether physical and biological factors that control DA production differ significantly in the two regimes.
- Contrast healthy and aged natural assemblages of *Pseudo-nitzschi*a to compare and contrast the environmental controls on DA production in cells at different stages of growth *in situ*.
- Determine the biophysical mechanisms of *Pseudo-nitzschia* advection to the coast, resulting in shellfish toxification. Possible mechanisms include the following scenarios: a) a healthy *Pseudo-nitzschia* population is advected directly from the offshore eddy to coastal shellfish during a storm event; b) an aged *Pseudo-nitzschia* population is advected from the eddy to the coast where it becomes a "seed" population that becomes toxic only when later supplied with nutrients from local coastal upwelling; or c) the nearshore, "seed" population toxifies the coastal shellfish directly after local upwelling followed by a storm.

The integrated field and modeling studies of ECOHAB PNW described above will make significant strides toward satisfying our long term goal—to develop a mechanistic basis for forecasting toxic *Pseudo-nitzschia* bloom development here and in other similar coastal regions in Eastern Boundary upwelling systems.

References

1. Wright, J.L.C., *et al*., 1989. Can. J. Chem. 67: 481-490.
2. Work, T.M., *et al*., 1993. J. Zoo Wildlife Med. 24: 54-62.
3. Wekell, J.C., *et al*., 1994. Nat. Toxins 2: 197-

205.
4. Scholin, C.A., *et al*., 2000. Nature 403: 80-84.
5. Trainer, V.L., *et al*., 2002. Limnol. Oceanogr. 47: 1438-1446.
6. Horner, R.A. & J.R. Postel, 1993. Hydrobiol. 269/270: 197-205.
7. Trainer, V.L. & J.C. Wekell, 2000. Red Tides Newsletter: The cost of harmful algal blooms on the West Coast. Autumn 2000. Northwest Fisheries Science Center and Washington Sea Grant (eds.), 8 pp.
8. Maldonado, M.T., *et al*., 2002. Limnol. Oceanogr. 47: 515-526.
9. Adams, N.G., *et al*., 2000. J. Shellfish Res. 19: 1007-1015.
10. Horner, R.A., *et al*., 2000. S. Afr. J. Mar. Sci. 22: 299-308.
11. Trainer, V.L., *et al*., 2001. *In*: Harmful Algal Blooms 2000. Hallegraeff, G. *et al*. (eds.), IOC of UNESCO, Paris, p. 46.
12. Stehr, C.M, *et al*., 2002. J. Phycol. 38: 55-65.
13. Bates, S.S., *et al*., 1991. Can. J. Fish. Aquat. Sci. 48: 1136-1144.
14. Pan, Y., *et al*., 1996a. J. Phycol. 32: 371-381.
15. Pan, U., *et al*., 1996b. Mar. Ecol. Prog. Ser., 131: 235-243.
16. Rue, E. & K.W. Bruland, 2001. Mar. Chem. 76: 127-134.

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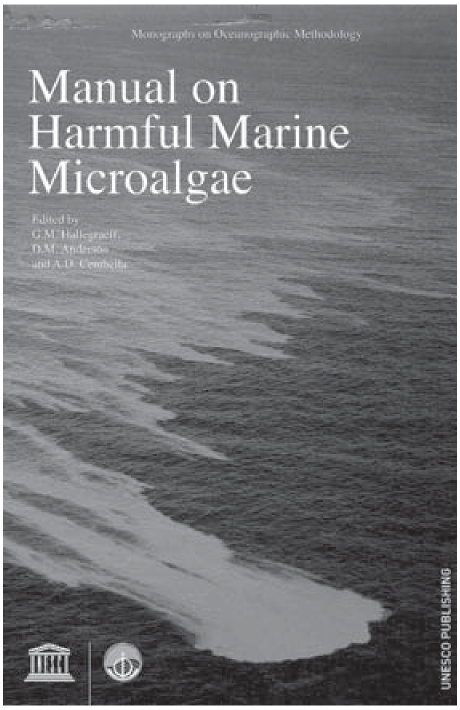

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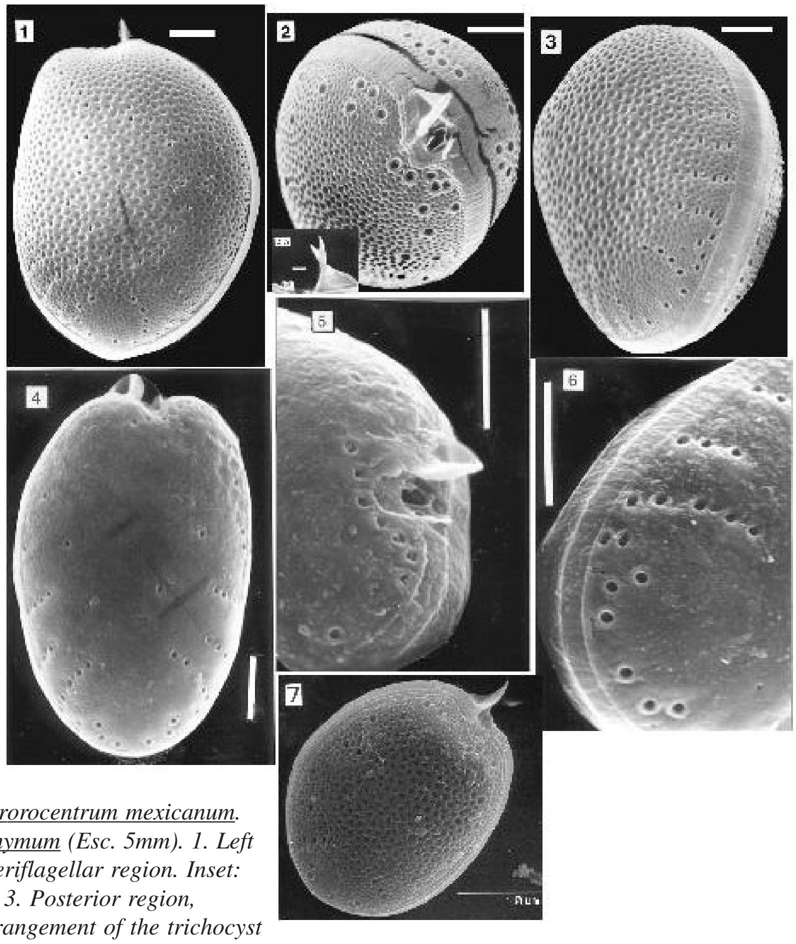
• Mexico

Prorocentrum mexicanum and *P. rhathymum* are different species

Osorio-Tafall (1942)[1] was the first to describe *P. mexicanum* under light microscope (=LM). He found the cells collecting plankton samples off Oaxaca, into the Gulf of Tehuantepec on the Mexican south Pacific. Loeblich III *et al.* (1979)[2] described *P. rhathymum* by scanning electron microscope (=SEM), from the clone 486 of samples obtained from surface waters in Cinnamon Bay, St.Johns, Virgin Islands. Later, since 1983, the species were marked as synonyms and further records and studies were labeled as *P. mexicanum* [3]. When observing samples of red tides dominated by *P. balticum* in Mazatlán Bay, México, during March and April, 1999-2000, we found several cells that perfectly fit the original description of Osorio-Tafall. When a detailed analysis of the morphology was made by SEM, we found several differences between *P. mexicanum(=Pm)* and *P. rhathymum(=Pr)* [4]. While *Pm* shape resembles a letter "D", *Pr* is neatly oval (Figs. 1 and 4 respectively). The periflagellar region and in particular, the spines, are different with two or three points in *Pm* (a unique characteristic of the species) (Figs. 2 and 5). Furthermore, trichocyst pores in the periflagellar rim are present in both valves in *Pm* while in *Pr* occur only in the valve where the periflagellar region is delimited, the right, according to Taylor [5]. The whole surface of the valves is covered by poroids increasing in size from the margin to the center of the cell of Pm. On the contrary, in Pr, the surface is smooth or rough, and the few trichocyst are aligned as radii along depressions or trenches (Figs. 3 and 6).

As mentioned above, at the moment, all records of *Pm* referred *Pr* like cells, the former is a planktonic organism and the natural habitat of the later is benthic as shown by its low mobility and the mucus layer that frequently produces. Nevertheless, *Pr* can be observed as ticoplanktonic, as the bloom reported in La Paz Bay, México [7], the origin of cells in Figs. 4, 5 and 6. Toxicity reports of *Pr-like* cells are common while in true *Pm*, the toxicity has not been proved yet. The known distribution of *Pr* is wide, being found in temperate and tropical regions. The knowledge of *Pm* distribution is scarce, in Mazatlán, is not very abundant and at the moment has not been observed causing discolorations by itself. The abundance of



Figs. 1-3 Prorocentrum mexicanum. 4-6 P. rhathymum (Esc. 5mm). 1. Left Valve. 2. Periflagellar region. Inset: bifid spine. 3. Posterior region, annular arrangement of the trichocyst pores. 4. Right valva. 5. Periflagellar region, a single line of thrichocyst pores. 6. Posterior

Pm seems to increment in direction to the Equator. *P. maximum* (=*Pmax*), a species which also may be easily confused with *Pm,* has not been re-described by SEM yet. Preliminary data obtained with samples collected in the Gulf of Nicoya, Costa Rica, indicates that the cells resembles *P. micans* and the spine in the periflagellar region is lanceolated (fig. 7) [8]. Cells mentioned as *Pmax* have been reported in estuaries in the Gulf of Guayaquil, Ecuador [9], with abundances close to 1000 cells/ml, dominating the area. A detailed (SEM) descriptions of the cells is not available, in particular the spine and periflagellar region, thus, it remains to be demonstrated to which of the three mentioned taxa they belong.

References

1. Osorio-Tafall, B.F., 1942. An. Esc. Nac. Cienc. Biol. 11: 435-447.
2. Loeblich III, A.R., *et al.*, 1979. J. Plankton Res. 1: 113-120.
3. Steidinger, K.A., 1983. Prog. Phycol. Res. 2: 147-88
4. Cortés, A.R. & A. Sierra, 2002. J. Phycol. In Press.
5. Taylor, F.J.R. (ed.) 1987. *In*: The Biology of Dinoflagellates. Botanical Monographs. Vol.21. Blackwell, Oxford. pp. 24-91.
6. Faust, M.A., 1990. J. Phycol. 26: 548-558.
7. Gárate, L.I. & A. Martínez L., 1997. Rev. Biol. Trop. 45: 1263-1271
8. Vargas-Montero, M., 2001. Tesis de Licenciatura en Biología Marina. Universidad Nacional, Costa Rica.
9. Jiménez, R., 1996. *In*: Harmful and toxic Algal Blooms. Yasumoto T. *et al*. (eds.), IOC-UNESCO, pp. 109-112.

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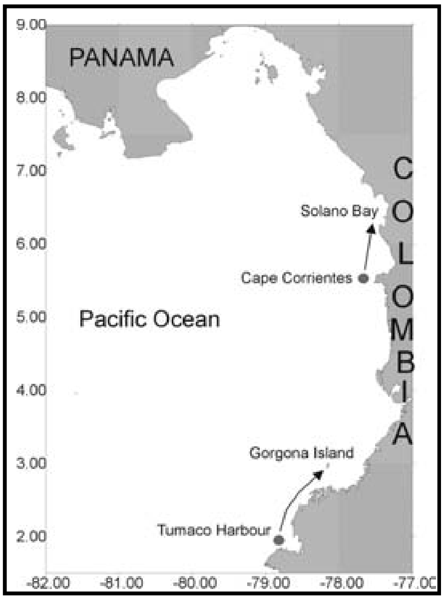
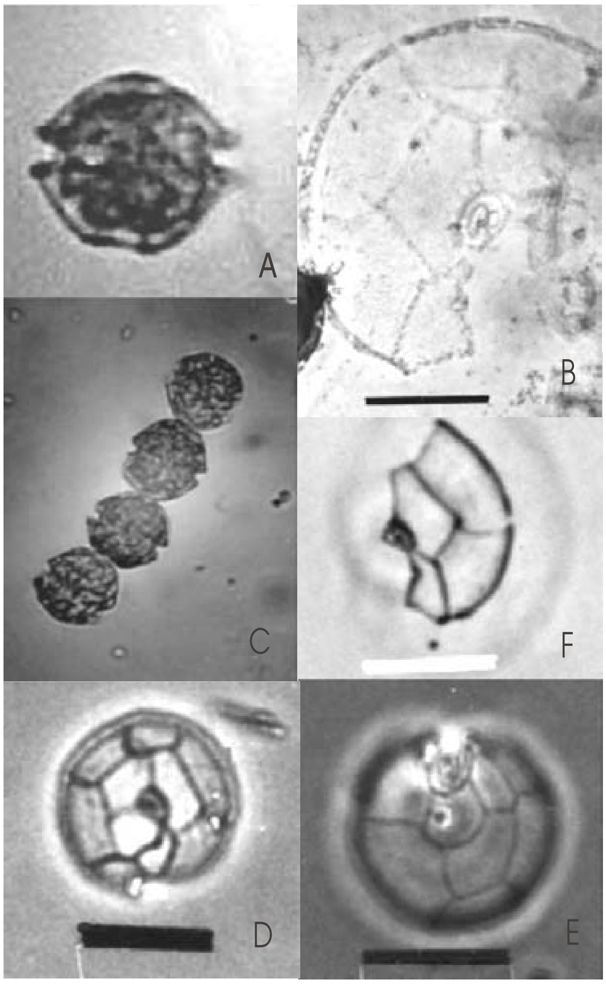
• Colombia

HABs due to *Alexandrium tamarense* on the Pacific coast of Colombia.

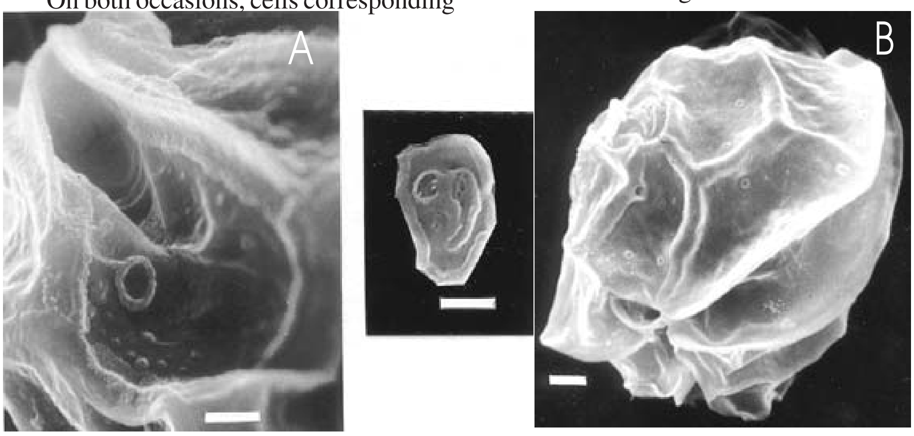


From 26 April to 15 May, 2001, a huge bloom was observed off Tumaco Bay, on the tropical Pacific coast of Colombia (Fig. 1 MAPA). This was the first time a harmful algae bloom (HAB) is reported in the region, reaching north to Gorgona Island. A year later (10 March, 2002), a new offshore occurrence of a HAB event developed from Corrientes Cape to Solano Bay, also on the Pacific of Colombia. Cell counts during these blooms reached 7.5x10^6 cells.l^{-1} and 1.6x10^6 cells.l^{-1}, respectively. During both events, low temperature and high salinity were recorded. While the average measurements in the area are 27-27.5°C and 30-31.5 psu, the values observed during the events were 24-24.6 °C and 33-34 psu, 3°C below the normal and more than 2.5 psu above the average values, indicative of local upwelling at the time of the events. During these events there were no reports of observable effects on the marine biota or human poisoning, since the blooms occurred offshore and far from exploited shellfish beds.

On both occasions, cells corresponding to the *Alexandrium* complex represented 99-100% of the biomass. Samples were preserved in Lugol-acetate solution. Phase contrast observations with the aid of Klein's silver stain, allowed detailed description of the apical pore complex, the first apical plate and the posterior sulcal plate of cells collected in 2002 (Figs. 2a-e FOTOS PHASE). Shape, dimensions (L= 25-40μ, X= 32μ, W= 25-37.5μ, X= 31.6μ, n = 50) and detailed structure of the plates were consistent with *Alexandrium tamarense* [1, 2]. It was difficult to differentiate the cells from *Alexandrium catenella*, but the presence of short chains of only 4 cells (single cells represented most of the biomass) was suggestive of *A. tamarense*. Some cells were gold/palladium-coated and observed in SEM. Following the description of Fukuyo [1], the shape and position of the ventral pore on plate 1' and a cell shape slightly longer than wider confirm the identification (Fig. 3 FOTO SEM).



Alexandrium tamarense is normally found in temperate waters (16°C in average) [3], but is also reported in warmer regions (=*Gonyaulax tamarensis f. excavata*) [4, 5]; it has not been reported before in the tropical Pacific. In 1976 a red tide was recorded in summer (July and September) North of Cape Corrientes but the causative organism was not reported [6]. The Centro de Control de Contaminacion del Pacifico of the Colombian Navy has been monitoring the area since 1994 without previous records of this species or HABs, and it may represent an introduction which is favoured by local upwelling.



References

1. Fukuyo, Y., 1985. Bull. Mar. Sci.,37(2):529-537.
2. Balech, E., 1995. Sherkin Island Marine Station: 38-42.
3. Cembella, A.D. *et al.*, 1988. J. Shellf. Res., 7(4): 611-621.
4. Steidinger, K.A. & J. Williams, 1970. Mem. Hourglass Cruises, Florida Dept. Natural Resources, St. Petersburg, Florida, 2: 251 pp.
5. Balech, E., 1971. Serv. Hidrogr. Naval, Buenos Aires, H 654: 1-103 plus 12 plates.
6. Maldonado, J., 1978. INDEREN- Rev. Divulg. Pesquera 12(2): 1-18.

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Elusive red tides in Kuwait coastal waters

The shallow (<33 m), well mixed, and illuminated but eutrophicated Kuwait Bay waters constitute a highly stressed ecosystem in the arid Arabian Gulf region. These waters contain about 15 potentially harmful phytoplankton taxa some of which attain red tide proportions (>20 µg chl a l^{-1} and $5x10^6$ cells l^{-1}). During the year 2000, two red-water episodes occurred which were ephemeral and massive (>4525 µg chl a l^{-1} and about 2 billion cells l^{-1}) with the patches extending from 50 m^2 to$15x10^4$ m^2. The dominant species differed each time e.g. *Prorocentrum* spp. *Pseudo-nitzschia seriata*, *N. longissima*, *Leptocylindrus* sp. and *Trichodesmium erythraeum*. The blooms were orange greenish-brown and appeared as thick foamy rafts, meshes and strands entraining gas bubbles. In experimental growth studies, eolian dust rich in essential micronutrients for phytoplankton growth had a positive effect on summer phytoplankton growth and yielded 526.8 mg chl a m^{-3}, similar to red tide proportions. Blooms of *Karenia* sp. during September-October 1999 were implicated in the mortality of 30 tons of wild mullets and 150 tons of caged sea bream at a cost of $7 million, but the cause could not be linked to phycotoxins as no toxin analyses were done. Suggestions are presented for a regional institutionalized long term approach to generate a high frequency sampling over extensive areas, to elucidate physiological ecology of suspect phycotoxin producing algae and to investigate the role of dust storms as a major ecological force in the formation of algal blooms.

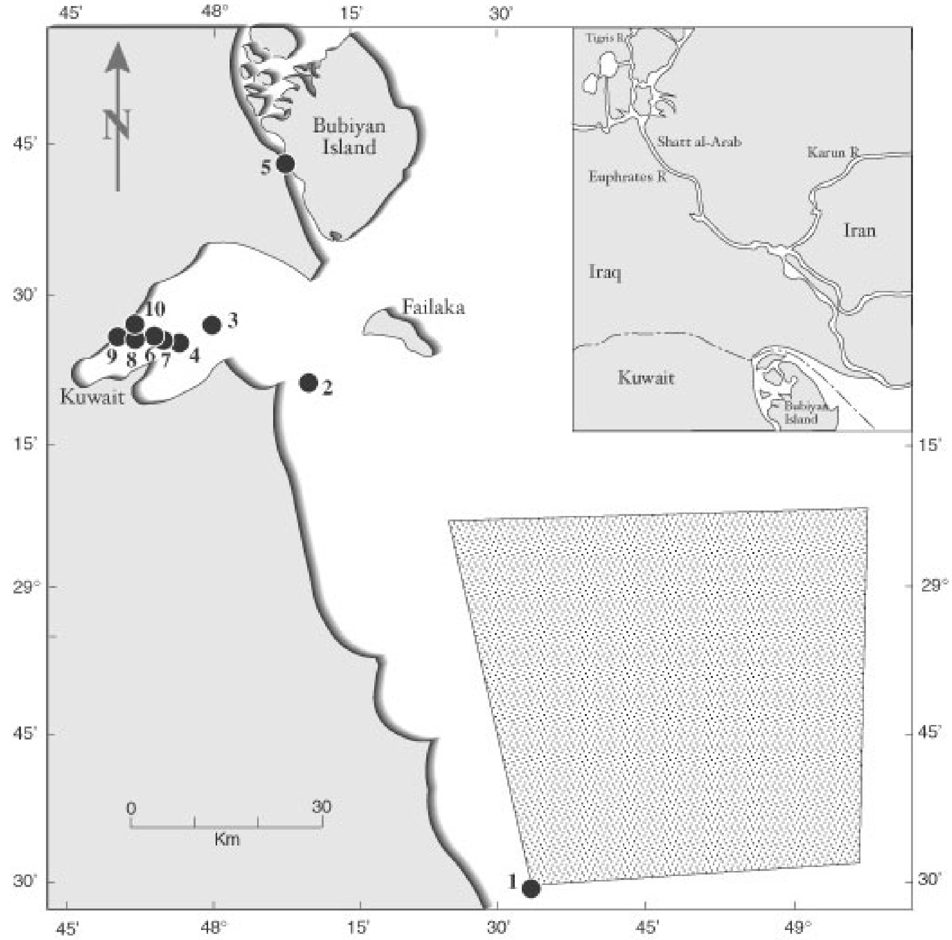

Fig. 1. Kuwait Bay and stations where red tides occurred during May 1997 to July 2000. Numbers represent the sequence of occurrence of blooms (see Table 1). Shaded area represents Trichodesmium erythraeum blooms on 19th May 2000.

The Arabian Gulf is a shallow (mean depth 30 m), sub-tropical, hypersaline, and enclosed basin. The Tigris, Euphrates and Karun rivers join to form the Shatt al-Arab River which empties into the northern region of the Gulf (Fig.1). The Shatt al-Arab outflow of about 1456 m^3 s^{-1} [1] is nutrient rich and is the main fresh water input to the Gulf [2]. As evaporation exceeds run off and because of its semi-enclosed nature, the Gulf acts as a negative estuary [3] and a trap for pollutants as well [1]. With an annual spill of about 200,000 barrels of oil and associated products the Gulf is extremely polluted [4].

To the south of Shatt al-Arab is Kuwait Bay, a highly stressed body of water. The sources of stress include nutrients from the Shatt al-Arab, discharges from 12 major industries including two petrochemical companies, three refineries, discharges of raw sewage, thermal and chlorinated effluents from six dual purpose desalination plants, wastes from slaughter houses, hospital wastes and pollutants associated with the extensive shipping industry [5]. For example in addition to the 0.003 x 10^6 km^3 d^{-1} sanitary wastewater, 0.023 x 10^6 km^3 d^{-1} wastewater from petrochemical refineries and fertilizer and polypropylene industries [6] and 0.282 x 10^6 km^3 d^{-1} raw or partially treated sewage are discharged into the Bay [7]. This sewage has the highest organic content amongst the Gulf countries [8]. Daily discharges from the power plants amount to 33.6 km^3 chlorinated cooling water and about 17 metric tons of residual oxidants [9]. Because of infilling, dredging of the shipping channels has to be continuous with 4.66 x 10^6 m^3 silt dredged annually. On the tacit assumption that the ongoing urbanization of the coastal areas in these arid Gulf countries will increase, stresses on the marine environment are also bound to intensify.

These stressed territorial waters of Kuwait and Kuwait Bay support a variety of biotopes including some of the world's most northerly coral reefs [10]. The Bay waters are well illuminated with 325-575 W m^{-2} and 83-275 W m^{-2} near the surface and the bottom respectively, sufficient for phytoplankton growth [11]. With a pronounced (3.5 m) tidal amplitude [12], and absence of thermal stratification, the water column is well mixed, and oxygenated except in waters deeper than 30 m where a strong cold bottom current exists in contrast to the upper layer (J.M. Al-Hassan unpublished). These waters are eutrophic and never stripped of the macronutrients i.e. phosphate, silicate and nitrate [11] but cannot be included under the 'very eutrophic category' [13]. Phytoplankton biomass, however, was usually low [10] and ranged between 0.01 to 12.8 mg chl a m^{-3} in individual samples and in the column from 3.8 mg chl a m^{-2} to mostly less than 90.0 mg chl a m^{-2}.

Red tides are almost unknown from the arid zone waters. The absence of pronounced typical or atypical buildup of biomass in the nutrient rich, well illuminated and well mixed waters off Kuwait, is of prime interest. Red tides have escaped attention, save for a few anecdotes from this region. One of us (J.M. Al-Hassan) observed red tides in 1981 and 1982, but did not report them. Subba Rao *et al*. [14] reported qualitative and quantitative changes in algal species, size fractionated biomass and their primary production characteristics of a red tide from Kuwait coastal waters in 1997. In this paper we have integrated recent observations which illustrate how red tide episodes off Kuwait are frequent, ephemeral and massive.

Surface waters were collected by bucket from a private yacht, stored in polypropylene bottles and transported in ice-coolers to the laboratory for standard chemical and plankton analyses. Salinity was determined using the Orion Conductivity/Salinity Meter, Model 140. Nutrient analyses were based on procedures described in the ROPME manual [15] using Per Storp Analytical Autoanalyzer System and Beckman DU Series 600 Spectrophotometer. Unfortunately on 19 May 2000, phosphate levels, which would have been of significance in view of the Trichodesmium bloom could not be determined. Following examination of live water samples under a microscope, samples were preserved with 1% paraformaldehyde+ glutaraldehyde (50:50 volume). Phytoplankton cell densities were enumerated using an inverted plankton microscope. Chlorophyll a was estimated by the fluorometric method [16].

Following three days of calm weather in the waters between $28^0$30' and 29^0 05' Lat. N and $48^0$20' to $49^0$05' Long. E, (Fig. 1, Station #1 and hatched area) massive blooms of the blue green alga *Trichodesmium erythraeum* occurred on 19th May 2000]. These blooms had >900 µg chl a l^{-1} and consisted of 100 million cells l^{-1}; nitrate and silicate levels were 3 and 39 µg at l^{-1} respectively. From our field observations, captured in figure 2 (panels A to D), it is possible to reconstruct the formation of the local red tide patches. The patches consisted of strands and lattice-like structures (panel A) at the surface, which coalesced into extensive floating mats (panel B). The algal aggregates varied from a thin sheen to approximately two cm thick; the thick layers included foamy oily complexes with heterogeneous strands, lattice, or rope-like structures in hues of green, blue, pink, red, orange, brown, and gray (panel C). The approximate size of the patches varied from 50 m^2 to 15 x 10^4 m^2. Intact patches at the sea surface had a smell similar to decaying vegetables, mechanical agitation resulted in the release of a pungent odor, which affected the human nervous system causing difficulty in breathing, nausea, coughing, choking, irritation to the eyes, a lethargic feeling and loss of co-ordination. Upon storage the odor worsened over 24 h making removal of samples for analysis difficult. Biotoxicity tests could not be carried out because of a lack of facilities. By the following day (20th May) a strong northerly wind and the ebb tide caused the blooms to advect south and disappear.

On 7 July, 2000 (Fig.1, Station #2) massive blooms with *Pseudo-nitzschia seriata* cell densities (749.5-1008.9 millions per litre) were present in the scum thus at least an order of magnitude higher than any literature values from seawater. Other cell densities (millions per litre) were for picoplankton (720.1-962.8), *Prorocentrum* spp. (2.9-4.3), *Nitzschia longissima* (10.1-11.5), *Leptocylindrus* sp. (5.76-10.09), *Gymnodinium* spp. (2.9). Chlorophyll levels were very high (2906.75 – 4525.47 µg chl a l^{-1}). The salinity of the water ranged from 42.2- 42.4 PSU. Despite the heavy blooms nutrients were not exhausted and ranged (µg at l^{-1}) between 0.02 and 1.20 PO_4, 0.06-0.24 NO_2, 0.01-0.52 NO_3, and 11.65-37.07 SiO_3. The algal cells formed orange greenish- brown thick foamy rafts, meshes and strands that could be scooped from the surface (Fig. 2, Photos A-D). These patches were ~20x30 m in extent and a 12 cm perched bird – Sylvia nana (Mutrag in Arabic) could not free itself (Fig. 2, Panel D). Upon storage this foam turned greenish-brown. Although there were several entrained live phytoplankton cells, these rafts contained many dead and decayed phytoplankton cells (unusually large die-offs of the bloom species). Gas bubbles, of undetermined chemical composition, were entrained in the scum for more than 48 h. Under the influence of southeast winds, the associated currents and the high amplitude of tides these patches meandered into Kuwait Bay (Stations #3, 4, 6 to 10). By the third day the blooms had advected out of the bay

Table 1: Summary of occurrences of algal blooms and their biomass (Chl. a µg or x 10^6 cells l^{-1}) in Kuwait Bay

Occurrence	Station	Taxonomic group	Taxa	Biomass	Reference
Nov. to Jan., March and May 1987 to 1988	Kuwait Bay	Haptophyte	*Phaeocystis* sp.	136 *a*	Al-Hassan *et al.* 1990 #28
October 1996		Ciliates	*Myrionecta rubra*	156 *a*	Al-Yamani *et al.* 1997 #29
May 1997	1	Diatom Dinoflagellates	*Nitzschia* spp. and *Gymnodinium* sp.	501 *a*	Subba Rao *et al.* 1999a #19
May 2000	9	Cyanobacteria	*Trichodesmium erythraeum*	900 *a*	Present report
July 2000	10	Diatoms	*Pseudo-nitzschia seriata*	749.5 to 1008.9 cells 2906.75 to 4525.47*a*	Present report
	10	Diatoms	*N. longissima*	10.1-11.5 cells	
	10	Diatoms	*Leptocylindrus* sp.	5.8-10.1 cells	
	10	Cyanobacteria Picoplankton		720.1 to 962.8 cells	
	10	Dinoflagellates	*Prorocentrum* spp.	2.9 to 4.3 cells	
	10	Dinoflagellates	*Gymnodinium* spp.	2.9 cells	

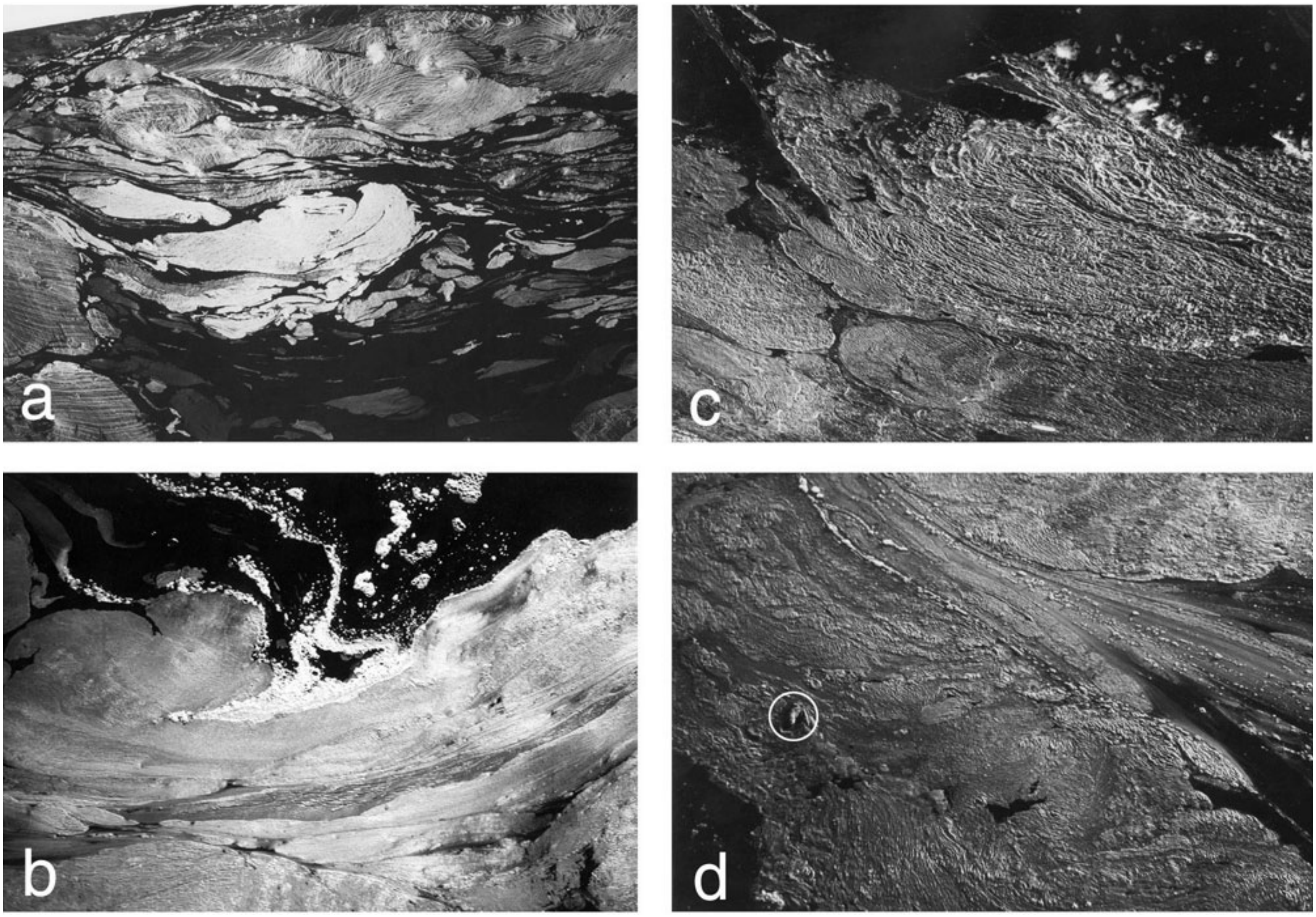

Fig. 2. Panels A,B,C and D showing progressions and patterns of discoloration due to red tide in Kuwait Bay. Panel D shows an entangled bird Sylvia nana.

eastwards (Station 5) towards Failaka Island and finally south into the open Gulf.

In this arid zone sea with no pronounced seasonal growth of phytoplankton, the time of occurrence of algal blooms, their constituents and magnitude varied widely in contrast to red tide episodes in the temperate embayments. Thus blooms of *Phaeocystis* species occurred during November-January, March and May [17] with 136 µg chla l^{-1}, with *Myrionecta rubra* (156 µg chl a l^{-1}) during August [18], *Pseudo-nitzschia* spp. and *Gymnodinium* spp. blooms (501 µg chl a $l^{-1,}$ Station #1) during May 1997 [14], and with the benign diatoms *Chaetoceros curvisetus*, *Nitzschia longissima*, and the ciliate *Myrionecta rubra*, and the gymnodinian *Karenia* sp. [19] (265 µg chl a l^{-1}) during September-October 1999 (Stations #2, 3, 4, 6, 7 and 8).

On average Kuwait experiences 27 dust storms annually with an average annual dust fall of 33.38 g m^2 in Kuwait Bay [20]. Phytoplankton samples collected during summer and enriched with dust produced more rapid doublings of biomass than the control and attained chlorophyll values as high as 526.8 mg chl a m^{-3}, similar to red tide proportions [21]. The response of phytoplankton to the addition of eolian dust was rapid and dose dependent in the range of 10^5 to 10^7 mg m^{-3} enrichments; the differences in the doubling rates and biomass were statistically significant. Of the 29 species initially present, a small Naviculoid diatom (<6 x 3 µm) attained red tide proportions (23.1 x 10^6 cell l^{-1}) [21]. The dust contained trace metals in the following ranking: Fe > Zn > Cu > Mn > Co > Ni, V > Pb > Cr, some of which constitute essential micronutrients for phytoplankton growth. Because of their impact, the role of dust storms as a major ecological force in the formation of algal blooms must also be included in any environmental study. The "iron hypothesis" proposes that iron is the limiting nutrient in "high nutrient low chlorophyll" (HNLC) regions, and extensions of it suggest the iron can be supplied by dust storms. There is now quite a large literature about this, and Walsh and colleagues have suggested that wind blown iron makes nitrogen available to *Karenia* via N-fixing *Trichodesmium* blooms.

In Kuwait waters, the 1999 bloom was implicated in the death of 30 tonnes of surface feeding wild mullets and 150 tonnes of caged sea bream, resulting in a loss of $7 million and consumer confidence. Confirmatory data on the identity of the suspect toxigenic organisms, nature of the toxin, bioassy, total quantity of toxin delivered are not available but are crucial before implicating the ephemeral algal patches as causative agents of fish kills. Gills of sea bream from the cage cultures yielded levels (µg g^{-1}) of As (20-24), Fe (274-987), Ni (7-13.5), Cu (18-31) and Zn (45-252) much higher than the corresponding 4, 36, 1.6, 1.9, and 15 in the gills of wild sea bream. The Se:Ni, Fe:Ni, Zn:Pb ratios in the gills were higher than those in wild fish. It is plausible these metallic elements may have played a compounding role in causing mass mortality of the sea bream [19].

Because of the heavy sea traffic either for recreation, trade, fishing and defence, and because the population is mostly coastal in this arid zone kingdom, the users should be alert to any red tide sightings and report these to a central agency. A regional multinational, multidisciplinary institutionalized marine science program, backed by remote sensing to track red tides would be highly desirable.

Acknowledgements

We thank Dr. James E. Stewart, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada and Dr. Tim Wyatt, Instituto de Investigaciones Marinas del CSIC Eduardo Cabello, 6. Vigo, Spain for constructive comments on the manuscript.

References

1. Reynolds, M., 1993. Mar. Poll. Bull., 27: 35-39.
2. Abayachi, J.K. *et al*., 1988. Hydrobiologia, 166: 217-224.
3. Banse, K., 1997. J. Mar. Res., 55: 1049-1067.
4. Vander Mer, D.C., 1996. Environmental Health Perspectives, 104: 260-265.
5. Subba Rao, D.V. & F. Al-Yamani, 2000. *In*: Seas at the Millennium: An environmental Evaluation, Sheppard, C.R.C. (Ed.), Elsev. Sci. Ltd. ,pp. 1-16.
6. Al-Muzaini, S. & M.F. Hamoda (eds.), 1998. Proceedings of The Third Middle-East Conference on Marine Pollution and Effluent Management, Kuwait, 305 pp.
7. Al-Muzaini, S. *et al*., 1991. Water Sci.Techn., 23: 7-31.
8. ROPME, 1997. Oceanography and pollution studies in the ROPME sea area. A bibliography. ROPME/GC-9/001, Regional Organization for the Protection of the Marine environment, Kuwait.
9. Al-Mutaz, I.S., 1991. *In:* Proc. 12th Int. Symposium on Desalination and Water Re-use. Vol .4. Evaporative Processes Operations, Electrodialysis, Material Selection and Corrosion 84: 1-105.
10. Carpenter, K.E. *et al*., 1997. The Corals and Coral Reef Fishes of Kuwait. Kuwait Institute for Scientific Research, Kuwait, 166 pp.
11. Subba Rao, D.V. & F. Al-Yamani, 1999. Ind. Jour. Mar. Sci., 28: 416-423.
12. Anon., 1997. Tide tables year 1997, Kuwait Port Authority, State of Kuwait.
13. Morel, A. & J.F. Brethon, 1989. Limnol. Oceanogr., 34: 1545-1562.
14. Subba Rao, D.V. *et al*., 1999. J. Plank. Res., 21: 805-810.
15. ROPME 1989. Manual of Oceanographic Observations and Pollutant Analysis methods. Revised edition. Regional Organization for the Protection of the Marine environment, Kuwait.
16. Parsons, T.R. *et al*., 1984. A manual of chemical and Biological Methods for Seawater Analysis. Pergamon Press, Oxford,173 pp.
17. Al- Hassan, R.H. *et al*., 1990. Mar. Biol., 105: 9-14.
18. Al-Yamani, F. *et al*., 1997. Assessment of the effects of the Shatt-Al-Arab's altered discharge regimes on the ecology of the northern Arabian Gulf. Final report – FM006K. Kuwait Institute for Scientific Research, Kuwait, 247 pp.
19. Al-Yamani, F. *et al*., 1999. *In*: Hallegraeff, G. (Convener) Abstracts from the 9th International Conference on Harmful Algal Blooms 2000, Hobart, Tasmania. Australia, 77 p.
20. Anwar, M. *et al*., 1986. Surface modelling of dust fallout on the ROPME Sea Area. KISR annual research report. ISSN 0250-4065, Safat.
21. Subba Rao, D.V. *et al*., 1999. Naturwissenschaften, 86: 525-529.

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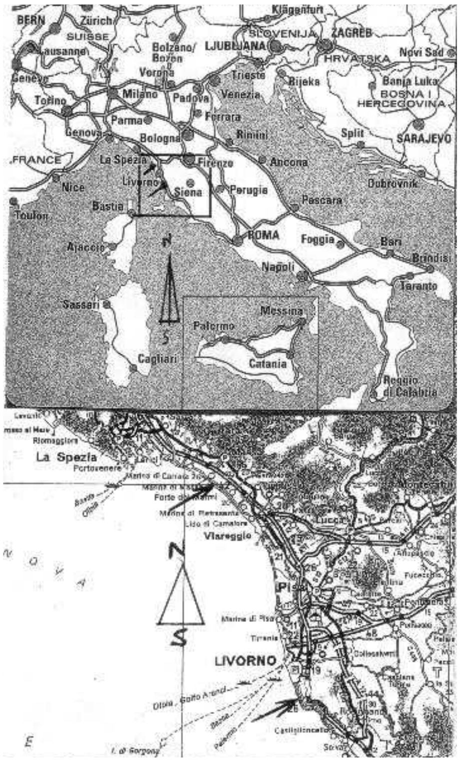
• Italy

Harmful epiphytic dinoflagellate on Tyrrhenian Sea reefs

Epiphytic and benthic dinoflagellates present on the reefs of the Tuscany shore have been studied. at two main monitoring areas: one of them on the artificial reef located in submerged sand opposite Marina di Massa beach, to prevent erosion; the other, on natural reefs in the Livorno oligotrophic lagoon. Macroalgae samples (*Corallina mediterranea*, *Cystoseira spicata*, and others) were collected in bags with surrounding seawater. The macroalgae were shaken in sampling water to remove dinoflagellates and weighed. The seawater was filtered through 125 mm mesh net, and the volume measured. Cell counts were made with an inverted microscope at 100 x, while algae identification was carried on at 600 x UV after colouring thecal plates with calcofluor. The first stage of research showed a bloom of Ostreopsis ovata, see table 1 from Simoni et al (2002).

The results indicate that the *Ostreopsis ovata* quickly colonizes the algae of the natural and artificial reefs in late spring and in summer, when the temperature of water reaches 22 °C. *Ostreopsis ovata* is



MONITORING AREAS

Table 1

Sampling zone	Date	pH	water temperature	*Ostreopsis ovata* (density +,++,+++)
Marina di Massa	30/08/00	8.7	26.5 °C	+++
Marina di Massa	27/09/00	8.4	22.5 °C	++
Marina di Massa	01/12/00	8.3	14.5 °C	+
Livorno	01/12/00	8.8	17.5 °C	+
Livorno	14/02/01	8.8	12 °C	0
Livorno	29/04/01	8.8	15 °C	0
Marina di Massa	04/05/01	8.3	16.9 °C	0
Marina di Massa	01/06/01	8.3	20 °C	0
Livorno	22/06/01	8.4	22 °C	+++
Livorno	03/08/01	8.5	23°C	+++
Marina di Massa	09/08/01	8.4	24°C	+++

most abundant in summer, decreases in autumn and disappears in winter. We assume this species is able to produce resistant forms, such as spores or vegetative hibernating forms, which survive at lower temperatures.

Further studies, started in summer 2001, verified the presence of other harmful epiphytic dinoflagellates. Reef macroalgae were colonized by the potentially toxic *Coolia monotis* (29 x 44 µm), *Prorocentrum lima* (38 x 28 µm), *Prorocentrum emarginatum* (35x27 µm), as well as *Ostreopsis ovata*. The results of the quantitative monitoring are shown in Table 2.

The results seem to confirm the tropical characteristics of *Ostreopsis ovata*: it is not found in winter nor in early spring, when the water temperature barely reaches 11°C (lowest temperature limit in the Mediterranean). On the other hand, *Coolia monotis*, *Prorocentrum lima*, and *Prorocentrum emarginatum* are present all year. The results show that natural reefs are colonized by more species than artificial cliffs. Other flagellates found on these natural reefs are *Scrippsiella trocoidea*, *Goniaulax* sp., *Amphidinium* sp., and the cyanobacterium *Oscillatoria* sp. Diatoms prevail during the whole year.

On artificial reefs, where suspended sand and mud often make shallow waters turbid, the number of epiphytic and benthic species are noticably reduced. On the other hand, selective pressure caused by high water temperature (up to 27°-28°C) produce algal blooms of the thermophilic *Ostreopsis ovata*, on artificial reefs of Marina di Massa in August.

Ostreopsis ovata, *Coolia monotis*, *Prorocentrum lima*, *Prorocentrum emarginatum* have been found also on reefs in Elba, (Simoni 2002), Sicily, and Sardinia (Institute Talassografico CNR Messina), but only Ostreopsis ovata has been spotted on Viareggio (LU) artificial reefs, and on La Spezia natural reefs (ARPAL La Spezia) and near Bari (Bari Laboratory Marine Biology). These species are apparently absent in the northern Adriatic Sea.

Ostreopsis ovata develops intense bloom in August in the breakwater of Marina di Massa, where waters are calm and reach high temperatures owing to insufficient water circulation. In summer 2002, concentrations of *Ostreopsis ovata* in Marina di Massa reached 10550 cells L^{-1}, and of *Coolia monotis* 1025 cells L^{-1}.During blooms, *Ostreopsis ovata* were found associated with floating detached macroalgae in the warmest periods of the year. In some areas, this phenomenon has been associated with respiratory irritation in bathers. Epidemiological investigations are now in progress to establish a possible relationship between the two phenomena. Furthermore, shellfish and *Arbacia* sp. mortality has been observed during *Ostreopsis ovata* blooms on Marina di Massa reefs.

An additional study highlights the possible presence of ciguatoxins and DSP in the alimentary chain of the reef ecosystem; immunological methods (Cigua-check and DSP-Check) indicate the presence of DSP-like and ciguatoxin-like toxins (table 3):

These results indicate that ciguatera-like substances accumulate in the trophic chain. However, the lack of epidemiological evidence of neurological and gastro-intestinal symptoms in fish consumers does not presently allow evaluation of the potential toxicological risk to public health. Sampling and analysis will continue to verify the possible increase of the test-positivity in summer and autumn.

Table 3

Organism	Date	Tissue	Origin	Cigua-Check ppb	DSP-Check ppb
Scorpena porcus *Scorpena porcus* *Scorpena porcus*	15/01/02	flesh	Livorno fish market	0.9 0.9 0	<2
S. porcus *S. porcus* *S. porcus*	15/01/02	liver	Livorno fish market	1.2 0.9 0.8	1.3 <2
Murena helena	15/01/02	flesh	"	0.8	<2
M. helena	15/01/02	liver	"	1.2	3
Conger sp.	05/01/02	flesh	"	1.0	<2
Charonia sp *Charonia* sp	02/03/02	flesh	Cliff in Livorno	1.3 0.9	5
Patella sp.	08/03/02	flesh	Cliff in Livorno	0.8	
Octopus vulgaris 2 Kg *Octopus vulgaris* 2 Kg	05/03/02	tentacle	Cliff in Livorno	1.0	0.9
O. vulgaris 0.3 Kg	05/03/02	tentacle	Cliff in Livorno	0.9	
Mullus surmuletus	10/03/02	flesh	Cliff in Livorno	0.8	0.9
Crenilabrus sp. *Crenilabrus* sp.	10/03/02	flesh	Cliff in Livorno	0.8 0	0.6
Serranellus sp.	10/03/02	flesh	Cliff in Livorno	0.8	0.7
Mitilus sp.	08/03/02	flesh	Cliff M. di Massa	0.9	
S. porcus	24/04/02	flesh	Livorno fishmans	0.8	0.2
Labrus turdus	24/04/02	flesh	Livorno fishmans	0.8	0.5
M. surmuletus *M. surmuletus*	24/04/02	flesh	Livorno fishmans	0.8 0.8	0.5 0
Boops salpa	24/04/02	flesh	Livorno fishmans	0.8	1.8

Table 2

Date	Stations	pH	T. °C	in 1 gr of algae				in 1 gr of algae			
				O .ovata		*C. monotis*		*P. lima*		*P. emarginatum*	
				mean	range	*mean*	range	*mean*	range	*mean*	range
02/10/01	Livorno	8.23	21.5	67.8	16-94	18.1	9.4-35	15.4	5-40	0	0
04/10/01	M.di Massa	8.0	21.3	9.3	2-23	1	0-1.6	0	0	0.5	0-1.82
19/10/01	M.di Massa	7.9	20.8	2.2	0-3.5	0	0	0	0	0	0
29/10/01	Livorno.	8.0	21.5	15.7	0-32	14	0-38	10.8	0-25.7	5	0-15.5
20/11/01	M.di Massa	8.4	12.5	0	0	0	0	0	0	0	0
26/11/01	Livorno..	8.2	13.6	12.7	7.2-20	6.6	1.7-16	5.6	0-15.3	0	0
06/12/01	Livorno..	7.90	10.9	39.9	19-112	19.7	9-34	17.3	9-32	3.2	1-7
06/12/01	M.di Massa	8.0	10.5	0	0	0	0	0	0	0	0
03/01/02	Livorno	8.01	11.2	1	0-2	2.8	1-4	8.2	1-23	1.2	0-5
02/02/02	Livorno	8.01	11.8	1	0-6	16	0-57	3	0-12	1	0-3
05/03/02	Livorno	7.97	13.5	0	0	2.9	1.8-4.1	12.13	1.48-3.11	0.9	0-2.7
08/03/02	M.di Massa	8.28	14	0	0	0	0	0	0	0	0
19/04/02	Livorno	8.12	17.5	0	0	33	0-39	6	3-7	4	1-7
17/05/02	Livorno	8.02	19	0	0	25	2-53	7	1-20	7	3-20
20/05/02	M.di Massa	8.2	19	0	0	0	0	0	0	0	0
03/06/02	Livorno	8.28	21	0	0	10	1-24	16	5-21	10	8-15
03/06/02	M.di Massa	8.16	21	0	0	0	0	0	0	0	0

References

1. Simoni, F., *et al,* 2002. Acqua & Aria, maggio 2002: 95-102.

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GEOHAB

Global Ecology and Oceanography of Harmful Algal Blooms

Announcement of an Open Science Meeting on the Core Research Project: HABs in Upwelling Systems

LISBON, PORTUGAL

Instituto Nacional de Investigação Agrária e das Pescas - INIAP-IPIMAR

17-20 November 2003

Conveners

Teresa Moita, Portugal
Grant Pitcher, South Africa

Co-ordinating Committee

Francisco G. Figueiras, Spain
Raphe Kudela, USA
Trevor Probyn, South Africa
Vera Trainer, USA

GEOHAB

The GEOHAB Programme, endorsed by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO, is an international programme aimed at fostering and promoting co-operative research directed toward improving the prediction of harmful algal bloom events.

Core Research Project: HABs in Upwelling Systems

The GEOHAB Core Research Project on Harmful Algal Blooms (HABs) in Upwelling Systems must be comparative, interdisciplinary, and international. It will directly address the goal of GEOHAB of improved prediction of HABs by determining the ecological and oceanographic mechanisms underlying their population dynamics, integrating biological, chemical, and physical studies supported by enhanced observation and modelling techniques.

Upwelling systems can be classified according to their physical, chemical and biological characteristics. Development of a Core Research Programme on HABs in Upwelling Systems is built on the premise that understanding the ecology and oceanography of HABs in upwelling systems will benefit from a comparative approach. The comparative method is the method of choice when controlled experimentation is not practical. To the extent that experimental control in the study of marine ecosystems is problematic, comparison presents an alternative for drawing scientific inference. Comparisons will allow the grouping of harmful species from similar habitat types. The extent, to which HAB species respond in a similar way, in systems which share similar characteristics, will assist in establishing the oceanographic processes that influence HAB population dynamics and community interactions. Equally important will be identification of similar systems that do not have the same functional HAB species or groupings. Understanding the response of harmful algae to perturbations within upwelling systems will assist in prediction, and identification of divergences from predicted responses will also be informative. Sharing of expertise and resources, the formulation of common research objectives and methods, and the implementation of similar research activities and field investigations in each of the designated upwelling systems will permit comparison.

Invitation

This announcement serves as an invitation to the broad scientific community to participate in the formulation and design of a GEOHAB Core Research Project on HABs in Upwelling Systems. Scientists working in physical, chemical and/or biological disciplines related to harmful algal research, and on the development of relevant instrumentation and models are encouraged to participate.

Meeting Format and Objectives

Monday & Tuesday:
Presentations relating to our current knowledge and understanding of HABs in upwelling systems. Presentation topics will relate to:

- Identification of the HAB species in given upwelling systems
- Identification of the physical, chemical and biological processes that define or characterise upwelling systems and quantification of the response of HAB species to these processes
- Development of models of HABs in upwelling systems to support fundamental research and predictive capabilities.

Wednesday & Thursday:

- Review of current national and regional projects/programmes in order to identify elements of research that could contribute to the Core Research Project.
- Formulation and design of a plan to guide core research in upwelling systems.
- Identification of framework activities to support the research plan.
- Identification of interested participants and designated regions for comparative research.

Friday:

- A GEOHAB Core Research Project Planning Committee will meet in closed session to finalise a report of the Open Science Meeting.

For further information:

About the GEOHAB Open Science Meeting: http://ioc.unesco.org/geohabcore/

About local arrangements please contact:
Teresa Moita, Email: tmoita@ipimar.pt or Sofia Palma, Email: sofia@ipimar.pt, Instituto Nacional de Investigação Agrária e das Pescas, Av. Brasília 1449-006 Lisboa, Portugal, INIAP-IPIMAR (website: http://ipimar-iniap.ipimar.pt)

GEOHAB
Global Ecology and Oceanography of Harmful Algal Blooms

Announcement of an Open Science Meeting on the Core Research Project: HABs in Fjords And Coastal Embayments

VALPARAÍSO, CHILE

COMITE OCEANOGRAFICO NACIONAL

26-30 April 2004

Conveners

Leonardo Guzman, Chile
Allan Cembella, Germany

GEOHAB

The GEOHAB Programme, endorsed by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO, is an international programme aimed at fostering and promoting co-operative research directed toward improving the prediction of harmful algal bloom events.

Core Research Project: HABs in Fjords and Coastal Embayments

The GEOHAB Core Research Project on Harmful Algal Blooms (HABs) in Fjords and Coastal Embayments must be comparative, interdisciplinary, and international. It will directly address the goal of GEOHAB of improved prediction of HABs by determining the ecological and oceanographic mechanisms underlying their population dynamics, integrating biological, chemical, and physical studies supported by enhanced observation and modelling techniques.

The overall objective is to understand and quantify the critical processes underlying HAB population and community dynamics in fjords and coastal embayments at temperate latitudes.

Fjords and coastal embayments are combined in this GEOHAB Core Research Project because they share features such as the importance of geographical constraints on water exchange and bloom retention and the dominance of meso-scale structures. Classic fjords, usually characterised by a high ratio of length to width, a deep wedge-shaped basin, freshwater input, and a sill located toward the mouth, create retention and/or initiation zones that favour the proliferation of a particular suite of HAB species. Many groups of key species (e.g., *Alexandrium* spp., *Pseudo-nitzschia* spp., and various raphidophytes) are virtually identical in fjords in the Northern and Southern hemispheres at similar latitudes. Such ecosystems are often only marginally affected by human activities because of low population densities, thus they are usually not subject to eutrophication. Coastal embayments are a broader category of an ecosystem type; generally, such systems comprise relatively shallow nearshore marine environments, partially surrounded by land, and often affected by terrigenous run-off, but on a smaller spatial scale than open coastal or upwelling systems. As with fjords, the hydrodynamic processes may be complex, with an accentuated role of tidal flux, storm surges, wind-driven mixing, and salinity and thermal stratification. The physical processes associated with HABs in these systems are most often related to «density adjustment» problems, that is, buoyancy and frontal dynamics, geostrophic adjustment, establishment of a pycnocline after a storm and perhaps topographic frontal motion. The effects of benthic-pelagic coupling are likely to be crucial in understanding HAB dynamics in fjords and coastal embayments. Coastal embayments with limited exchange to the open coast may serve as «seed beds» for benthic cysts or relict populations of HAB species. Such systems are particularly vulnerable to anthropogenic changes in the biological and chemical regime, and the introduction of exotic species via deballasting and transfer of aquaculture stock. Many fjords and coastal embayments are well characterised in terms of long-term plankton records and toxicity events. Optical data sets on ocean colour and relevant plankton patches are becoming increasing available from these systems. Furthermore, basic circulation models (both 2-D and 3-D) are already available from several locations around the world.

Overall Objective: To understand and quantify the critical processes underlying HAB population and community dynamics in fjords and coastal embayments in temperate latitudes.

Invitation

This announcement serves as an invitation to the broad scientific community to participate in the formulation and design of a GEOHAB Core Research Project on HABs in Fjords and Coastal Embayments. Scientists working in physical, chemical and/or biological disciplines related to harmful algal research, and on the development of relevant instrumentation and models are encouraged to participate.

For further information:

http://ioc.unesco.org/geohabcore/ or http://www.jhu.edu/scor/OSM2Program.htm

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HARMFUL ALGAE NEWS

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ISSN 0020-7918