BioInvasions Records (2012) Volume 1, Issue 1: 65–69
doi: http://dx.doi.org/10.3391/bir.2012.1.1.14

Open Access

Aquatic Invasions Records

A benthic diatom bloom in the Gulf of California, Mexico

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Received: 21 September 2011 / Accepted: 3 February 2012 / Published online: 15 February 2012

Abstract

We report a large bloom of a benthic diatom, *Biddulphia biddulphiana*, in the Midriff Islands region of the Gulf of California (GOC), Mexico. The bloom is seemingly invasive in nature (abnormal spatial domination of the benthic environment), and no similar blooms have been previously described in the GOC. Quantitative results indicate a non-significant increase in density and reveal an expansion of affected area from "ground zero" on Isla San Esteban during the year after first observance (2009 to 2010). Observational evidence from colleagues suggests that the bloom had completely disappeared from the areas of highest density by June 2011. It is unclear how a seemingly growing bloom can retract so significantly in such a short time.

Key words: centric diatom, *Biddulphia biddulphiana*, benthic bloom, Gulf of California, overgrowth

Introduction

Benthic invertebrate and algal blooms, often the result of a biological invasion, can be harmful to the shallow marine environment and often involve a single species spatially dominating an ecosystem (e.g., Griffiths et al. 1991; Meinesz et al. 1993; Watson and Estes 2011). In some cases, these blooms may represent an alternate stable state, reaching levels that are detrimental to competitors or to associated species that rely on the characteristics of the natural environmental state. In the shallow, coastal marine environment, invertebrate and algal blooms are often a result of accidental human transport of exotic species (Carlton 1996; Ruiz et al. 1997; Ruiz et al. 2000) and can be costly and very difficult to reverse (though reversal is possible in some cases; e.g., Anderson 2005). Furthermore, these events occur most frequently in areas of high human population, travel, or commerce (Ruiz et al. 1997), ecosystems that are already highly impacted by human presence (Lotze et al. 2006).

In the summers of 2009 and 2010, during expeditions around the Gulf of California (GOC), Mexico to systematically survey both conspicuous and cryptic reef fishes and invertebrates (Figure 1; Aburto-Oropeza et al. 2011), we observed a benthic algal bloom, seemingly invasive in nature, at the relatively remote (though fished) Isla San Esteban, in the Midriff Islands, Central GOC. Here we report on those observations and the results of our preliminary study of the alga.

Study site and context

The GOC is a semi-enclosed basin, located between the Baja California peninsula and the Mexican mainland, approximately 1300 km long by 100-150 km wide (Figure 1). The Midriff Islands are located in the central GOC, between 28 degrees and 30 degrees N and constitute one of the more productive marine ecosystems in the world (Brusca 2010). That region is characterized by consistent tidal (Paden et al. 1991) and coastal (Badan-Dangon et al. 1985) upwelling that support high surface productivity and large communities of seabirds, marine mammals, pelagic and reef fishes, and artisanal fishers. Isla San Esteban is nearly equidistant to the Baja Peninsula and the Mexican mainland (Figure 1) and is approximately 40-70 km from the nearest permanent settlements. However, even given its relative remoteness, Isla San Esteban is fished by communities in Bahía de

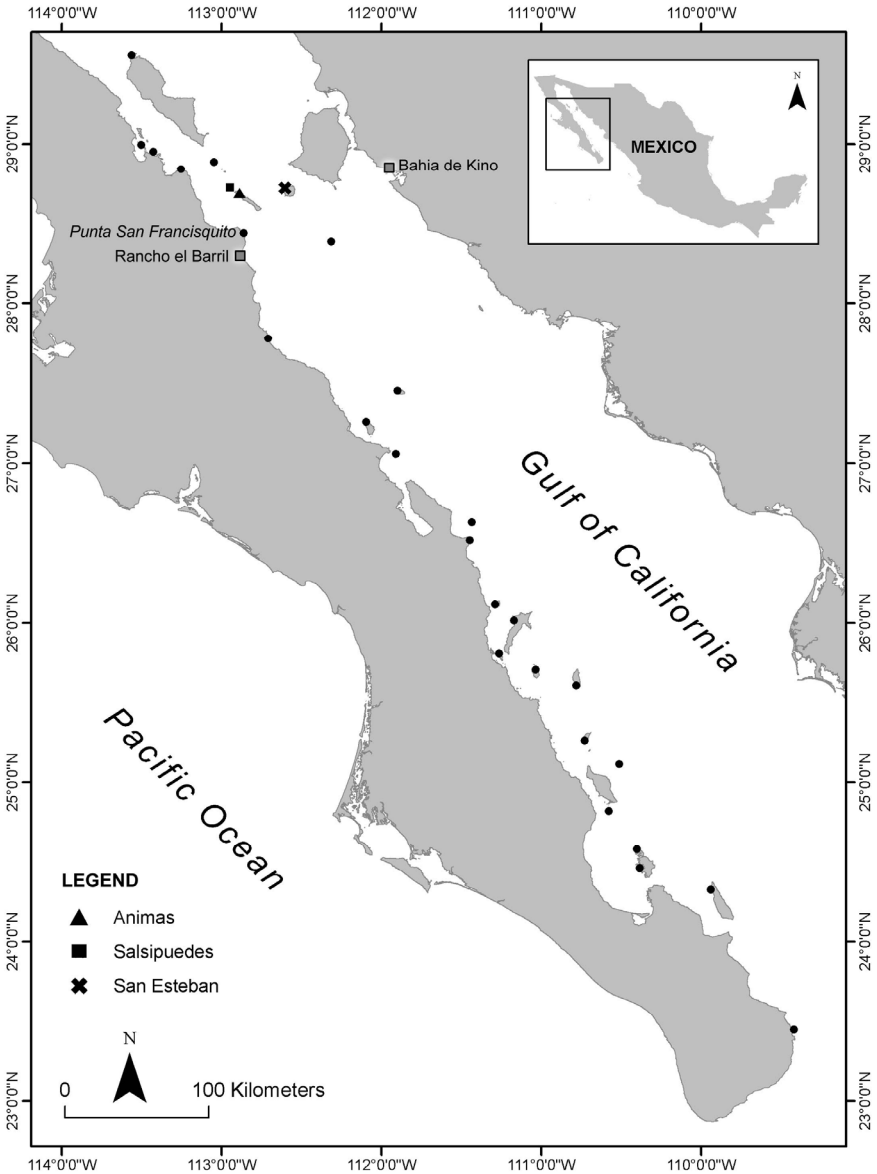

Figure 1. Map of sites surveyed in 2009-2010. **x** marks Isla San Esteban, "ground zero" for the diatom bloom; dots represent sites surveyed in 2009-2010 that did not have evidence of the diatom's presence. El Barril, San Francisquito, and Kino Bay are communities with fishers who exploit the reefs of the Midriff Islands.

Kino on the Mexican mainland and Bahía de San Francisquito and El Barril on the Baja Peninsula (Moreno-Báez et al. 2010).

During expeditions in July 2009 and July 2010, we visited 28 sites at islands throughout the central and southern GOC and along remote areas of the Baja Peninsula, including ten sites in the Midriff Islands region. Sites stretched from the Midriff Islands to Cabo Pulmo National Park near the tip of the Baja Peninsula and covered more than six degrees of latitude (Figure 1).

Methods

At each island/peninsular area, we set up a 10 m^2 area to study the benthos and the benthic fish community. Sites were chosen based on appropriate benthic fish habitat, were consistent (3-5 m deep, rocky reef, dominated by boulders of all sizes) across the GOC, and were representative of the reefs in each area. Using a pvc camera frame and SCUBA gear, we photographed the benthos at nine nonrandom

locations within the study area (three regularly spaced rows of three regularly spaced photos). Photoquadrats from the 2009 expedition are 0.25 m^2, and those from 2010 are 0.35 m^2. In the lab, all images were analyzed in PhotoGrid 1.0, where the substrate was described at fifty stratified random points per image. For the purposes of this study, each point was given a value of 1 (= diatom mat) or 0 (= no diatom mat), and percent cover was calculated for all images.

After the opportunistic discovery of the algal bloom at Isla San Esteban in both 2009 and 2010, we collected samples that were preserved in the field in 10% formalin or 90% ethanol and others that were returned to the lab without preservation (in seawater). In the lab, filamentous material and supernatant (viscous liquid secreted by the filamentous material) were extracted from the non-preserved (seawater) sample and prepared for further analysis. The material was washed once with tap water to remove excess salt, plated on a microscope slide, and viewed using scanning electron microscopy (SEM). Preserved samples are stored at Scripps Institution of Oceanography, La Jolla, CA, USA.

Results and discussion

Analysis of samples via SEM confirmed that the blooming species is a diatom, *Biddulphia biddulphiana* (J.E. Smith) Boyer, 1900 (Figure 2). This centric diatom forms chains that may attach to benthic substrates and is also often found in the phytoplankton (Round et al. 1990). As with many coastal species that have planktonic stages (and can be easily transported by the shipping industry), it is difficult to know the natural home range of *B. biddulphiana*; however, algal checklists from North and South America and from Western Europe include the species, implying a wide current distribution (see Guiry and Guiry 2012). In their in-depth study of the planktonic diatoms of the GOC, Moreno et al. (1996) report its presence at some locations in the GOC, but to date there have been no similarly systematic surveys of benthic diatoms in that region. Our observations of *B. biddulphiana* at Isla San Esteban seemingly constitute a first report of a benthic bloom of this nature in the GOC.

In 2009, we observed the benthic *B. biddulphiana* bloom only on the rocky reefs of Isla San Esteban (Figure 1). According to our PhotoGrid 1.0 analysis, it covered an average of 31% of the area of each photoquadrat at that time (*e.g.,* Figure 3) and was attached to all substrates, including a demonstrated ability to overgrow colonies of *Porites californica* Verrill, 1868, one of the few species of stony corals that survives in that region (*e.g.,* Figure 3 inset). It was not observed at any of our other sites that year. In 2010, we measured a non-significant increase in average percent cover at Isla San Esteban (37%; Man-Whitney $P>0.05$) and observed the same diatom on the shallow rocky reefs of two nearby islands in the Midriff Islands group: Isla Salsipuedes and Isla Las Animas (Figure 1). In that year at Isla Salsipuedes, *B. biddulphiana* covered an average of 11% of the photoquadrats, and at Isla Las Animas, it was not observed inside any quadrat but was noted during a general survey of the area.

SEM analysis revealed several individuals of much smaller diatom species living on *B. biddulphiana* cells (Figure 2). This relationship between *B. biddulphiana* and smaller epiphytic diatoms has been previously described by Tiffany and Lange (2002) in San Diego, CA, USA. Those authors described their San Diego site at 20-24 m depth as containing "vast carpets of diatoms on the seafloor" and identified several species attached to *B. biddulphiana* cells (Tiffany and Lange 2002). The high densities that we observed are analogous to the "vast carpets" reported there. The potential advantages or costs to the host cells and the possible facilitation of a carpet-forming, benthic lifestyle by this symbiosis should be explored in greater detail.

This study is the first to describe a dense benthic bloom of *B. biddulphiana* in the GOC. Its ability to attach to most surfaces and overgrow other benthic species, including stony corals, along with the apparent trend of increased density of coverage at Isla San Esteban, was noticeably affecting the habitat and could be affecting the survival of other sessile benthic organisms and benthos-associated fishes and invertebrates. For example, we observed several individuals of tube-dwelling fishes struggling to feed and court females through patches of the *B. biddulphiana* carpet. Furthermore, if Isla San Esteban was ground zero for this bloom, the fact that our 2010 surveys revealed new patches of *B. biddulphiana* at two of the nearest islands may indicate its ability to spread or a wider expansion of the environmental conditions that favor its growth.

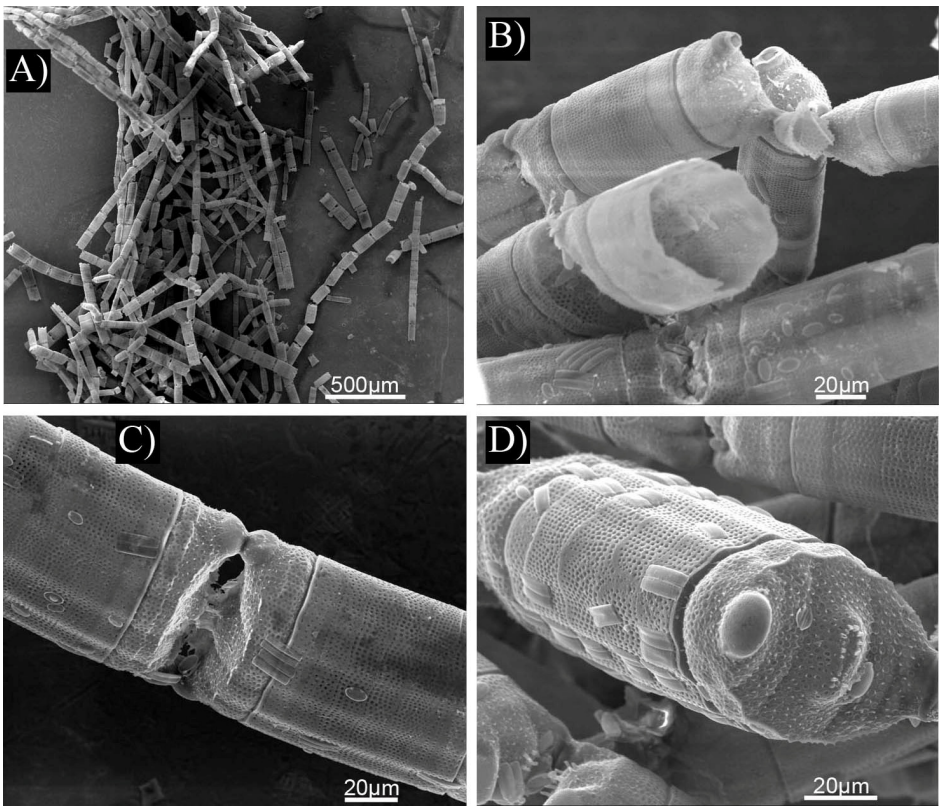

Figure 2. Scanning Electron Microscope images of *Biddulphia biddulphiana* collected from the bloom at Isla San Esteban and used for identification. A) shows several cells of the chain-forming diatom, and B)-D) show close-up shots of individual cells with associated, epiphytic diatoms attached at several locations along the cells' tests.

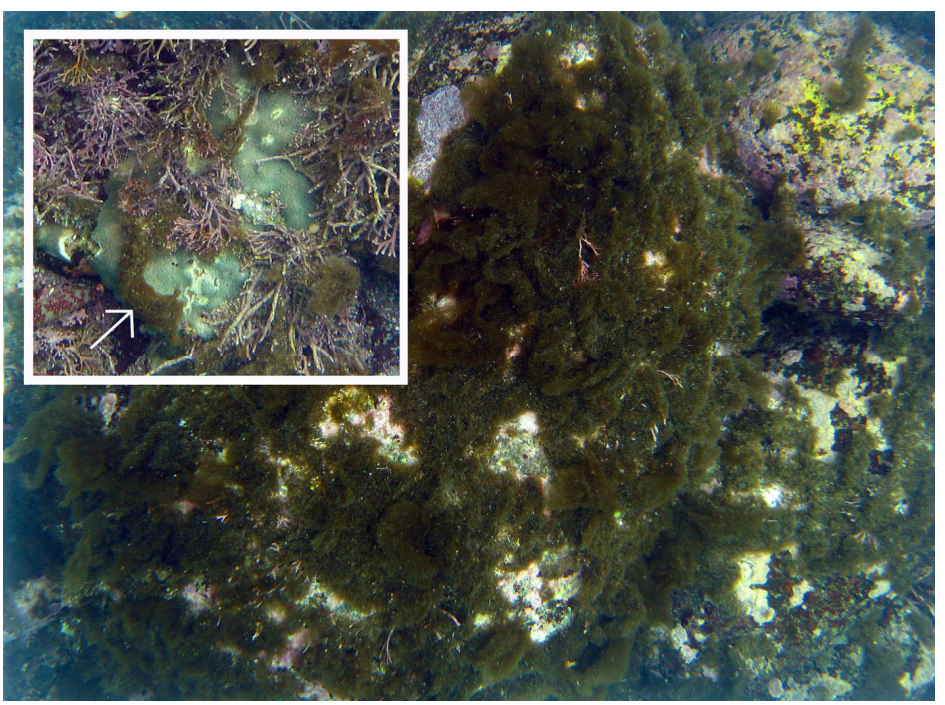

Figure 3. Photograph of the *Biddulphia biddulphiana* bloom at Isla San Esteban. Inset shows overgrowth of the stony coral *Porites californica.* Photos courtesy of J. Lund.

Notably, in July 2011, we received information from a credible source that the *B. biddulphiana* bloom is gone (T.A. Pfister pers. comm.). During a research expedition in June 2011 to the Midriff Islands, no *B. biddulphiana* patches were observed at any of the sites that we discuss here. While that expedition did not include quantitative, photographic surveys of the benthic environment, we received no reports of opportunistic observations of the diatom. Furthermore, the 2011 expedition included one researcher (T.A. Pfister) who also participated in our 2009 expedition, when the bloom was first discovered, and who has 25 years of experience diving in the Midriff Islands without ever observing a bloom like the one in 2009-2010.

Unlike in the case of benthic blooms of undoubtedly exotic species, we were unable to determine the cause of the bloom and subsequent bust of *B. biddulphiana* at these sites. The environmental factors that could lead to these observations should be investigated further. The high productivity and high oceanographic variability characteristic of the Midriff Islands could play a role, but the specific variables that led to this phenomenon are unknown. Consistent monitoring and experimental study of the interactions among the species in the benthic community there could help reveal these variables and allow researchers and managers to predict/prevent future blooms that potentially negatively affect the benthic fish and invertebrate communities.

Acknowledgements

We thank B.E. Erisman and O. Aburto-Oropeza for helping to organize field expeditions that allowed us to conduct these observations. J. Lund provided invaluable support in the field and served as a dive buddy. Scanning Electron Microscopy images were made available by M. Hildebrand and the Scripps Institution of Oceanography Analytical Facility. Funding for expeditions was provided by a Pew Marine Conservation Fellowship awarded to E. Ezcurra and by anonymous donors. Additional funding to support this work was provided by the Center for Marine Biodiversity and Conservation at Scripps.

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