

Environmental Assessment and Risk Analysis Element



Research Project Summary

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Brown Tide Bloom Assessment Project in NJ Coastal Waters: 2000-2002

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Abstract

Brown tide blooms, caused by the rapid growth of a minute alga, *Aureococcus anophagefferens*, caused the demise of the scallop industry in coastal bays of Long Island, NY, in the mid-1980s. These blooms were also suspected in Barnegat Bay, NJ, at the same time but were not confirmed until 1995. Because of limited data, and to determine whether these blooms were a threat to coastal waters in NJ, the Division of Science Research and Technology (DSRT) established the Brown Tide Assessment Project to assess brown tide blooms in Barnegat Bay-Little Egg Harbor (BB/LEH) from 2000-2002 through 1) mapping the abundances of the brown tide using the Brown Tide Bloom Index; 2) assessing the relationship between the brown tide abundances and environmental factors (e.g., salinity, temperature, nitrogen species); and 3) analyzing of the risk of brown tide blooms to submerged aquatic vegetation communities. Brown tide abundances were detected at all stations; the most severe brown tide blooms (Category 3), as well as less severe (Category 2) blooms, recurred during each of the three years of sampling and covered significant geographic areas of the BB/LEH. While the highest abundances of brown tide are positively associated with warmer water temperatures and higher salinity, these factors are not sufficient to promote blooms. Extended drought conditions with corresponding low freshwater inputs and elevated bay water salinities occurred during this time, possibly contributing to these blooms. Abundances of brown tide in New Jersey coastal bays are high enough to cause potentially harmful effects on juvenile hard clams. Results of the analysis of the risk of brown tide blooms to submerged aquatic vegetation (SAV) habitat indicated that 35% of the state's SAV habitat in BB/LEH is at significant risk of negative impacts due to brown tide blooms. Over 70% of the state's SAV habitat is located in BB/LEH. Graphic displays of the spatial patterns of the brown tide blooms and environmental factors can be viewed at: <http://crssa.rutgers.edu/projects/btide/index.html>.

Introduction

Brown tide blooms, caused by the rapid growth of a minute alga, *Aureococcus anophagefferens*, were first observed in 1985 along the northeast coast of the United States in Narragansett Bay, RI, Peconic Bay and Great South Bay systems of Long Island (L.I.), NY, and caused the devastation of the scallop industry in L.I. (Casper et al. 1987). While these blooms were suspected in Barnegat Bay at the same time, they were first documented in 1995 in Little Egg Harbor and in southern Barnegat Bay, NJ, and associated with reductions in growth of juvenile hard clams (*Mercenaria mercenaria*) at a commercial aquaculture facility in Tuckerton. Brown tides were reported again in Barnegat Bay in 1997 and 1999.

While not reported to be harmful to human health, brown tide blooms may cause negative impacts to shellfish (e.g., hard clams, oysters, scallops) and submerged aquatic vegetation (SAVs). According to the Brown Tide Bloom Index (Fig. 1), the most severe blooms (Category 3) and less severe blooms (Category 2), may negatively impact shellfish by causing reduced feeding, reduced growth rates and/or mortality. Based

on effects on brown tide blooms extending beyond one and one half to two months in duration in coastal bays of Long Island in the mid-1980s (Dennison et al. 1989), blooms may cause severe shading on growing (SAV) beds, especially eelgrass, resulting in significant negative effects on the health and production of SAVs. SAVs have several important ecological functions including: 1) providing a source of nutrients to the waters as they take up nutrients when growing and slowly release these nutrients as they decay and die-off; 2) reducing shoreline erosion by dissipating the energy of incoming waves; 3) increasing water clarity by helping suspended sediments to settle out of the water column; 4) supporting the food chain and providing breeding and nursery grounds for commercially and recreationally important finfish and shellfish; and 5) being part of the food chain for waterfowl and invertebrates. Over 70% of the state's eelgrass habitat is located in Barnegat Bay/Little Egg Harbor.

The objectives of this study were to 1) classify and map brown tide abundances using the categories of the Brown Tide Bloom Index; 2) assess the relationship between the brown tide abundances and environmental data; and 3) analyze the risk of the

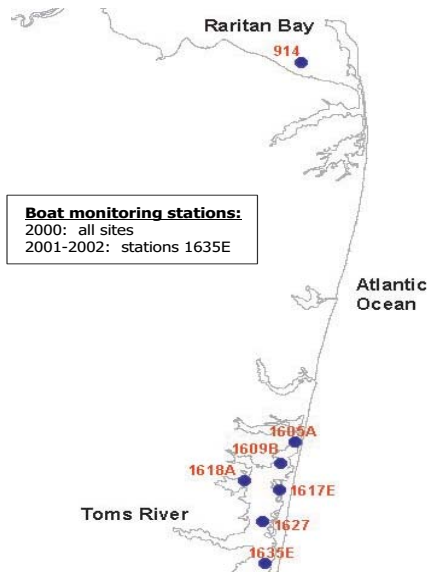
severity and duration of brown tide blooms to submerged aquatic vegetation communities.

Figure 1. Brown Tide Bloom Index (Gastrich & Wazniak, 2002)

- CATEGORY 1:** < 35,000 *Aureococcus anophagefferens* cells ml⁻¹
(No observed impacts)
- CATEGORY 2:** ≥ 35,000 to < 200,000 cells ml⁻¹
- Reduction in growth of juvenile hard clams, *Mercenaria mercenaria*
 - Reduced feeding rates in adult hard clams
 - Growth reduction in mussels (*Mytilus edulis*) and bay scallops (*Argopecten irradians*)
- CATEGORY 3:** ≥ 200,000 cells ml⁻¹
- Water becomes discolored yellow-brown
 - Feeding rates of mussels severely reduced
 - Recruitment failures of bay scallops and high mortalities
 - No significant growth of juvenile hard clams
 - Negative impacts to eelgrass due to algal shading
 - Copepod production reduced and negative impacts to protozoa

Figure 2. Maps of the sampling sites: Raritan Bay and northern Barnegat Bay; Little Egg Harbor; Great Bay and Great Egg Inlet (Maps: Right to Left = North to South).

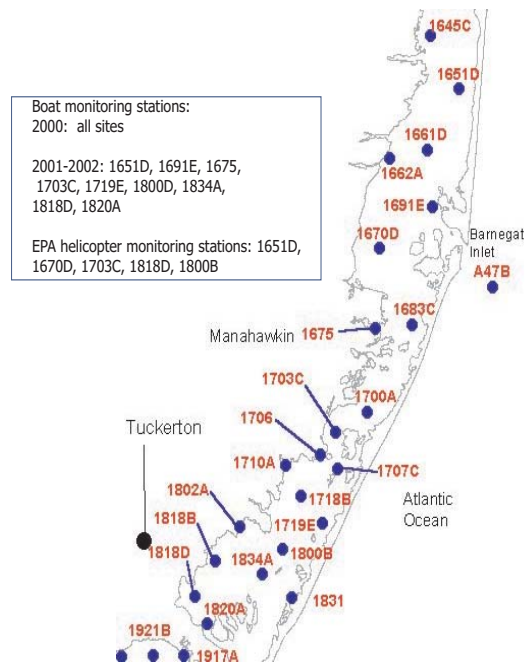
Raritan Bay and Northern Barnegat Bay



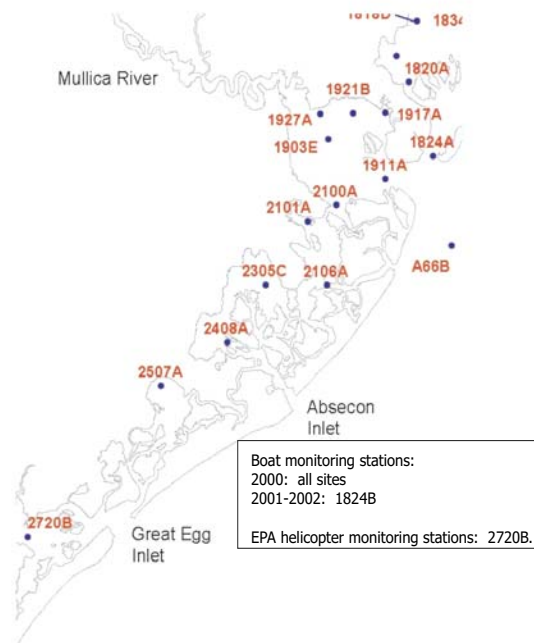
Methods

Water samples (N = 523) were collected at NJDEP Water Quality Network stations (NJDEP, 2000) during a three year period (2000-02) in Raritan Bay (2000), Barnegat Bay/Little Egg Harbor (BBLEH) (2000-02), Great Bay (2000-2002), and Great Egg Harbor (2000-2001) (Fig. 2).

Little Egg Harbor



Great Bay and Great Egg Harbor



Samples were collected by boat at 44 stations in 2000 on a variable schedule from April through December, and at 11 stations in 2001-02 in BB/LEH during April (1x), May (1X), June (4X), July (2X), August (1X) and September (1X) and by helicopter (6 stations, bi-weekly 2000-02). *A. anophagefferens* abundances were determined using a monoclonal antibody analysis (Carron et al. 2003). Data on salinity, temperature, nitrogen, dissolved oxygen, pH, transmissiometry, photosynthetically active radiation (PAR), depth and Secchi disk were collected simultaneously. Brown tide abundances were classed into one of the three categories of the Brown Tide Bloom Index (Fig. 1) and all data were mapped using the ArcView geographic information system software.

The average daily flow from the Toms River, as well as the 50-year mean, and freshwater discharge were used as an indicator of the prevailing precipitation and/or drought conditions. The analysis of the risk of brown tide blooms to SAV habitat involved the overlay and comparison of two types of maps: 1) median *A. anophagefferens* abundance; and 2) previously generated maps of SAV spatial distributions from the mid-1990s using ArcView GIS (Lathrop et al. 2001).

Results

Category 2 and 3 brown tide blooms, with the potential to cause negative impacts on shellfish and SAVs, occurred each year in the study area. Elevated *A. anophagefferens* abundances, Category 2 and 3 brown tide blooms, occurred at all stations during the three year sampling period; all stations in BB/LEH in 2002 had Category 3 blooms with the exception of one station (located in the middle of Little Egg Inlet).

Five stations in Little Egg Harbor had Category 3 blooms throughout the three years (Table 1.) The highest *A. anophagefferens* abundances ($> 10^6$ cells ml^{-1}) occurred for all three years at two stations each year in Stafford Township (Ship Bottom) (1703C) and Long Beach Township (near Beach Haven Terrace) (1820A), with the highest maximum abundance recorded in southwest Little Egg Harbor, Tuckerton Bay (1820A) in 2000. In addition, station 914 in Raritan Bay (4.5×10^4 cells ml^{-1} in August in 2000) and station 2720B in Great Egg Harbor had Category 2 blooms (9.1×10^4 cells ml^{-1} in August 2000 and 1.19×10^5 cells ml^{-1} in August 2001). The highest abundance of blooms (Category 3) occurred mainly in Little Egg Harbor but blooms of lower abundance (Category 2) occurred at most all locations in 2001 and 2002 and over several months. Year 2002 had the highest mean and median brown tide abundances (Table 1). Each year, there were especially high *A. anophagefferens* abundances in the vicinity of Manahawkin Bay (station 1703C, Fig. 3), which is the connecting section of the BB/LEH system that lies north of Little Egg Harbor and south of Barnegat Bay proper. A consistent pattern emerged from analysis of the animated graphics, across all three years of study, showing that Category 3 blooms first originated in the vicinity of Manahawkin Bay and persisted longest at this location.

While cooler water temperatures of April were associated with the lowest (Category 1 or 2) bloom conditions, Category 3 blooms were associated with warmer water temperatures and higher salinities (Table 1). The highest median and mean salinity for the three years of sampling occurred in 2002 (Table 1).

This appears to be related to lower freshwater flows immediately prior to and during 2002. While water temperature and salinity are important, they appear not to be the sole environmental factors driving the growth and decline of brown tide blooms. In addition, there was no evidence of a clear relationship between brown tide abundances and nitrogen concentration. As expected, the regression analysis indicated there was a weak inverse relationship between Secchi depth (and transmissiometry) and brown tide abundances.

A large percentage of Barnegat Bay/Little Egg Harbor's mapped SAV habitat may be at significant risk of negative impacts due to brown tide (Fig. 3; Table 2A, B). In all three years, over 50% of the total mapped SAV habitat area (BB/LEH) was overlain with a Category 2 or 3 brown tide bloom (April-September). Year 2002 was especially severe with over 85% or over 12,800 acres of the mapped SAV beds overlain by a Category 3 bloom and thereby classified as High Risk for negative impacts. Year 2001 was the lowest risk year with the lowest amounts of both Category 2 and 3 areas. During the three years, the location of the highest risk area for SAV habitat is associated with the brown tide "hot spot" (e.g., Category 3 blooms) in the Manahawkin Bay, this is the same area where brown tide begins to bloom in May-June and then extends to Little Egg Harbor stations. The medium risk areas for SAV habitat are the areas throughout Barnegat Bay and Little Egg Harbor that are associated with Category 2 blooms. Conversely, the northern third of Barnegat Bay, which has previously been documented as having experienced SAV declines (Lathrop et al. 2001), does not appear to be in a high risk zone for (Category 3) brown tide blooms but is identified as a medium risk zone because of the occurrence of Category 2 brown tide blooms.

Figure 3. Maps of median and maximum *A. anophagefferens* (BT) abundance (cells ml^{-1}) for the April to September sampling period for Years 2000, 2001, and 2002 in Barnegat Bay/Little Egg Harbor, N.J.

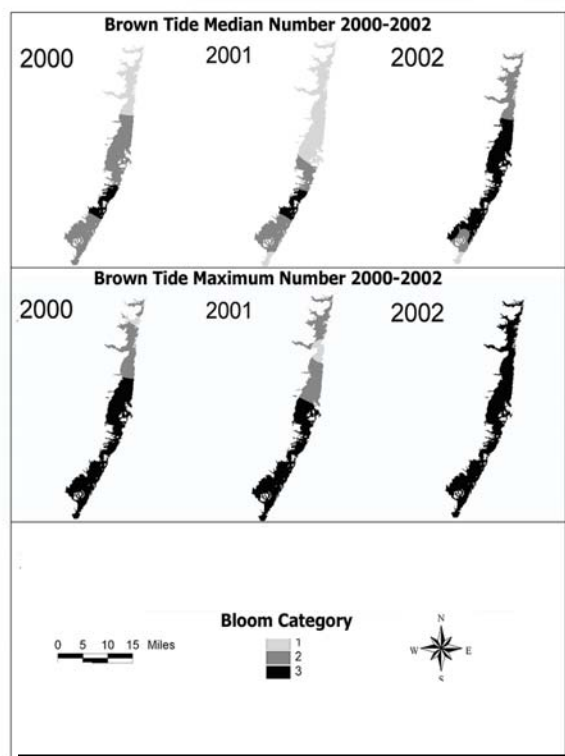


Table 1. Univariate statistics for *A. anophagefferens* abundances (cells ml⁻¹) Salinity (ppt); Temperature (°C); Nitrogen concentrations (ppb) and Secchi depth (m).

Parameter-Year	N	Mean	Median	¹ S. D.	Maximum
<i>A. anophagefferens</i>					
2000	207	216,000	41,000	456,000	2,155,000
2001	148	253,000	40,000	422,000	1,883,000
2002	128	282,000	125,000	317,000	1,561,000
Temperature					
2000	208	19.7	21.6	5.4	28.3
2001	149	21.6	23.1	4.6	29.2
2002	111	20.9	21.3	4.5	28.2
Salinity					
2000	207	27.1	28.2	3.3	33.8
2001	114	26.9	27.8	3.5	31.6
2002	111	29.5	30.3	3.1	34.1
Nutrients (2002)					
Total Nitrogen	46	338.8	279.0	184.0	878.3
NH ₃	46	9.3	6.5	8.3	47.6
NO ₂ NO ₃	46	46.6	13.0	110.0	726.6
² DON	46	311.1	242.3	184.1	851.8
Secchi depth					
2001	109	0.94	0.90	0.51	2.8
2002	109	0.71	0.60	0.48	3.0
³PAR					
2001	114	0.51	0.56	0.25	0.95
2002	86	0.57	0.58	0.21	0.97
Chlorophyll a					
2002	44	1.64	0.60	2.22	9.76
Transmissometry					
2002	109	41.89	39.30	21.02	91.6
pH					
2001	116	7.76	7.70	0.31	8.5
2002	109	7.75	7.79	0.26	8.25
⁴DO					
2001	127	7.22	6.48	2.14	16.81
2002	109	7.21	7.54	1.16	9.73

¹S.D. = standard deviation

²DON = dissolved organic nitrogen

³PAR = photosynthetically active radiation/Reference PAR

⁴DO = dissolved oxygen

Conclusion and Recommendations

This study indicates that elevated brown tide abundances (Category 2 and 3 blooms) occurred during all three years in New Jersey coastal bays. The continued monitoring of brown tides, along with associated environmental factors, at the same stations will provide a better understanding of the pattern of these blooms and the potential factors which may be significantly contributing to the promotion and maintenance of these blooms. In addition, because brown tide was detected at every station monitored during the three years, and these blooms have been detected as far south as Maryland, the extension of reconnaissance monitoring for brown tides and environmental factors southward to other coastal bays in New Jersey may be appropriate.

The *A. anophagefferens* abundance has been documented in other studies to have negative impacts to shellfish and SAVs (Fig. 1). The result of this study indicates a potential risk of brown tide blooms to negatively impact New Jersey's shellfish and SAV habitat. Category 3 and 4 blooms occur during the growing season for juvenile hard clams. Little Egg Harbor, which has been hit with Category 3 brown tide blooms since 1995, had an historic hard clam population in the mid-

Table 2. Results of the cross-tabulation of the Brown Tide *A. anophagefferens* Bloom Category and SAV maps for Years 2000, 2001, and 2002.

A. Acres of SAV

Bloom Category	Year 2000	Year 2001	Year 2002
1	1,905.6	7,386.5	0.0
2	10,373.0	5,197.6	2,006.4
3	2,600.4	2,294.9	12,872.6

B. Percent of SAV

Bloom Category	Year 2000	Year 2001	Year 2002
1	12.8	49.7	0.0
2	69.7	34.9	13.5
3	17.5	15.4	86.5

Recent results of a 2001 hard clam stock assessment in Little Egg Harbor indicated that the hard clam population in Little Egg Harbor has decreased over 67% from 1986/87 levels (Celestino, 2003). While brown tide abundances documented in this area have a potential to negatively impact hard clams, there may be other contributing causes of this decline. Therefore, changes in hard clam abundance over time in BB/LEH in conjunction with brown tide occurrence will be useful in understanding the potential contribution of brown tide blooms to shellfish declines. Likewise, information on changes in SAV occurrence or abundance in conjunction with brown tide bloom data would be useful in understanding the potential impact of these blooms on fragile SAV populations in New Jersey.

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