

Chapter 7.2

Assessment of harmful algae bloom species in the Maryland Coastal Bays

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Abstract

Thirteen potentially harmful algae taxa have been identified in the Maryland Coastal Bays: *Aureococcus anophagefferens* (brown tide), *Pfiesteria piscicida* and *P. shumwayae*, *Chattonella* spp., *Heterosigma akashiwo*, *Fibrocapsa japonica*, *Prorocentrum minimum*, *Dinophysis* spp., *Amphidinium* spp., *Pseudo-nitzschia* spp., *Karlodinium micrum*, and two macroalgae genera (*Gracilaria* and *Chaetomorpha*). The greatest number of species occurred in the polluted tributaries of the St. Martin River and Newport Bay. Approximately five percent of the phytoplankton species identified in the Maryland Coastal Bays represent potentially harmful algal bloom (HAB) species. The HABs are recognized for their potentially toxic properties and, in some cases, their ability to produce large blooms capable of negatively affecting light and dissolved oxygen resources. Brown tide (*A. anophagefferens*) has been the most widespread and prolific HAB species in the area in recent years, producing growth impacts to juvenile clams in test studies and potential impacts to seagrass distribution and growth (see Chapter 7.1). Macroalgal fluctuations may be evidence of a system balancing on the edge of a eutrophic (nutrient-enriched) state. No evidence of toxic activity has been detected among the Coastal Bays phytoplankton. However, species such as *Pseudo-nitzschia seriata*, *Prorocentrum minimum*, *Pfiesteria piscicida*, *Dinophysis acuminata* and *Karlodinium micrum* have produced positive toxic bioassays or generated detectable toxins in Chesapeake Bay. *Pfiesteria piscicida* was retrospectively considered as the likely causative organism in causing a large historical fish kill on the Indian River, Delaware. Similarly *Chattonella* cf. *verruculosa* was implicated in a large fish kill and persistent brevetoxins detected in Delaware's Rehoboth Bay during 2000. Tracking potential HAB species diversity, abundance, distribution and toxic activity through time provides important indicators of environmental change within the Coastal Bays.

Introduction

Algae are important components of aquatic ecosystems, forming the base of the food chain by converting sunlight to energy (photosynthesis). Certain types of algae may become harmful if they occur in an unnaturally large abundance (termed an HAB) or if they produce a toxin that can harm aquatic life or humans. HABs are increasing worldwide. Many have been related to increases in aquatic nutrient concentrations from human activities. Blooms of harmful algae can potentially cause economic losses related to decreased recreational and commercial fishing, and tourism.

Data sets

Biomonitoring programs identify species and estimate abundance of algae through light microscope counts and genetic probe technologies. Routine samples were collected monthly at a subset of Maryland Department of Natural Resources (DNR) fixed water quality monitoring stations (Figure 7.2.1). There are recognized thresholds for some HABs from regions in the world where particular algal species have presented chronic problems to human health and the environment. Such threshold levels have been used by managers or industries to initiate shellfish fishery and recreational beach closures, and to intensify monitoring, including toxin testing. Toxin testing may proceed if human or living resource impacts are observed (Table 7.2.1). While no algae has shown toxicity from Maryland's Coastal Bays, some of the same organisms have proven to be toxic along the eastern seaboard, in particular in the Chesapeake and Delaware bays.

Draft HAB Indicator: Threshold exceedances

Data analysis

The list of HABs and published thresholds of management interest were used in this analysis as a means of producing an environmental indicator for tracking by site, watershed, and the Coastal Bays overall. Threshold level exceedances of abundance measured in samples for each recognized HAB species in the region were based on routine phytoplankton monitoring program results (Table 7.2.1). For some species, no density threshold exists.

Table 7.2.1: Summary of harmful algae species present in the Coastal Bays and associated threshold levels.

Species	Abundance Threshold	Comments
<i>Aureococcus anophagefferens</i>	Category 1 < 35,000 Category 2 \geq 35,000 and \leq 200,000 Category 3 > 200,000	Gastrich and Wazniak 2000
<i>Chattonella cf. verruculosa</i>	10,000 cells*ml ⁻¹ (Test for brevetoxin)	Estimated based on the 2000 Rehoboth Bay fish kill that included brevetoxin detection. Bourdelais et al. 2002.
<i>Heterosigma akashiwo</i>	1,000 cells*ml ⁻¹	Average of 500-1,000 cells*ml ⁻¹ from fish kill events that require mitigation. Anderson et al.
<i>Fibrocapsa japonica</i>	None available, (Test for fibrocapsin or toxic bioassay).	
<i>Pfiesteria piscicida</i> , <i>P. shumwayae</i>	Low, Toxic bioassay tests required.	300 cells*ml ⁻¹ of <i>Pfiesteria</i> Complex Organisms has been considered but toxicity bioassays required.
<i>Prorocentrum minimum</i>	3,000 cells*ml ⁻¹ Bioassay toxicity tests – toxin is not yet characterized.	Initial effects thresholds on living resources, EPA 2003
<i>Dinophysis</i> sp.	5 cells*ml ⁻¹ Test for okadaic acid. (Some international standards available)	Levels that can initiate further testing for toxins around the world.
<i>Pseudo-nitzschia</i> sp.	200-1000 cells*ml ⁻¹ Test for domoic acid (Some international standards available)	In Canada, Domoic acid only detected with > 1,000 cells*ml ⁻¹ ; New Zealand increases shellfish testing > 200 cells*ml ⁻¹ and closes shellfisheries > 500 cells*ml ⁻¹
<i>Amphidinium</i> sp.	None available. Test for ciguatera toxin*.	* <i>Amphidinium</i> has been found toxic in subtropical and tropical waters, not yet at temperate latitudes.
<i>Karlodinium micrum</i> <i>Microcystis aeruginosa</i>	10,000 cells*ml ⁻¹ Test for karlotoxin activity: hemolytic, cytotoxic and ichthyotoxic testing may occur.	Kempton et al. 2002 lower threshold for fish kill effects.
Macroalgae	No threshold	

Results

Results are summarized by station in Figure 7.2.1 and by taxonomic group in the following text.

I. Raphidophytes: *Chattonella*, *Heterosigma*, and *Fibrocapsa*

The Raphidophyte group contains 12 known species. Four have been identified from the Coastal Bays: *Chattonella cf. verruculosa*, *C. subsalsa*, *Heterosigma akashiwo*, and *Fibrocapsa japonica*. Strains of *Chattonella cf. verruculosa*, *H. akashiwo*, and *F. japonica* have demonstrated toxic activity elsewhere in the world. **However, there was no evidence of toxins from any Raphidophyte in Maryland tidewaters.**

Chattonella

There are two species of *Chattonella* known in the Coastal Bays, *Chattonella cf. verruculosa* (may produce toxin), and *C. subsalsa* (not known to produce toxin). *Chattonella cf. verruculosa* is a potentially toxic species that has been implicated in causing fish kills as near as the Delaware Coastal Bays and can be potentially harmful to humans when producing brevetoxins. Brevetoxin is in the same class of toxins as those produced by *Karenia brevis* (previously *Gymnodinium breve*), an HAB species associated with red tides, fish kills, and sea mammal deaths in the Gulf of Mexico, and fish kills in Japan and Norway. Human exposure to brevetoxins can cause itchy skin, runny nose, watery eyes, wheezing, and, in some cases, serious asthma attacks. Continued monitoring has not found the toxin in Maryland. Densities above 10,000 cells*ml⁻¹ have been associated with toxin production and impacts on fish health (Bordelais et al. 2002). *Chattonella cf. verruculosa* has been mainly found in Marshall Creek, Ayer Creek, and the St. Martin River.

Analysis of historic state phytoplankton data from intensive surveys of the St. Martin River in 1983 and 1992 suggested that *Chattonella cf. verruculosa*, *C. subsalsa*, and *Fibrocapsa japonica* were present in what appeared to be lower concentrations ten to twenty years ago than what was observed in recent survey years. Historical identifications were based on journal drawings of cells identified in the Maryland Department of Environment monitoring program.

What follows are brief descriptions of HAB monitoring findings from recent years:

2000 A toxic bloom of *C. cf. verruculosa* was detected in the Delaware Bays and correlated with a fish kill event and persistence of brevetoxin in the water. *Chattonella* was detected but not in a toxic state in Maryland. The presence of *Chattonella cf. verruculosa* in Delaware coastal waters was the first published account of the organism in U.S. coastal waters.

- 2001 In late June 2001 low levels were detected in Ayer, Newport, Trappe, Marshall and St. Martin Creek, however, identification was to genus level.
- 2002 In late May, *Chattonella* was present in Marshall Creek in low numbers (<1/ml). In early July, *Chattonella cf. verruculosa* was present in the St. Martin River, as well as Ayer, Trappe and Marshall Creeks. The densities for *Chattonella cf. verruculosa* in St. Martin River were 106 cells/ml (XDN4797) and 2,491 cells/ml (XDM4486). The Marshall Creek sample had approximately 2,000 cells*ml⁻¹ of *C. cf. verruculosa* and one of the Ayer Creek samples had approximately 900 cells*ml⁻¹ (Figure 7.2.1) with no evidence of impaired fish health. Lower concentrations of *C. verruculosa* were found at the other Ayer Creek and Trappe Creek sites. During a fish kill on Massey's Branch, August 17, 2002, a large bloom of *C. subsalsa* (nontoxic) was present at approximately 10,000 cells*ml⁻¹ with very little potentially toxic *C. cf. verruculosa* at the site. No evidence of toxicity was detected and hypoxic dissolved oxygen conditions were noted. On August 21, *C. subsalsa* was present in Marshall Creek and Newport Creek. In September 2002, routine monitoring of the St. Martin River found *C. cf. verruculosa* concentrations at approximately 10,000 cells*ml⁻¹ (approaching threshold conditions) and ~3,000 cells*ml⁻¹ in Marshall Creek, but no suggestions of toxic activity or signs of fish in distress were observed. Samples collected from Marshall Creek in October 2002 showed no toxic activity in laboratory testing.
- 2003 *Chattonella cf. verruculosa* was present at elevated densities of 18,815 cells/ml on August 6, 2003 in the St. Martin River, well above threshold concentrations (Figure 7.2.1). This station is the site of DNR's continuous water quality monitoring meter in Bishopville Prong on the upper St. Martin River. Again, no fish kills were reported in this region coincident with elevated *Chattonella* concentrations, possibly due to an extended summer period of chronic hypoxic to anoxic dissolved oxygen levels limiting fish community persistence.

Heterosigma

Heterosigma akashiwo has been found on both coasts of the United States (Hargraves and Maranda 2002) and is considered the causative organism involved in offshore fish farm kills in Washington State. Net-penned fish deaths related to *Heterosigma* have been particularly prominent in the northeast Pacific Ocean, notably around Japan. Predictability of blooms has been most related to temperature (warmer season waters >15 degrees C) and moderate salinity (approximately 15 ppt) in the coastal zone (Li and Smayda 2000, Connell and Jacobs 1997). Blooms have been observed to persist as long as stable water stratification persists in the warmer months. An unidentified ichthyotoxin (i.e., fish killing toxin) has been suggested as the causative agent in mariculture fish kills. No documented effects to humans were evident from such blooms.

- 2002 On April 24, *H. akashiwo* was detected at 1961 cells*ml⁻¹ in the Newport

Bay watershed.

- 2003 *H. akashiwo* was detected in Newport Bay from May through September and one time in November in the St. Martin River. Abundances exceeded 1,000 cells*ml⁻¹ in Newport Bay on June 18, (7,685 and 4,240 cells*ml⁻¹), September 10, (6,095 cells*ml⁻¹) and September 30 (4558 cells*ml⁻¹), with no evidence of toxic activity.

Fibrocapsa

Fibrocapsa has had devastating impacts on mariculture operations in Japan. Strains of *Fibrocapsa japonica* collected from the North Sea in Europe have been capable of producing toxin that killed fish in laboratory tank studies. The body tissues of two seals that died in the Wadden Sea of Germany were found to have high levels of the toxin fibrocapsin. North Sea strains of *F. japonica* grow well under laboratory conditions of 11-25°C, 20-30 ppt salinity, and N/P ratio of 24.

- 2002 In May, *Fibrocapsa* was present in the St. Martin River. The densities for *Fibrocapsa japonica* were 53 cells*ml⁻¹ (station XDN4797) and 159 cells*ml⁻¹ (station XDM4486). *Fibrocapsa japonica* was collected in low to moderate densities during June through August 2002 from the St. Martin River (≤ 583 cells*ml⁻¹). *Fibrocapsa* was detected once each on Newport Creek and Trappe Creek in 2002 at low densities (53 cells*ml⁻¹). Fish populations sampled at the same time and locations as the algal samples were all healthy.
- 2003 *Fibrocapsa* was detected in low concentrations on July 29 in the St. Martin River (53 cells*ml⁻¹) and Newport Bay (53 cells*ml⁻¹).

II. *Pfiesteria*: *P. piscidia* and *P. shumwayae*

There are two species of *Pfiesteria*, *Pfiesteria piscicida* and *Pfiesteria shumwayae*, both of which are potentially toxic to fish and people. *Pfiesteria* species have been shown to have a highly complex life cycle, with more than 24 reported forms that live in either the bay sediment or water.

Pfiesteria was first detected with targeted sampling in the Coastal Bays of Maryland beginning in 1998. Water and sediment surveys have been conducted in the Coastal Bays using Polymerase Chain Reaction (PCR) techniques to detect these potentially harmful species. Rapid response efforts by Maryland Department of the Environment and Department of Natural Resources have examined fish kills and fish health events (distressed fish or fish with lesions reported) annually since 2000 occasionally detecting *Pfiesteria* species at the events. Bioassays, however, have all been negative for signs of toxicity. **No toxic *Pfiesteria* has ever been detected in Maryland's Coastal Bays.** The

presence of *Pfiesteria* was predominantly in the Newport Bay system (Ayer, Trappe, Marshall, and Newport Creeks).

- 2000 *Pfiesteria* was detected at fish health events in Ayer, Trappe, Marshall, and Newport Creeks (stations AYR0017, NEWPCT5, TRC0024, TRC0031, and MSL0011; note that NEWPCT5, TRC0024, and TRC0031 do not appear on Figure 7.2.1, but refer to fish kill sites on Newport and Trappe Creeks).
- 2001 *Pfiesteria* was first detected on Trappe Creek in June at station XCM4878 (positive for *P. piscicida* and negative for *P. shumwayae*). In July, *Pfiesteria* was also detected in Ayer, Trappe, and Newport Creeks (stations AYR0017, NEWPCT5, TRC0024, and TRC0031). In August, *Pfiesteria* was recorded in Ayer, Trappe, and Marshall Creeks (stations AYR0017, NEWPCT5, TRC0024, TRC0031, and MSL0011). Fish samples (menhaden;*Brevoortia tyrannus*) collected in Ayer and Newport Creeks were healthy. No menhaden were captured on Trappe or Marshall Creeks.
- 2002 *P. piscicida* was found in Ayer Creek, Newport Bay, and the St. Martin River (one occurrence each). *Pfiesteria* sp. was first seen in Newport Bay in March. In late June, it was detected in Ayer Creek and in late July, *Pfiesteria* was present in Trappe Creek (upstream and downstream of its confluence with Ayer Creek). In August sampling of Newport Creek (due to a small fish kill) and Marshall Creek / Massey Branch revealed *P. piscicida* present at both stations on Newport Creek and all three stations on Marshall Creek / Massey Branch. Both *Pfiesteria* species were identified in association with the lesioned menhaden in Turville Creek in late September and early October. Fish bioassays were negative for toxicity for a sample containing *P. shumwayae*, collected on September 25.
- 2003 In 2003, two water column samples tested positive for *P. piscicida* in the Newport Bay watershed. *P. shumwayae* was not detected in routine water column sampling during 2003.

Sediment *Pfiesteria* results

Between 1999 and 2002, a north to south gradient in *Pfiesteria* detections occurred in sediment samples with no *Pfiesteria* detected in sediment of the St. Martin River, 8 percent of samples on the Herring/Turville Creeks (*P. piscicida* only), 17 percent on Trappe Creek (*P. shumwayae* only), and 87 percent of samples from Marshall Creek had one or both species of *Pfiesteria* (Table 7.2.2). Both species were also detected in the sediments of Scarboro Creek. No significant relationships with *Pfiesteria* presence and sediment composition have been found (Trice 2004).

Table 7.2.2: 2003 Sediment *Pfiesteria* results showing the presence of *Pfiesteria piscicida* (pisc) and *Pfiesteria shumwayae* (shum).

Tributary	none	pisc	shum	pisc&shum
Marshall	3	4	12	5
Saint Martins	12			
Scarboro Creek	2		3	
Trappe Creek	10		2	

III. *Prorocentrum*

Prorocentrum blooms have been linked to widespread harmful ecosystem impacts including: anoxic and hypoxic events, finfish kills, aquaculture shellfish kills, submerged aquatic vegetation losses, and positive toxicity bioassays. Such events in this region are typically related to the planktonic species *Prorocentrum minimum*. In the Coastal Bays blooms have occurred in April and May in mid-salinity waters (upper parts of creeks and rivers). This species is considered potentially toxic to humans with rare cases of associated shellfish poisoning worldwide. No such cases related to *P. minimum* have been reported from Maryland waters although isolates from the Choptank River (Chesapeake Bay watershed) indicated toxicity to shellfish larvae in laboratory testing. High biomass blooms have also been responsible for low dissolved oxygen events leading to fish kills in Chesapeake Bay embayments and an extended bloom in 2000 was suspected in declines of seagrass in the mid-Chesapeake Bay region during 2001.

Effects on bay organisms were identified at concentrations as low as 3,000 cells* ml⁻¹ (EPA 2003) providing a threshold for tracking and assessing blooms. Threshold exceedances were recorded once each year during 2001 and 2002 in samples from the St. Martin River. Brief descriptions of *Prorocentrum* findings from the DNR phytoplankton monitoring program are given below (bolded values indicate threshold exceedances).

2001 *Prorocentrum minimum* was detected on Bishopville Prong in April at densities of **5,459 cells*ml⁻¹** (Figure 7.2.1). All other detections were < 3,000 cells*ml⁻¹ and typically < 1,000 cells*ml⁻¹.

2002 *P. minimum* was found in the St. Martin River and Turville and Herring Creeks during the spring (April and May). Most concentrations were low (under 3,500 cells*ml⁻¹) and were not considered to be a public health threat since the river was closed to shellfish harvesting. However, one sample on the St. Martin River on April 29 had a density of **21,253 cells*ml⁻¹** (station XDM4486) (Figure 7.2.1). Levels < 3,000 cells*ml⁻¹ were detected in the Newport Bay watershed, and additional detections were made in the St. Martin River.

2003 In 2003, no sample collected was above 2,809 cells*ml⁻¹ (April 28; station XDN4312).

IV. *Dinophysis*

Dinophysis acuminata has been the most commonly encountered representative of this genus in Maryland's Coastal Bays. The genus *Dinophysis* is represented in Chesapeake Bay by five species (*D. acuminata*, *D. acuta*, *D. fortii*, *D. caudata* and *D. norvegica*). All are known to produce okadaic acid or other toxins causing diarrhetic shellfish poisoning (DSP) (Marshall 1996). DSP has occurred in humans consuming contaminated shellfish, resulting in symptoms that include intestinal discomfort, abdominal pain, nausea, headache, chills, and vomiting. No cases of DSP have been reported in Maryland.

Management actions in the countries of Italy, Norway, and Denmark to protect human health against DSP when *Dinophysis* is present include intensified monitoring of shellfish harvest waters, toxin testing of the shellfish, and application of restrictions or closures of fisheries. Thresholds of 500-1,200 cells*L⁻¹ are used by managers in these countries to initiate temporary closures or intensified monitoring; toxin test results ultimately determine the extent of actions necessary (Anderson et al. 2001). Europe and Japan appear to be the most highly affected areas for cases of DSP, however, outbreaks in North America were confirmed in Eastern Canada during 1990 and 1992. Okadaic acid was found in association with a *D. acuminata* bloom in 2002 on the Potomac River. However, levels were well below FDA levels for seafood safety. Despite thousands of documented cases of DSP worldwide since 1960, there are no reported fatalities associated with the illness.

A threshold ten times the minimum used in Europe (i.e., 0.5 x 10 = 5 cells*ml⁻¹) has been implemented as a tracking indicator for this species, given the lack of evidence for toxic effects by the genus to the East Coast of the United States. *Dinophysis* has been observed above threshold concentrations in Assawoman Bay (once in 2001, once in 2003), Isle of Wight (once in 2002), and the St. Martin River (once in 2001, seven times in 2002, and twice in 2003). However, no evidence exists demonstrating toxicity to date in the Coastal Bays systems. Brief descriptions of *Dinophysis* detection in Coastal Bays samples follow.

2001 In 2001, *D. acuminata* was detected on May 22 (station XDM4486 at 1 cell*ml⁻¹) in the St. Martin River and *Dinophysis* sp. on December 17 (XDN3445 at 1 cell*ml⁻¹) in Assawoman Bay. No exceedances of the threshold were detected.

2002 During 2002, one sample from January 22 on St. Martin Creek contained 1 cell*ml⁻¹. Two samples from St. Martin Creek contained *D. acuminata* at 1 cell*ml⁻¹ (station XDN4797) and 4 cells*ml⁻¹ (station XDM4486) in March. In April, *Dinophysis acuminata* was identified at all three phytoplankton stations in the St. Martin River. Station XDN4312 had

2*ml⁻¹ and station XDN4797 had 6*ml⁻¹. Station XDM4486 had 1 cell *ml⁻¹. In May, *Dinophysis* was also found in the St. Martin River and in Herring and Turville Creeks. The greatest concentrations of *Dinophysis* (up to 10 cells*ml⁻¹) were found in areas closed to shellfish fishing (St. Martin, Turville, and Herring Creeks). For perspective, the Canada action threshold for *Dinophysis* is considered 5 cells*ml⁻¹. Low concentrations (up to 2 cells*ml⁻¹) were observed in the Isle of Wight (Figure 7.2.1).

2003 In 2003, *D. acuminata* was detected only in December and collected from station XDN4797 (St. Martin Creek on December 2) with **10 cells*ml⁻¹** and station XDN3445 (Little Assawoman Bay on December 1) with **8 cells *ml⁻¹** (Figure 7.2.1).

V. Pseudo-nitzschia

Diatoms in the genus *Pseudo-nitzschia* are recognized worldwide as potential producers of the toxin domoic acid (DA). Shellfish feeding on toxic *Pseudo-nitzschia* can accumulate DA. Humans consuming the contaminated shellfish may subsequently experience Amnesic Shellfish Poisoning (ASP). Symptoms of ASP include vomiting, confusion, memory loss, coma, or death. ASP was first identified on the east coast of North America at Prince Edward Island, Canada, in 1987. Despite a recall of all bivalve products from the Prince Edward Island region, the outbreak resulted in 107 illnesses that included 13 fatalities. In 1995, a shellfish closure occurred due to elevated levels of DA. Recent illnesses have only occurred from recreational harvests that have disregarded the shellfish closures.

Pseudo-nitzschia cell densities of 200 cells*ml⁻¹ *P. seriata* are used in Denmark and 5-10 cells*ml⁻¹ in New Zealand to trigger toxin testing of shellfish meats (Anderson et al. 2001). In New Zealand, the shellfish industry conducts voluntary closures of a fishery where cell densities measure > 5 x 10⁵ cells*L⁻¹ (Anderson et al. 2001). Canada has indicated detectable levels of DA in the shellfish at levels of at least 1,000 cells*ml⁻¹ (Anderson et al. 2001).

Between 2001-2003, no samples obtained from the Coastal Bays contained *Pseudo-nitzschia* >106 cells*ml⁻¹.

VI. Amphidinium

The algae *Amphidinium operculatum* is an epibenthic dinoflagellate. This species was found in Newport Creek in October 1999 in very small numbers. This unusual organism was detected in a water sample through centrifuging 15 ml of the sample to look at another species. *Amphidinium* has been linked with ciguatera toxins in subtropical and tropical habitats. There is no evidence of toxicity for this species in the Coastal Bays.

VII. *Karlodinium micrum*

Karlodinium micrum may cause water to become discolored a reddish-brown, known as a mahogany tide. Mahogany tides may severely reduce the amount of oxygen available to living resources at localized bloom sites. In large numbers, *Karlodinium micrum* will give the water a coffee color. *Prorocentrum minimum* tends to bloom earlier in the spring than *K. micrum* (late spring and early summer), although both species may occasionally be found blooming throughout the year on a local scale.

Karlodinium micrum is increasingly recognized for its ichthyotoxic effects in estuarine waters. Threshold levels for impacts on fish are considered 10,000 to 30,000 cells*ml⁻¹. *Karlodinium micrum* is synonymous with *Gyrodinium galatheanum* Braarud and *Gymnodinium micrum*, and was historically reported as *Gyrodinium estuariale* in Maryland. Recent work by Deeds et al. (2002) has demonstrated that Maryland isolates of the dinoflagellate from Chesapeake Bay produced toxins with hemolytic, cytotoxic, and ichthyotoxic properties. Testing has not yet been conducted on samples from the Coastal Bays. Initial studies indicate *K. micrum* may produce sufficient toxin to result in fish mortality in the field at cell densities of 10,000 to 30,000 cells*ml⁻¹ and above (Deeds et al. 2002, Goshorn et al. 2002). No human health effects have been associated with blooms of *K. micrum*. Brief descriptions of annual *K. micrum* detection in Coastal Bays samples follow.

- 2001 *K. micrum* was detected in St. Martin River, Little Assawoman Bay, and Newport Creek (identified as *G. estuariale*) always at concentrations less than 10,000 cells*ml⁻¹.
- 2002 *K. micrum* was detected in St. Martin River, Isle of Wight Bay, and Assawoman Bay and Newport Creek less than or equal to 1,696 cells*ml⁻¹ in all samples.
- 2003 *K. micrum* was detected in St. Martin River, Isle of Wight Bay, and Newport Bay watersheds at less than or equal to 1,696 cells*ml⁻¹ in all samples, well below threshold levels of concern for living resources

VIII. *Microcystis aeruginosa*

Toxic cyanophytes have been shown to affect a broad range of living resources. *Microcystis aeruginosa* is not unlike other possibly toxic phytoplankton species in that there may be a gradient of strain-related toxicity. Studies have shown negative effects on feeding to zooplankton by toxic and non-toxic *M. aeruginosa*. Fish kills have been attributed to cyanobacterial blooms, and sublethal effects on fish can include reduced filtering rates, liver damage, modified ionic regulation, and changes in behavior (Erickson et al. 1986, Rabergh et al. 1991).

Cyanophyte (bluegreen algae) concentrations at Bishopville Prong, Trappe Creek, and

Ayer Creek have all shown declines from any pre-2000 phytoplankton sampling.

IX. Potentially harmful macroalgae

Macroalgae are considered harmful by the National Oceanographic and Atmospheric Administration (NOAA) when they produce dense overgrowth in localized areas, such as coastal embayments, that receive excessive nutrient loads. These accumulations can be so high as to cover the bottom, excluding other life. Also, when such large masses of macroalgae begin to die, excessive oxygen consumption associated with the decomposition process can decrease dissolved oxygen (Bushaw-Newton and Sellner 1999). Further, large increases in macroalgal may be evidence of a seagrass dominant system balancing on the edge of a eutrophic state (Valliela et al. 1997).

Two genera of macroalgae are believed to qualify as HABs, under NOAA's definition, in specific areas of the Coastal Bays. First, *Gracilaria* in Turville Creek was so dense in 1999-2001 that it caused the DNR fishery monitoring program to relocate a monitoring station in operation for more than 25 years. This system is prone to low dissolved oxygen levels that are probably influenced by these blooms. Furthermore, total maximum daily load (TMDL) models of this system were insufficient in predicting the low dissolved oxygen, likely because they failed to incorporate primary producers other than phytoplankton. Second, *Chaetomorpha* levels in Chincoteague Bay were so dense from 1998 through 2001 they are believed to have impacted scallop restoration efforts and seagrass density in some areas (Orth 2004, Tarnowski 2004).

Summary

HAB species are recognized for their potentially toxic properties as well as their ability to produce large blooms negatively affecting light and dissolved oxygen resources. Approximately five percent of the phytoplankton community identified for Maryland's Coastal Bays was comprised of HAB species. Table 7.2.3 summarizes the HAB species found at each station from 1988 through 2003. Brown tide (*A. anophagefferens*) has been the most widespread and prolific HAB species in the area in recent years producing growth impacts to juvenile clams in test studies and potential impacts to seagrass distribution and growth (see Chapter 7.1). No evidence of toxic activity has been detected among the Coastal Bays phytoplankton, however, species such as *Pseudo-nitzschia seriata*, *Prorocentrum minimum*, *Pfiesteria piscicida*, *Dinophysis acuminata*, and *Karlodinium micrum* have produced positive toxic bioassays or generated detectable toxins in Chesapeake Bay. *Pfiesteria piscicida* was retrospectively considered as the likely causative organism in a large fish kill on the Indian River, Delaware. Similarly *Chattonella* cf. *verruculosa* was implicated in a large fish kill and persistent brevetoxins detected in Delaware's Rehoboth Bay during 2000. Tracking HAB species diversity, abundance, distribution, and toxic activity through time will provide important indicators of environmental change for the Coastal Bays.

Thirteen potentially harmful algae species have been identified in the Coastal Bays. These include *Aureococcus anophagefferens* (brown tide), *Pfiesteria piscicida* and *P. shumwayae*, *Chattonella*, *Heterosigma akashiwo*, *Fibrocapsa japonica*, *Prorocentrum minimum*, *Dinophysis sp.*, *Amphidinium sp.*, *Pseudo-nitzschia sp.*, *Karlodinium*, and two macroalgae genera (*Gracilaria*, *Chaetomorpha*). Presence of HAB species has been most diverse (i.e., greatest richness of HAB species) in polluted tributaries of the St. Martin River and Newport Bay (Figure 7.2.1).

Threshold exceedances included *C. cf. verruculosa* in September 2002 on St. Martin River. A bloom of *C. cf. verruculosa* during 1999 in the Delaware Coastal Bays was related to a fish kill event. No evidence of toxicity by any of these species has been associated with similar events in Maryland waters. Threshold exceedances (3,000 cells*ml⁻¹) of *P. minimum* were recorded once each year during April 2001 and 2002 on Bishopville Prong in the St. Martin River. *Heterosigma akashiwo* blooms of 750-1,000 cells*ml⁻¹ have been known to affect mariculture operations. However, *H. akashiwo* has thus far shown no evidence of toxic activity in the Coastal Bays when recorded above this threshold. *Fibrocapsa japonica* was present in the Coastal Bays, but no known cell density thresholds were available to estimate possible effects or warrant intensified surveys for this species.

Dinophysis was observed above threshold concentrations in Assawoman Bay (once in 2001, once in 2003), Isle of Wight (once in 2002), and the St. Martin River (once in 2001, seven times in 2002, and twice in 2003). However, there was no evidence for toxicity to date in the Coastal Bays systems. All samples could potentially warrant intensified monitoring for toxins, but 5 cells*ml⁻¹ is probably a more appropriate threshold.

Between 2001-2003, no samples from the Coastal Bays exceeded suggested living resource effects levels of $\geq 10,000$ cells*ml⁻¹ for *K. micrum* or 200 cells*ml⁻¹ for *Pseudo-nitzschia sp.*. Bluegreen algae were encountered, but declined compared with pre-2000 data. Rarity of *Microcystis aeruginosa* was likely due to limited freshwater and low salinity habitat for this species.

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Table 7.2.3: Potential HAB species found at each sampling station from 1988 through 2003. For a discussion of brown tide, see Chapter 7.1.

Station	Potential HAB species	Station	Potential HAB species
XDN6454	Brown tide <i>Karlodinium micrum</i> <i>Prorocentrum minimum</i>	TUV0019	Brown tide <i>Dinophysis acuminata</i> <i>Heterosigma akashiwo</i> <i>Prorocentrum minimum</i>
XDM4486	Brown tide <i>Chattonella cf. verruculosa</i> <i>Chattonella subsalsa</i> <i>Dinophysis acuminata</i> <i>Fribrocapsa japonica</i> <i>Heterosigma akashiwo</i> <i>Karlodinium micrum</i> <i>Prorocentrum minimum</i> <i>Pfiesteria sp.</i>	AJR0017	Brown tide <i>Chattonella cf. verruculosa</i> <i>Chattonella subsalsa</i> <i>Karlodinium micrum</i> <i>Heterosigma akashiwo</i> <i>Microcystis sp.</i> <i>Prorocentrum minimum</i>
XDN4797	Brown tide <i>Chattonella cf. verruculosa</i> <i>Chattonella subsalsa</i> <i>Dinophysis acuminata</i> <i>Fibrocapsa japonica</i> <i>Heterosigma sp.</i> <i>Karlodinium micrum</i> <i>Prorocentrum minimum</i>	TRC0043	Brown tide <i>Chattonella cf. verruculosa</i> <i>Chattonella subsalsa</i> <i>Heterosigma akashiwo</i> <i>Karlodinium micrum</i> <i>Microcystis sp.</i> <i>Prorocentrum minimum</i>
XDN4312	Brown tide <i>Chattonella cf. verruculosa</i> <i>Dinophysis acuminata</i> <i>Heterosigma sp.</i> <i>Karlodinium micrum</i> <i>Prorocentrum minimum</i>	NPC0012	Brown tide <i>Chattonella cf. verruculosa</i> <i>Chattonella subsalsa</i> <i>Heterosigma akashiwo</i> <i>Karlodinium micrum</i> <i>Microcystis sp.</i> <i>Prorocentrum minimum</i>
XDN3724	Brown tide	MSL0011	Brown tide <i>Chattonella cf. verruculosa</i> <i>Chattonella subsalsa</i> <i>Heterosigma akashiwo</i> <i>Karlodinium micrum</i> <i>Prorocentrum minimum</i>
XDN3527	<i>Chattonella cf. verruculosa</i> <i>Fibrocapsa japonica</i> <i>Heterosigma akashiwo</i> <i>Karlodinium micrum</i>	XCM0159	Brown tide <i>Prorocentrum minimum</i>
XDN3445	Brown tide <i>Dinophysis acuminata</i> <i>Karlodinium micrum</i> <i>Pseudo-nitzschia</i>	XBM1301	Brown tide
TUV0011	Brown tide <i>Chattonella cf. verruculosa</i> <i>Karlodinium micrum</i> <i>Prorocentrum minimum</i> <i>Pseudo-nitzschia</i>		

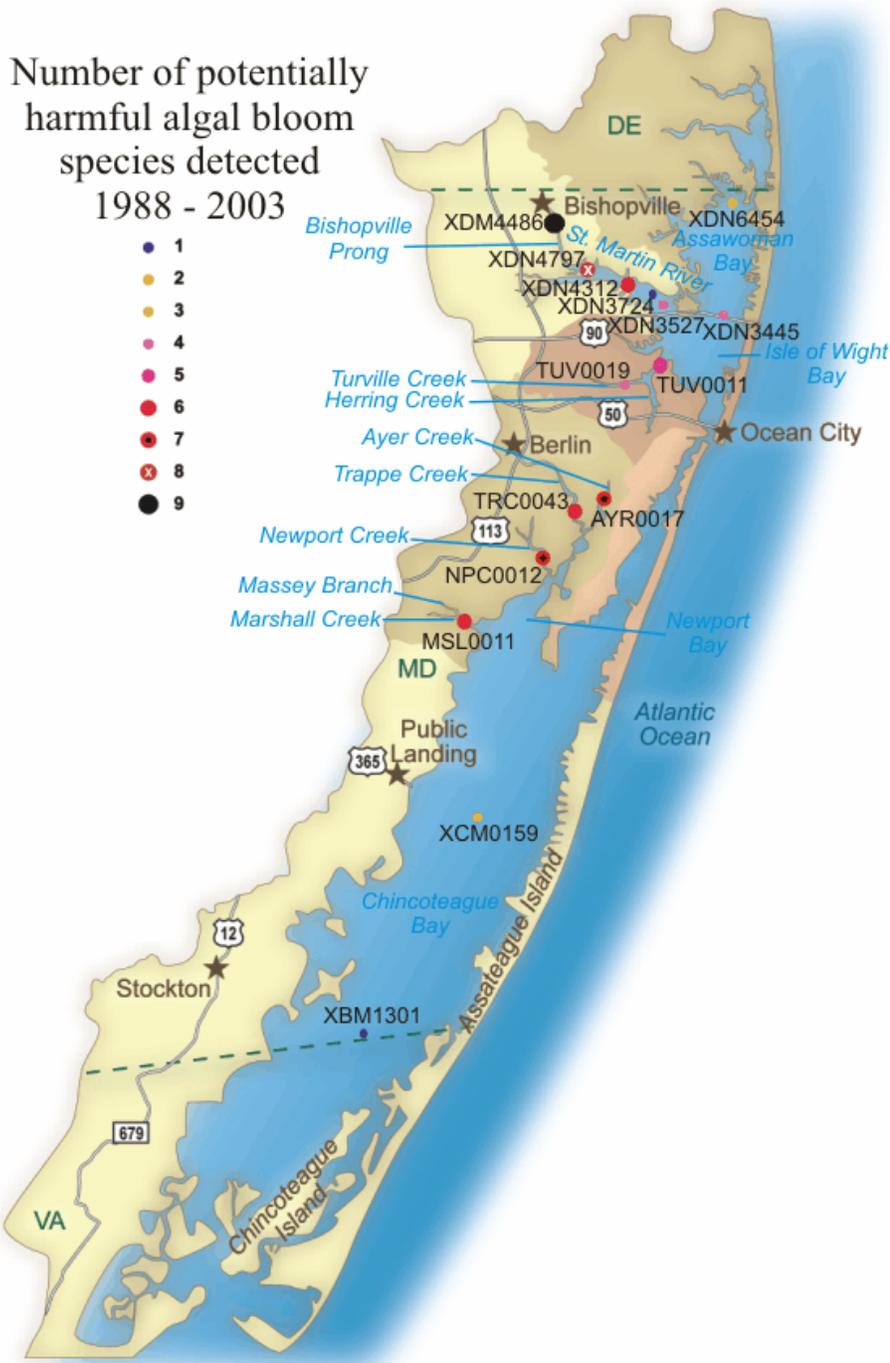


Figure 7.2.1: Locations of HAB sampling stations from 1988 through 2003. The number of potentially HAB species for each station is also indicated. Pertinent place names mentioned in the text are also shown in blue italics.