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Marine Science Review – 240

Algae and cyanobacteria, blooms and biotoxins

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In this review:

O/A denotes an open access article or journal

A. Recent articles – no abstract available

Engelhaupt, E. **New *Pfiesteria* toxin identified.** *Environmental Science and Technology* 41(4): 1060, 2007. O/A

B. Recent publications available online

Alcock, F. 2007. **An Assessment of Florida Red Tide: Causes, Consequences and Management Strategies.** Technical Report 1190. Mote Marine Laboratory, Sarasota. 40pp.

Available at:
http://www.mote.org/clientuploads/Documents/MPI/Final_MPI_RedTide_no_embargo_bar.pdf?PHPSESSID=208d94b0b383b42de702152036d885f0

Notes: Red tides have long been a fixture of the West Florida Shelf ecosystem and most scientists agree that the initiation of blooms and significant stages of their development occur offshore and deep in the water column. Once a bloom moves inshore, it may benefit from land-based nutrient fluxes. These fluxes occur naturally but they can also be exacerbated by coastal pollution. Reducing nutrients from land may ease the severity and duration of red tides, and reduction should be part of a comprehensive management strategy that responds to red tides. Reduced nutrient loads and better water quality will also generate ecological, social and economic benefits that are independent of any connection to Florida red tides. It is imperative that scientists, policymakers and stakeholders move beyond polarized debate surrounding the links between coastal pollution and red tide. Conclusive scientific evidence of a strong linkage between coastal pollution and red tide blooms would no doubt generate political momentum for a pollution-reduction agenda. However, the nature of nutrient conditions on the West Florida Shelf and the variety of nutrient sources that likely contribute to red tides make it very difficult to pinpoint or assess the relative significance of each source. Conclusive evidence remains elusive but Florida needs to act now. Florida needs to reduce nutrient loads to its watersheds for reasons that go beyond red tide and it needs to develop a comprehensive management strategy for red tides that goes beyond reducing coastal pollution.

Jewett, E.B., Lopez, C.B., Dortch, Q. and Etheridge, S.M. 2007. **National Assessment of Efforts to Predict and Respond to Harmful Algal Blooms in U.S. Waters.** Interim Report. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC. 61pp.

Available at: http://ocean.ceq.gov/about/docs/iwg4h_prrpt_final.pdf

Notes: This report, also known as the Prediction and Response Report, assesses the harmful algal bloom problem in U.S. waters and identifies progress made since 2000 by federal agencies in prevention, control, and mitigation of harmful algal blooms in the U.S. The report calls for the coordinated federal program to develop a strategy for maximizing progress in areas identified for major potential advancement including: - a refined focus on research for prevention, control, and mitigation of harmful algal blooms, - sustained and coordinated infrastructure, including increasing availability of standards and probes, shared-use facilities, platforms for continuous real-time monitoring, and training, - incorporating social sciences in harmful algal bloom response strategies, and - improving and coordinating event response. The study reports that the frequency of harmful algal bloom events is increasing and their geographical distribution now impacts all the coastal states. Freshwater harmful algal blooms are an increasing problem in inland states as well. Human activities such as nutrient pollution are thought to contribute to some of these increases. The economic effects of harmful algal blooms in the U.S. is estimated to reach at least $82 million per year in lost income for fisheries, lost recreational opportunities, decreased tourism, public health costs of illness, and expense of monitoring and management.

C. Recent articles with abstracts

Garcia-Camacho, F., Rodriguez, J.G., Miron, A.S., Garcia, M.C.C., Belarbi, E.H., Chisti, Y., and Grima, E.M. **Biotechnological significance of toxic marine dinoflagellates.** *Biotechnology Advances* 25(2): 176-194, 2007.

Notes: Dinoflagellates are microalgae that are associated with the production of many marine toxins. These toxins poison fish, other wildlife and humans. Dinoflagellate-associated human poisonings include paralytic shellfish poisoning, diarrhetic shellfish poisoning, neurotoxic shellfish poisoning, and ciguatera fish poisoning. Dinotlagellate toxins and bioactives are of increasing interest because of their commercial impact, influence on safety of seafood, and potential medical and other applications. This review discusses biotechnological methods of identifying toxic dinoflagellates and detecting their toxins. Potential applications of the toxins are discussed. A lack of sufficient quantities of toxins for investigational purposes remains a significant limitation. Producing quantities of dinoflagellate bioactives requires an ability to mass culture them. Considerations relating to bioreactor culture of generally fragile and slow-growing dinoflagellates are discussed. Production and processing of dinoflagellates to extract bioactives, require attention to biosafety considerations as outlined in this review.

Genovesi-Giunti, B., Laabir, M., and Vaquer, A. **The benthic resting cyst: A key actor in harmful dinoflagellate blooms - A review.** *Vie et Mileau* 56(4): 327-337, 2006.

Notes: Resting cysts (RC) constitute a coupling between benthic and pelagic stages and influence the bloom development in a number of bloom forming dinoflagellate species. Encystment capability coupled with high vegetative cell density (> one million cells 1^{-1}) contribute to the formation of an accumulation zone: " the cyst bank ", which is directly linked to the success of bloom initiation and its recurrence. The survival time of benthic RCs (few weeks to several years), their viability which could be negatively affected by predation, and their mandatory dormancy period (few days to several months) are variable and influence the seeding potential of the population significantly. Excystment rate, mainly controlled by temperature and oxygen level, and the germling cells' viability determine the inoculum size. Many biological processes in RCs have been shown to be controlled by endogenous and environmental factors, and vary between species and within the same species as a function of geographic strains.

Moeller, P.D.R., Beauchesne, K.R., Huncik, K.M., Davis, W.C., Christopher, S.J., Riggs-Gelasco, P., and Gelasco, A.K. **Metal complexes and free radical toxins produced by *Pfiesteria piscicida*.** *Environmental Science and Technology* 41(4): 1166-1172, 2007.

Notes: Metal-containing organic toxins produced by *Pfiesteria piscicida* were characterized, for the first time, by corroborating data obtained from five distinct instrumental methods: nuclear magnetic resonance spectroscopy (NMR), inductively coupled plasma mass spectrometry (ICP-MS), liquid chromatography particle beam glow discharge mass spectrometry (LC/PB-

GDMS), electron paramagnetic resonance spectroscopy (EPR), and X-ray absorption spectroscopy (XAS). The high toxicity of the metal-containing toxins is due to metal-mediated free radical production. This mode of activity explains the toxicity of *Pfiesteria*, as well as previously reported difficulty in observing the molecular target, due to the ephemeral nature of radical species. The toxins are highly labile in purified form, maintaining activity for only 2-5 days before all activity is lost. The multiple toxin congeners in active extracts are also susceptible to decomposition in the presence of white light, pH variations, and prolonged heat. These findings represent the first formal isolation and characterization of a radical forming toxic organic-ligated metal complex isolated from estuarine/marine dinoflagellates. These findings add to an increased understanding regarding the active role of metals interacting with biological systems in the estuarine environment, as well as their links and implications to human health.

Giacobbe, M.G., Penna, A., Gangemi, E., Maso, M., Garces, E., Fraga, S., Bravo, I., Azzaro, F., and Penna, N. **Recurrent high-biomass blooms of *Alexandrium taylorii* (Dinophyceae), a HAB species expanding in the Mediterranean.** *Hydrobiologia* 580: 125-133, 2007.

Notes: Summer outbreaks of the dinoflagellate *Alexandrium taylorii* Balech are recurrent events in nearshore waters of Sicily (Italy) -- a central region in the Mediterranean Sea -- producing dense yellowish-green patches. Beyond the local phenomenon, the problem covers a broader geographic scale, involving also other European localities, mostly in Spain. Biological, environmental, and molecular data are reported here from a semi-closed bay of Sicily (Vulcano Island, Tyrrhenian Sea, 2000-2003), showing in summer the recurrence of high-biomass blooms and events of water discolouration. Without underestimating the setbacks to the tourism industry, the ecological impact of *A. taylorii* blooms may be important considering the high levels of biomass produced (West Bay, Vulcano: up to a magnitude order of 107 cells l^{-1}, 50-180 μgChl*a* l^{-1}, June 2002 and 2003) and coincident conditions of oxygen supersaturation of the waters (130-170%). Trophic trends in the Tyrrhenian site indicate high amounts of nutrients linked to the increased anthropogenic activity in summer, although recently there has been an apparent shift of the marked eutrophic conditions towards a slighter eutrophy. Genetic data on isolates of *A. taylorii* from the Mediterranean Sea are also discussed. Molecular analyses implied the sequencing of target rDNA regions (5.8S rDNA and ITS regions) of several isolates from different Mediterranean localities, as well as the application of species-specific PCR assays for rapid species identification in preserved field samples. The confirmation of the specific identity provided new insights into the biogeography of this species and further evidence of the occurrence of *A. taylorii* in a number of Mediterranean localities, both in the western side (the Catalan coast of Spain) and the eastern area (Greece). Analyses of the molecular diversity of geographically distinct isolates of *A. taylorii* from Italy, Spain, and Greece based on the 5.8S rDNAITS region sequences showed a high level of similarity, indicating the existence of an unique Mediterranean population.

Haglund, P., Malmvarn, A., Bergek, S., Bignert, A., Kautsky, L., Nakano, T., Wiberg, K., and Asplund, L. **Brominated dibenzo-p-dioxins: A new class of marine toxins?** *Environmental Science and Technology* 41(9): 3069-3074, 2007.

Notes: Levels of polybrominated dibenzo-p-dioxins (PBDDs) were measured in marine fish, mussels, and shellfish. PBDDs were nondetectable in samples from freshwater environments, and their levels were successively higher in samples from the marine environments of the Bothnian Bay and Bothnian Sea, the West Coast of Sweden, and the Baltic Proper. In Baltic Proper littoral fish the levels of PBDDs generally exceeded those of their chlorinated analogues (PCDDs). This is alarming as some Baltic fish species already are contaminated by chlorinated dioxins to such an extent that they cannot be sold on the European market. By comparing spatial trends in PBDD and PCDD distributions, and PBDD patterns in fish, mussels, and algae, we show that the PBDDs are probably produced naturally, and we propose a route for their biosynthesis. We further show that the levels of PBDDs are high (ng/g wet weight) in mussels, and that the levels increase over time. Finally, we discuss the possibility that the PBDDs have adverse biological effects, and that the levels are increasing as a result of global warming and eutrophication.

Verity, P.G., Brussaard, C.P., Nejstgaard, J.C., van Leeuwe, M.A., Lancelot, C., and Medlin, L.K. **Current understanding of *Phaeocystis* ecology and biogeochemistry, and perspectives for future research.** *Biogeochemistry* 83(1-3): 311-330, 2007.

Notes: The phytoplankton genus *Phaeocystis* has well-documented, spatially and temporally extensive blooms of gelatinous colonies; these are associated with release of copious amounts of dimethyl sulphide (an important climate-cooling aerosol) and

alterations of material flows among trophic levels and export from the upper ocean. A potentially salient property of the importance of *Phaeocystis* in the marine ecosystem is its physiological capability to transform between solitary cell and gelatinous colonial life cycle stages, a process that changes organism biovolume by 6-9 orders of magnitude, and which appears to be activated or stimulated under certain circumstances by chemical communication. Both life-cycle stages can exhibit rapid, phased ultradian growth. The colony skin apparently confers protection against, or at least reduces losses to, smaller zooplankton grazers and perhaps viruses. There are indications that *Phaeocystis* utilizes chemistry and/or changes in size as defenses against predation, and its ability to create refuges from biological attack is known to stabilize predator-prey dynamics in model systems. Thus the life cycle form in which it occurs, and particularly associated interactions with viruses, determines whether *Phaeocystis* production flows through the traditional "great fisheries" food chain, the more regenerative microbial food web, or is exported from the mixed layer of the ocean. Despite this plethora of information regarding the physiological ecology of *Phaeocystis*, fundamental interactions between life history traits and system ecology are poorly understood. Research summarized here, and described in the various papers in this special issue, derives from a central question: how do physical (light, temperature, particle distributions, hydrodynamics), chemical (nutrient resources, infochemistry, allelopathy), biological (grazers, viruses, bacteria, other phytoplankton), and self-organizational mechanisms (stability, indirect effects) interact with life-cycle transformations of *Phaeocystis* to mediate ecosystem patterns of trophic structure, biodiversity, and biogeochemical fluxes? Ultimately the goal is to understand and thus predict why *Phaeocystis* occurs when and where it does, and the bio-feedbacks between this keystone species and the multitrophic level ecosystem.

Larkin, S.L. and Adams, C.M. **Harmful algal blooms and coastal business: economic consequences in Florida.** *Society and Natural Resources* 20(9): 849-859, 2007.

Notes: The impacts of harmful algal blooms (HABs) on coastal businesses in the Ft. Walton Beach and Destin areas of northwest Florida were estimated for 1995-1999. Separate time-series models for the restaurant and lodging sectors revealed that HABs reduced restaurant and lodging revenues in the localized study area by $2.8 million and $3.7 million per month, respectively, which represents a 29% to 35% decline in average monthly revenues for each sector during months of red tide incidence. By comparison, a tropical storm was found to reduce monthly restaurant revenues by $0.5 million, and each inch of rainfall reduced revenues an additional $41,000. Adverse weather was not found to affect the lodging sector. While the estimates are conservative given the resolution of data, the magnitude of effects indicate that coastal communities have suffered significant revenue losses due to HABs and that these losses are larger than caused by other environmental events.

Fire, S.E., Fauquier, D., Flewelling, L.J., Henry, M., Naar, J., Pierce, R., and Wells, R.S. **Brevetoxin exposure in bottlenose dolphins (*Tursiops truncatus*) associated with *Karenia brevis* blooms in Sarasota Bay, Florida.** *Marine Biology* 152(4): 827-834, 2007.

Notes: Bottlenose dolphins (*Tursiops truncatus*) face a variety of threats, including risk of exposure to brevetoxins produced by blooms of the harmful alga *Karenia brevis* . This study investigated brevetoxin exposure in a population of dolphins inhabiting Sarasota Bay, Florida, USA (27ºN, 82ºW), utilizing tissues from dolphins recovered between 1994 and 2003. Brevetoxin levels detected by ELISA in tissues, gastric samples and excreta from dolphin carcasses (n = 19) associated with *K. brevis* blooms were compared with with levels in carcasses (n = 16) associated with background *K. brevis* conditions. In the *K. brevis*-exposed set, 84% of dolphin carcasses recovered during *K. brevis* blooms had detectable brevetoxin levels, with values ranging between 7 and 2,896 ng PbTx-3 eq g^{-1}. Over 50% of dolphin carcasses recovered during non-bloom conditions also tested positive by ELISA for brevetoxins, with concentrations ranging from 6 to 44 ng PbTx-3 eq g^{-1}. Control samples from the east coast of Florida were negative by the ELISA. Results from this study establish baseline brevetoxin body burdens in a dolphin population frequently exposed to *K. brevis* blooms, and data indicate that dolphin carcasses not associated with large-scale mortality events can contain levels of brevetoxins comparable to carcasses stranding during such events.

Peterson, B.J., Chester, C.M., Jochem, F.J., and Fourqurean, J.W. **Potential role of sponge communities in controlling phytoplankton blooms in Florida Bay.** *Marine Ecology Progress Series* 328: 93-103, 2007.

Notes: An unprecedented series of ecological disturbances have been recurring within Florida Bay since the summer of 1987. Persistent and widespread phytoplankton and cyanobacteria blooms have coincided with the large scale decimation of sponge

communities. One hypothesis is that the large scale loss of suspension-feeding sponges has rendered the Florida Bay ecosystem susceptible to these recurring blooms. The primary objective of this study was to experimentally evaluate the potential for suspension-feeding sponges to control nuisance phytoplankton blooms within Florida Bay prior to a large sponge die-off event. To achieve this objective, we determined the extent and biomass of the surviving sponge community in the different basins of Florida Bay. Many areas within Florida Bay possessed sponge densities and biomasses of 1 to 3 ind. m^{-2} or 100 to 300 g m^{-2} respectively. The dominant species included *Spheciospongia vesparia*, *Chondrilla nucula*, *Cinachyra alloclada*, *Tedania ignis* and *Ircinia* sp., which accounted for 68% of individual sponges observed and 88% of sponge biomass. Laboratory grazing rates of these dominant sponges were experimentally determined on 4 different algal food treatments: a monoculture of cyanobacteria *Synechococcus elongatus*, a monoculture of the diatom *Cyclotella choctawhatcheeana*, a monoculture of the dinoflagellate *Prorocentrum hoffmanianum*, and an equal volume of the 3 monocultures combined. To estimate the impact of a mass sponge mortality event on the system-wide filtration rate of Florida Bay, we combined estimates of the current sponge biomass and laboratory sponge filtration rates with estimates of mean volumes of the sub-basins of Florida Bay. This study implies that the current blooms occurring within the central region of Florida Bay can be explained by the loss of the dominant suspension feeder in this system, and there is no need to invoke a new addition of nutrients within this region for the blooms to occur.

Glibert, P.M., Wazniak, C.E., Hall, M.R., and Sturgis, B. **Seasonal and interannual trends in nitrogen and brown tide in Maryland's coastal bays.** *Ecological Applications* 17(5): S79-S87, 2007.

Notes: A retrospective analysis revealed that water quality in the coastal bays of Maryland (USA) has been declining over the past decade, as evidenced by increases in total nitrogenous nutrients and in outbreaks of brown tides caused by the pelagophyte *Aureococcus anophagefferns*. However, the increases in total nitrogen are not a function of increases in inorganic nitrogen, but rather a function of increases in dissolved organic nitrogen (DON). A near-decadal record (1996-2004) demonstrates that an approximate doubling of DON over this time period correlates with a similar increase in total chlorophyll and an even larger increase in the proportion of chlorophyll that is composed of brown tide. Additionally, on an annual basis overall chlorophyll levels and strength of the brown-tide blooms were related to the DON availability that developed during the prior months. *Aureococcus anophagefferens* is a harmful algal bloom species that preferentially uses DON for its nutrition over inorganic nitrogen forms and thus is a symptom of organic rather than inorganic nitrogen-based eutrophication. These results demonstrate that long-term changes in nutrient quantity and composition have occurred in the coastal bays of Maryland during the past decade and that total phytoplankton biomass, as well as the proliferation of brown tide, are related to these changes. Whether these changes are evidence of a long-term trajectory or represent a short-term anomaly will be revealed in future monitoring.

Hernandez-Becerril, D.U., Alonso-Rodriguez, R., Alvarez-Gongora, C., Baron-Campis, S.A., Ceballos-Corona, G., Herrera-Silveira, J., Del Castillo, M.E.M., Juarez-Ruiz, N., Merino-Virgilio, F., Morales-Blake, A., Ochoa, J.L., Orellana-Cepeda, E., Ramirez-Camarena, C., and Rodriguez-Salvadoro, R. **Toxic and harmful marine phytoplankton and microalgae (HABs) in Mexican coasts.** *Journal of Environmental Science and Health Part A - Toxic/Hazardous Substances & Environmental Engineering* 42(10): 1349-1363, 2007.

Notes: Harmful Algal Blooms (HABs) are becoming an increasing problem to human health and environment (including effects on natural and cultured resources, tourism and ecosystems) all over the world. In Mexico a number of human fatalities and important economic losses have occurred in the last 30 years because of these events. There are about 70 species of planktonic and non-planktonic microalgae considered harmful in Mexican coasts. The most important toxin-producing species are the dinoflagellates *Gymnodinium catenatum* and *Pyrodinium bahamense* var. *compressum*, in the Mexican Pacific, and *Karenia brevis* in the Gulf of Mexico, and consequently the poisonings documented in Mexico are Paralytic Shellfish Poisoning (PSP) and Neurotoxic Shellfish Poisoning (NSP). Although there is evidence that Amnesic Shellfish Poisoning (ASP), Diarrhetic Shellfish Poisoning (DSP) and Ciguatera Fish Poisoning (CFP) also occur in Mexico, these problems are reported less frequently. The type of phytoplankton and epiphytic microalgae, their toxins and harmful effects as well as current methodology used to study these phenomena are presented in this paper. As an experienced group of workers, we include descriptions of monitoring and mitigation programs, our proposals for collaborative projects and perspectives on future research.

Steensma, D.P. **Exacerbation of asthma by Florida "red tide" during an ocean sailing trip.** *Mayo Clinic Proceedings* 82(9): 1128-1130, 2007.

Notes: A 36-year-old man with adult-onset nonallergic triad asthma developed acute bronchospasm and copious sputum production during an offshore sailing excursion on the Gulf Coast of Florida. Symptoms were linked to proximity to blooms of the marine dinoflagellate *Karenia brevis* ("red tide") and heavy aerosolized brevetoxin exposure, and symptoms recurred during rechallenge. Patients with respiratory disease who are planning a visit to red tide-prone seaside areas should be cautioned to bring their pulmonary medications, and clinicians should be aware that reactive airway symptoms may be triggered by exposure to red tide.

Edvardsen, B., Eikrem, W., Shalchian-Tabrizi, K., Riisberg, I., Johnsen, G., Naustvoll, L., and Throndsen, J. ***Verrucophora farcimen* gen. et sp. nov. (Dictyochophyceae, Heterokonta) - a bloom-forming ichthyotoxic flagellate from the Skagerrak, Norway.** *Journal of Phycology* 43(5): 1054-1070, 2007.

Notes: Since 1998, a heterokont flagellate initially named *Chattonella* aff. *verruculosa* has formed recurrent extensive blooms in the North Sea and the Skagerrak, causing fish mortalities. Cells were isolated from the 2001 bloom off the south coast of Norway, and monoalgal cultures were established and compared with the *Chattonella verruculosa* Y. Hara et Chihara reference strain NIES 670 from Japan. The cells in Norwegian cultured isolates were very variable in size and form, being large oblong (up to 34µm long) to small rounded (5-9µm in diameter) with two unequal flagella, numerous chloroplasts, and mucocysts. The SSU and partial LSU rDNA sequences of strains from Norway and Japan were compared and differed by 0.4% (SSU) and 1.3% (LSU), respectively. Five strains from Norway were identical in the LSU rDNA region. Phylogenetic analyses based on heterokont SSU and concatenated SSU+LSU rDNA sequences placed *C.* aff. *verruculosa* and the Japanese *C. verruculosa* within the clade of Dictyochophyceae, with the picoflagellate *Florenciella parvula* Eikrem as the closest relative. Ultrastructure, morphology, and pigment composition supported this affinity. We propose the name *Verrucophora farcimen* sp. et gen. nov. for this flagellate and systematically place it within the class Dictyochophyceae. Our studies also show that *C. verruculosa* from Japan is genetically and morphologically different but closely related to *V. farcimen.* The species is transferred from the class Raphidophyceae to the class Dictyochophyceae and renamed *Verrucophora verruculosa.* We propose a new order, Florenciellales, to accommodate *V. farcimen*, *V. verruculosa*, and *F. parvula.*

Cloern, J.E., Jassby, A.D., Thompson, J.K., and Hieb, K.A. **A cold phase of the East Pacific triggers new phytoplankton blooms in San Francisco Bay.** *Proceedings of the National Academy of Sciences [USA]* 104(47): 18561-18565, 2007.

Notes: Ecological observations sustained over decades often reveal abrupt changes in biological communities that signal altered ecosystem states. We report a large shift in the biological communities of San Francisco Bay, first detected as increasing phytoplankton biomass and occurrences of new seasonal blooms that began in 1999. This phytoplankton increase is paradoxical because it occurred in an era of decreasing wastewater nutrient inputs and reduced nitrogen and phosphorus concentrations, contrary to the guiding paradigm that algal biomass in estuaries increases in proportion to nutrient inputs from their watersheds. Coincidental changes included sharp declines in the abundance of bivalve mollusks, the key phytoplankton consumers in this estuary, and record high abundances of several bivalve predators: Bay shrimp, English sole, and Dungeness crab. The phytoplankton increase is consistent with a trophic cascade resulting from heightened predation on bivalves and suppression of their filtration control on phytoplankton growth. These community changes in San Francisco Bay across three trophic levels followed a state change in the California Current System characterized by increased upwelling intensity, amplified primary production, and strengthened southerly flows. These diagnostic features of the East Pacific "cold phase" lead to strong recruitment and immigration of juvenile flatfish and crustaceans into estuaries where they feed and develop. This study, built from three decades of observation, reveals a previously unrecognized mechanism of ocean-estuary connectivity. Interdecadal oceanic regime changes can propagate into estuaries, altering their community structure and efficiency of transforming land-derived nutrients into algal biomass.

Sivonen, K., Halinen, K., Sihvonen, L.M., Koskenniemi, K., Sinkko, H., Rantasarkka, K., Moisander, P.H., and Lyra, C. **Bacterial diversity and function in the Baltic Sea with an emphasis on cyanobacteria.** *Ambio* 36(2-3): 180-185, 2007.

Notes: In this article we summarize the current knowledge of Baltic Sea cyanobacteria, focusing on diversity, toxicity, and nitrogen fixation in the filamentous heterocystous taxa. We also review the recent results of our microbial diversity studies in planktonic and benthic habitats in the Baltic Sea. Based on molecular analyses, we have improved the understanding of cyanobacterial population structure by assessing genetic diversity within species that are morphologically inseparable. Moreover, we have studied microbial functions such as toxin production and nitrogen fixation in situ under different environmental conditions. Phosphorus limitation of bloom-forming, nitrogen-fixing cyanobacteria was clearly verified, emphasizing the importance of continuous efforts to reduce this element in the Baltic Sea. We have designed a rapid and reliable detection method for the toxic cyanobacterium *Nodularia spumigena*, which can be used to study bloom formation of this important toxin producer.

Vahtera, E., Conley, D.J., Gustafsson, B.G., Kuosa, H., Pitkanen, H., Savchuk, O.P., Tamminen, T., Viitasalo, M., Voss, M., Wasmund, N., and Wulff, F. **Internal ecosystem feedbacks enhance nitrogen-fixing cyanobacteria blooms and complicate management in the Baltic Sea.** *Ambio* 36(2-3): 186-194, 2007.

Notes: Eutrophication of the Baltic Sea has potentially increased the frequency and magnitude of cyanobacteria blooms. Eutrophication leads to increased sedimentation of organic material, increasing the extent of anoxic bottoms and subsequently increasing the internal phosphorus loading. In addition, the hypoxic water volume displays a negative relationship with the total dissolved inorganic nitrogen pool, suggesting greater overall nitrogen removal with increased hypoxia. Enhanced internal loading of phosphorus and the removal of dissolved inorganic nitrogen leads to lower nitrogen to phosphorus ratios, which are one of the main factors promoting nitrogen-fixing cyanobacteria blooms. Because cyanobacteria blooms in the open waters of the Baltic Sea seem to be strongly regulated by internal processes, the effects of external nutrient reductions are scale-dependent. During longer time scales, reductions in external phosphorus load may reduce cyanobacteria blooms; however, on shorter time scales the internal phosphorus loading can counteract external phosphorus reductions. The coupled processes inducing internal loading, nitrogen removal, and the prevalence of nitrogen-fixing cyanobacteria can qualitatively be described as a potentially self-sustaining "vicious circle". To effectively reduce cyanobacteria blooms and overall signs of eutrophication, reductions in both nitrogen and phosphorus external loads appear essential.

Karjalainen, M., Engstrom-Ost, J., Korpinen, S., Peltonen, H., Paakkonen, J.P., Ronkkonen, S., Suikkanen, S., and Viitasalo, M. **Ecosystem consequences of cyanobacteria in the northern Baltic Sea.** *Ambio* 36(2-3): 195-202, 2007.

Notes: Cyanobacteria of the Baltic Sea have multiple effects on organisms that influence the food chain dynamics on several trophic levels. Cyanobacteria contain several bioactive compounds, such as alkaloids, peptides, and lipopolysaccharides. A group of nonribosomally produced oligopeptides, namely microcystins and nodularin, are tumor promoters and cause oxidative stress in the affected cells. Zooplankton graze on cyanobacteria, and when ingested, the hepatotoxins (nodularin) decrease the egg production of, for example, copepods. However, the observed effects are very variable, because many crustaceans are tolerant to nodularin and because cyanobacteria may complement the diet of grazers in small amounts. Cyanobacterial toxins are transferred through the food web from one trophic level to another. The transfer rate is relatively low in the pelagic food web but reduced feeding and growth rates of fish larvae have been observed. In the benthic food web, especially in blue mussels, nodularin concentrations are high, and benthic feeding juvenile flounders have been observed to disappear from bloom areas. In the littoral ecosystem, gammarids have shown increased mortality and weakening of reproductive success under cyanobacterial exposure. In contrast, mysid shrimps seem to be tolerant to cyanobacterial exposure. In fish larvae, detoxication of nodularin poses a metabolic cost that is reflected as decreased growth and condition, which may increase their susceptibility to predation. Cyanobacterial filaments and aggregates also interfere with both hydromechanical and visual feeding of planktivores. The feeding appendages of mysid shrimps may clog, and the filaments interfere with prey detection of pike larvae. On the other hand, a cyanobacterial bloom may provide a refuge for both zooplankton and small fish. As the decaying bloom also provides an ample source of organic carbon and nutrients for the organisms of the microbial loop, the zooplankton species capable of selective feeding may thrive in bloom conditions. Cyanobacteria also compete for nutrients with other primary producers and change the nitrogen (N): phosphorus (P) balance of their environment by their N-fixation. Further, the bioactive compounds of cyanobacteria directly influence other primary producers, favoring cyanobacteria, chlorophytes, dinoflagellates, and nanoflagellates and inhibiting cryptophytes. As the

selective grazers also shift the grazing pressure on other species than cyanobacteria, changes in the structure and functioning of the Baltic Sea communities and ecosystems are likely to occur during the cyanobacterial bloom season.

Brand, L.E. and Compton, A. **Long-term increase in *Karenia brevis* abundance along the Southwest Florida Coast.** *Harmful Algae* 6(2): 232-252, 2007.

Notes: Data collected along the southwest coast of Florida between Tampa Bay and Sanibel Island on the abundance of the toxic dinoflagellate *Karenia brevis* from 1954 to 2002 were examined for spatial and temporal patterns. *K. brevis* was found to be approximately 20-fold more abundant within 5 km of the shoreline than 20-30 km offshore. Overall, *K. brevis* was approximately 13-18-fold more abundant in 1994-2002 than in 1954-1963. In 1954-1963, *K. brevis* occurred primarily in the fall months. In 1994-2002, it was more abundant not only in the fall, but also in the winter and spring months. It is hypothesized that greater nutrient availability in the ecosystem is the most likely cause of this increase in *K. brevis* biomass, and the large increase in the human population and its activities in South Florida over the past half century is a major factor.

Villareal, T.A., Hanson, S., Qualia, S., Jester, E.L.E., Granade, H.R., and Dickey, R.W. **Petroleum production platforms as sites for the expansion of ciguatera in the northwestern Gulf of Mexico.** *Harmful Algae* 6(2): 253-259, 2007.

Notes: Ciguatera is a common human disease of tropical, coral reef ecosystems acquired by consuming finfish-containing ciguatoxins (CTX). There are few records of this disease in the northwestern Gulf of Mexico, a region characterized by soft muddy bottoms that are considered poor habitat for the CTX source dinoflagellate *Gambierdiscus toxicus*. However, the approximately 4000 petroleum production platforms and hundreds of state-sponsored artificial reefs located in the Gulf of Mexico provide hard substrate and often support coral and other components of the tropical benthos. In addition to their role in their resource extraction, these oil production platforms are also popular sites for recreational fishing and sport diving. We examined these platforms as potential substrate for *G. toxicus* and report a first record of this species in the NW Gulf of Mexico. All the platforms (n = 6) examined harbored the dinoflagellate as an epiphyte on the fouling community, with three finds of *G. toxicus* associated with the pelagic macroalga, *Sargassum*. Only minor toxicity (< 0.15 ppb) was noted in two of 20 great barracuda (*Sphyraena barracuda*) examined. Tagging data suggest trans-Gulf migrations by barracuda are common; thus, we cannot determine if the toxicity was acquired locally or transported in migrating fish. These platforms are a clear example of how human activity has altered the environment in a way that allows expansion of a HAB population. The rapid increase in production platforms since 1942 has provided novel substrate in a sandy/muddy bottom environment generally considered to be poor habitat for these benthic dinoflagellates. These platforms create a unique habitat in the upper euphotic zone and serve as intersection points for fishermen and potentially toxic fish. Many Gulf of Mexico states have active programs to turn non-producing platforms into artificial reefs. Our results suggest that the use of these platforms as fisheries enhancement structures could have unintended consequences for human health, particularly if projected rising sea-surface temperatures over the next century alter benthic distributions and fish migration patterns. These concerns also extend to mariculture operations around oil production rigs or offshore wind farms, both of which would also add substrate for epibenthic microalgae.

Schnetzer, A., Miller, P.E., Schaffner, R.A., Stauffer, B.A., Jones, B.H., Weisberg, S.B., Digiacomo, P.M., Berelson, W.M., and Caron, D.A. **Blooms of *Pseudo-nitzschia* and domoic acid in the San Pedro Channel and Los Angeles harbor areas of the Southern California Bight, 2003- 2004.** *Harmful Algae* 6(3): 372-387, 2007.

Notes: Abundances of *Pseudo-nitzschia* spp. and concentrations of particulate domoic acid (DA) were determined in the Southern California Bight (SCB) along the coasts of Los Angeles and Orange Counties during spring and summer of 2003 and 2004. At least 1500 km^2 were affected by a toxic event in May/June of 2003 when some of the highest particulate DA concentrations reported for US coastal waters were measured inside the Los Angeles harbor (12.7 μg DA L^{-1}). Particulate DA levels were an order of magnitude lower in spring of 2004 (February and March), but DA concentrations per cell at several sampling stations during 2004 exceeded previously reported maxima for natural populations of *Pseudo-nitzschia* (mean = 24 pg DA cell^{-1}, range = 0-117 pg DA cell^{-1}). *Pseudo-nitzschia australis* dominated the *Pseudo-nitzschia* assemblage in spring 2004. Overall, DA-poisoning was implicated in >1400 mammal stranding incidents within the SCB during 2003 and 2004. Ancillary physical and chemical data obtained during our regional surveys in 2004 revealed that *Pseudo-nitzschia* abundances, particulate DA and cellular DA concentrations were inversely correlated with concentrations of silicic acid, nitrogen and phosphate, and

to specific nutrient ratios. Particulate DA was detected in sediment traps deployed at 550 and 800 m depth during spring of 2004 (0.29-7.6 μg DA (g sediment dry weight^{-1}). The highest DA concentration in the traps was measured within 1 week of dramatic decreases in the abundances of *Pseudo-nitzschia* in surface waters. To our knowledge these are the deepest sediment trap collections from which DA has been detected. Sinking of the spring *Pseudo-nitzschia* bloom may constitute a potentially important link between DA production in surface waters and benthic communities in the coastal ocean near Los Angeles. Our study indicates that toxic blooms of *Pseudo-nitzschia* are a recurring phenomenon along one of the most densely populated coastal stretches of the SCB and that the severity and magnitude of these events can be comparable to or greater than these events in other geographical regions affected by domoic acid.

Lapointe, B.E. and Bedford, B.J. **Drift rhodophyte blooms emerge in Lee County, Florida, USA: Evidence of escalating coastal eutrophication.** *Harmful Algae* 6(3): 421-437, 2007.

Notes: Macroalgal blooms have increased globally in recent decades as a result of increased nutrient enrichment and eutrophication of coastal waters. In Lee County, Florida, this problem reached a critical stage in 2003/2004 when massive rhodophyte blooms washed ashore, making beaches unsuitable for recreation and requiring an expensive removal program. To better understand the ecology of these blooms, water quality and macroalgae sampling was conducted in August 2004, prior to hurricane Charley, and again in late October following several months of large freshwater discharges from the Caloosahatchee River. During both samplings, water and macroalgae were collected along a gradient extending from the Caloosahatchee River to natural and artificial reefs up to 26 km from shore. Dissolved nutrient concentrations were generally high throughout the study area, with significantly higher concentrations in the Caloosahatchee River. Mean dissolved inorganic nitrogen concentrations in the Caloosahatchee River increased from Ortona Lock (< 18 μM) to Franklin Lock (23-28 μM) downstream during both samplings, indicating significant enrichment within the basin. On coastal reefs, mean ammonium concentrations increased six-fold (≤ 0.20-1.31 μM) and soluble reactive phosphorus increased three-fold (0.30-0.92 μM) from August to October, respectively. Mean reef macroalgae C:N ratios were low and similar in August (13.9) and October (13.5), and C:P and N:P ratios were also low but decreased significantly from August to October (386-242 and 27.4-17.5, respectively). Macroalgal $\delta^{15}N$ values increased from Ortona Lock (+8 to 9‰) to Franklin Lock (+12 to 15‰) during both samplings, were within the sewage nitrogen range, and decreased with increasing distance from shore to ~ +3.0‰. At the most offshore reef, macroalgae (*Gracilaria*, *Hypnea*, *Botryocladia*, *Eucheuma*, *Sargassum*) collected in July 2004 from Lee County beaches had mean $\delta^{15}N$ values >+6.0‰, similar to values for macroalgae on inshore reefs and within the sewage nitrogen range. However, mean $\delta^{15}N$ values of reef macroalgae decreased from August (+5.84‰) to October (+3.89‰) as Caloosahatchee River discharges increased, suggesting relatively larger contributions from nitrogen sources with low $\delta^{15}N$ values (<+3‰), such as rainfall and agricultural fertilizers, in the wet season. Improved management of freshwater releases from Lake Okeechobee, combined with nutrient removal from sewage effluent within the Caloosahatchee River drainage basin, could help mitigate future macroalgal blooms in Lee County's coastal waters.

Maranda, L., Corwin, S., Dover, S., and Morton, S.L. ***Prorocentrum lima*** **(Dinophyceae) in northeastern USA coastal waters - II: Toxin load in the epibiota and in shellfish.** *Harmful Algae* 6(5): 632-641, 2007.

Notes: The seasonal variation in diarrhetic shellfish poisoning (DSP)-type toxins was followed in the epibiotic community and in shellfish between 41° and 44°N in coastal waters of the northwest Atlantic during a 2-year period. Low levels of okadaic-acid equivalents were detected at all stations in the <90 μm fraction of the collected epibiota as measured by the protein phosphatase inhibition assay, but only 3.5% of the samples had values greater than 100 ng (g dry weight of epibiota)$^{-1}$. No seasonal pattern could be detected due to differences in intensity, duration and timing of toxin content in the epibiota between the 2 years and between stations. Nevertheless, the concentration of DSP-type toxins in the epibiota correlated weakly but significantly with the abundance of *Prorocentrum lima*, when data from all stations were considered. A very limited toxin uptake by shellfish was measured at only one station in October and November 2001 and in June and July 2002 at times of maximum cell concentration of *P. lima* in the epibiota. Toxin levels in shellfish remained well below regulatory limits that would have required quarantine or bans on harvesting. Results from our 2-year survey suggest that, at this time, the threat of DSP events appears minimal. However, the presence of a known toxin producer and its demonstrated ingestion by shellfish would argue for further studies to better understand conditions leading to DSP outbreaks generated by an epiphytic dinoflagellate.

Sephton, D.H., Haya, X., Martin, J.L., LeGresley, M.M., and Page, F.H. **Paralytic shellfish toxins in zooplankton, mussels, lobsters and caged Atlantic salmon, *Salmo salar*, during a bloom of *Alexandrium fundyense* off Grand Manan Island, in the Bay of Fundy.** *Harmful Algae* 6(5): 745-758, 2007.

Notes: Substantial mortalities of Atlantic salmon (*Salmo salar*) at two aquaculture sites in Long Island Sound, off Grand Manan Island, Bay of Fundy (BoF) (New Brunswick, Canada) in September 2003, were associated with a bloom of *Alexandrium fundyense* (>3 x 10^5 cells L^{-1}), a dinoflagellate alga that produces toxins which cause paralytic shellfish poisoning (PSP). Cells of *A. fundyense* collected from surface waters while fish were dying had total paralytic shellfish (PS) toxin concentrations of 70.6 pg STX equiv. (saxitoxin equivalents) $cell^{-1}$ and PS toxin profiles rich in carbarnate toxins (78.2%). The zooplankton sampled contained PS toxins (63.1 pg STX equiv. G^{-1} wet wt) and the toxin profile matched that of *A. fundyense* cells. Mean PS toxin levels were low (<4 μg STX equiv. 100 g^{-1} wet wt) in stomach, gill and muscle tissues of moribund salmon, suggesting that PS toxins are very lethal to salmon. The PS toxin concentrations in blue mussels (*Mytilus edulis*) growing on the salmon cages (37; 526 μg STX equiv. 100 g^{-1} wet wt) were the highest recorded to date from this region. Their PS toxin profiles showed enhanced carbarnate contents (85.5%) compared with that found in *A. fundyense*. Blue mussels collected from an adjacent Canadian Food Inspection Agency (CFIA) monitoring site in Grand Manan had PS toxin concentrations of 4214 and 150 μg STX equiv. 100 g^{-1} wet wt in late September and December, respectively, well above the regulatory limit (RL), and horse mussels (*Modiolus modiolus*) collected in late September had PS toxin concentrations of 2357 μg STX equiv. 100 g^{-1} wet wt. Detoxification under laboratory conditions suggested that blue mussels may require up to 19 weeks for elimination below RL when they accumulate these high concentrations of PS toxins. This depuration period may be shorter in the field. PS toxin levels above RL were detected in hepatopancreatic tissues of lobster (*Homarus americanus*), with lower levels (< 16 μg STX equiv. 100 g^{-1} wet wt) in tail muscle and gills. These results illustrate the movement of PS toxins through the marine food chain following an *A. fundyense* bloom in the BoF, and support earlier studies suggesting that kills from the region of zooplanktivorous fish, such as herring (*Clupea harengus harengus*), can be attributed to blooms of *A. fundyense*. This is the first reported incident of PSP associated with mortalities of caged Atlantic salmon in the BoF. Analyses of muscle tissues and viscera from the affected salmon indicated that any portion would not be a health hazard if consumed.
