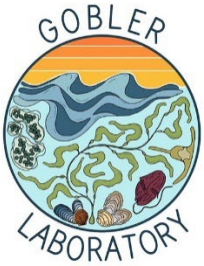
# Assessing nitrogen tipping points for harmful algal blooms in Peconic Estuary priority embayments, 2024 - 2027

**Progress Report for Peconic Estuary Partnership, March 2026**






Stony Brook University
School *of* Marine and
Atmospheric Sciences



**EXECUTIVE SUMMARY:** While harmful algal blooms have been a serious issue for the Peconic Estuary for more than 40 years, the past decade has seen a series of first ever events for the estuary regarding HABs including fish kills, turtle kills, and shellfish bed closures due to elevated levels of biotoxins from HABs. While excessive nutrient loading if often cited as the primary cause of HABs, this subject has been grossly under studies in the Peconic Estuary. This project was designed to address this informational short-coming defining the spatial and temporal variability of the three distinct HABs in the Peconic Estuary. *Alexandrium catenella* and *Dinophysis acuminata* can causes of paralytic shellfish poisoning (PSP) and diarrhetic shellfish poisoning (DSP), respectively, and are known to bloom during the months of March through June in the Peconic Estuary. Meanwhile, *Margalefinidium polykrikoides*, formerly *Cochlodinium*, is an ichthyotoxic dinoflagellate that has caused finfish and shellfish kills during summer. For this project, we monitored five locations in the Peconic Estuary (Meetinghouse Creek, Reeves Bay, Jockey Creek, Sag Harbor Cove, and Three Mile Harbor) as a time series from April through September, 2022-2025. We sought to fully characterize the nutrient regime within each site, before, during, and after these HABs. We then performed incubation experiments with water from these sites to assess the impact of added and reduced nitrogen (N) and phosphorus (P) concentrations on HAB growth. During the study, there have been 'record-breaking' and 'first ever' HABs in the Peconic Estuary. For example, in 2023, blooms of *Alexandrium catenella* led the three distinct shellfish bed closures by the NYSDEC that included sites never closed before due to biotoxins and the largest PSP closure ever in the Peconic Estuary. In 2024, an intense *Dinophysis acuminata* bloom occurred in Reeves Bay with cell densities exceeding 50 million cells per liter and cell densities over one million cells per liter sustained for over a month. This was the second largest *Dinophysis acuminata* bloom ever recorded anywhere in the world. In 2025, this project detected and documented the largest PSP event in the history of NYS and perhaps anywhere as *Alexandrium* densities exceeded 10 million cells per liter and shellfish samples during the bloom reached 2 mg saxitoxin per 100 g, both higher than any observation ever in NYS. This event also caused the longest shellfish bed closure in the history of NYS at four months. During experiments performed for this project, nutrient enrichment with N, and to a far lesser extent P, could increase total algal biomass within all sites. N was also found to specifically stimulate each of the individual HABs. Nutrient levels in these systems, especially Meetinghouse Creek and Jockey Creek, were so high (> 30 μM nitrate + ammonium) that in many cases, nutrient reductions of 50% to 90% were needed to significantly reduced the intensity of these HABs, with reductions needed being both site and HAB specific. Additional work is needed to clarify spatial nutrient-HAB dynamics and to establish HAB-nutrient dynamics in other HAB prone regions. Ultimately, this project is generating data to support managerial recommendations on precise nutrient load reductions required to mitigate HABs within specific regions of the Peconic Estuary.

**BACKGROUND**:

The Peconic Estuary has been plagued with harmful algal blooms (HABs) for decades. In 1985, brown tides caused by the pelagophyte, *Aureococcus anophagefferens* struck suddenly, recurred for three years, and caused the collapse the of $3M bay scallop fishery, as well as the destruction the eelgrass meadows (Gobler et al., 2005). While the final brown tide in the Peconic Estuary occurred at the end of the 20$^{th}$ century (Gobler and Sanudo-Wilhelmy, 2001), the 21$^{st}$ century has been a period of expansion and proliferation of HABs in the Peconic Estuary. In 2004, the first ever rust tide caused by *Cochlodinium polykrikoides* occurred across the Peconic Estuary (Gobler et al., 2008) and has since caused both fish kills and shellfish kills across the estuary (Kudela and Gobler, 2012; Li et al., 2012). While the first *Alexandrium* catenella bloom occurred in Northport in 2006 (Hattenrath et al., 2010), it was a decade later the most destructive *Alexandrium* bloom in the Peconics occurred, specifically in 2015. In May of that year, blooms occurred in multiple bays and tributaries across the western Peconics, leading to the closure of three shellfishing regions due to the presence of saxitoxin in shellfish and the threat of paralytic shellfish poisoning (PSP). During these blooms, hundreds of diamondback terrapin turtles died after consuming mussels contaminated with saxitoxin (Hattenrath-Lehmann et al., 2017). In the intervening years, there have been nearly 10 PSP closures in the Peconic Estuary within six locations (Sag Harbor Cove, James Creek, Deep Hole Creek, Terry Creek, Meetinghouse Creek, and Halls Creek). A final HAB of concern is caused by the dinoflagellate, *Dinophysis acuminata*, that synthesizes okadaic acid and causes diarrhetic shellfish poisoning (DSP). In 2011, the highest densities of *Dinophysis* ever recorded anywhere in the world (two million cells per liter) was quantified in Meetinghouse Creek (Hattenrath-Lehman et al., 2018). These three HABs recur annually across the Peconic Estuary with intensities and impacts varying year-to-year. Prior research has identified the ability of excessive nitrogen to promote and intensify these HABs (Hattenrath et al., 2010; Gobler et al., 2012; Hattenrath-Lehmann et al., 2015). Still, critical open questions regarding nitrogen and these HABs in the Peconic Estuary remain: Are the events similarly promoted by excessive nitrogen? What is the spatial and temporal variability of the nutrients promoting these events? What degree of nitrogen reduction is needed to lessen the intensity of these events? This project will aim to answer these questions.

**Objectives:**

1. Assess the temporal dynamics of nutrients and HABs within bloom prone regions of the Peconic Estuary.
2. Assess the ability of nitrogen and phosphorus to intensify HABs within bloom prone regions of the Peconic Estuary.
3. Asses the levels of nutrient load reduction needed to lessen the intensity of these HABs.

**APPROACH:**

Time series sampling of HABs and nutrients was performed at multiple locations across the Peconic Estuary from spring through fall, capturing the season succession of *Alexandrium*, *Dinophysis*, and *Cochlodinium*. Specifically, samples werecollected from: Sag Harbor, Three Mile Harbor, Jockey Creek, the Peconic River, Reeves Bay, and Meetinghouse Creek. During blooms of the HABs of interest, experiments were conducted. Bloom water was collected and transferred to two-liter polycarbonate bottles that were established in triplicate experimental treatments that include an unamended control, enrichment with nitrogen (ammonium), enrichment with phosphorus (orthophosphate) and enrichment with both elements. Parallel experimental bottles were established whereby nutrient levels are reduced by 25%, 50%, and 75% by mixing whole water with artificial seawater with no nutrients. To account for reductions in zooplankton grazing caused by dilution (Landry et al., 1995; Gobler et al., 2002), dilutions with nutrients added back to each dilution level will also be established. The concentrations of each HAB and nitrogenous nutrients and phosphorus were quantified at the start and end of each experiment. The functional relationship between HAB growth rates and nutrient levels were established. Thresholds of nutrient dilutions needed to cause low or negative growth rates were identified using linear regression models. The data generated from experiments regarding the level of nitrogen reduction required to lessen the intensity of HABs within distinct regions of the Peconic Estuary is being compared to management plans. This management end point can be used in conjunction with the Suffolk County Wastewater Subwatersheds Plan (2020) to identify the specific management actions that are most likely to achieve HAB mitigation.

Water samples from various sites were collected on a weekly basis from March to July, for *Alexandrium* and *Dinophysis*, and August to October for *Cochlodinium*. The sites collected included: Jockey Creek, Sag Harbor Cove, Three Mile Harbor, Reeves Bay, and Meetinghouse Creek. At each site subsurface water was collected and water quality parameters consisting of temperature, salinity, secchi depth, and dissolved oxygen.

The water samples were then processed in the lab. Each site had a pigment analysis using the Fluoroprobe. Concentrated lugols samples were also taken for each site sieving 1 L of water through a 200 µm mesh and a 20 µm sieve backwashed into a 15 mL centrifuge tube filling the tube to 14 mL (Hattenrath-Lehmann et al., 2013). Each sample was then counted for cell densities of *Alexandrium catenella* and *Dinophysis acuminata* under a light microscope using a 1 mL 1,000 grid Sedgewick rafter.

**2022**

*Alexandrium*

In 2022, *Alexandrium catenella* was monitored from 5-May-2022 to 22-June-2022. Jockey Creek had the most notable and highest bloom of all five sites in 2022 at a peak of 17,136

cells/L on 11-May-2022 (Fig. 1A). Meetinghouse Creek did not have any *A. catenella* blooms throughout the whole sampling period (Fig. 1A). Reeves Bay had one bloom on 9-May-2022 with a low density of 14 cells/L (Fig. 1A). *A. catenella* in Sag Harbor Cove first appeared on 14 cells/L had the second highest bloom of the five sites at a peak of 756 cells/L on 16-May-2022 (Fig. 1A). In Three Mile Harbor, *A. catenella* was consistent at 56 cells/L from 11-May-2022 to 23-May-2022 (Fig. 1A).

*Dinophysis*

In 2022, *Dinophysis acuminata* was monitored simultaneously with *A. catenella* from 5-May-2022 to 22-June-2022. Jockey Creek had consistent high-density blooms over 1,000 cells/L. *D. acuminata* first appeared on 18-May-2022 at 5,838 cells/L (Fig. 1B). Blooms were over 10,000 cells/L between 25-May-2022 to 6-June-2022 starting at 49,882 cells/L on 25-May-2022 (Fig. 1B). The highest density bloom of *D. acuminata* in Jockey Creek peaked at 171,500 cells/L on 1-June-2022 and was the highest amongst the five sites sampled (Fig. 1B). The bloom went down to 91,000 cells/L on 6-June-2022 (Fig. 1B). Meetinghouse Creek bloomed the second highest out of the five sites at its peak at 95,200 cells/L on 25-May-2022 (Fig. 1B). Reeves Bay bloomed below 1,000 cells/L throughout the whole monitoring period with the peak on 30-May-2022 at 756 cells/L (Fig. 1B). *D. acuminata* in Sag Harbor Cove bloomed consistently over 1,000 cells/L throughout the monitoring period except for the first day two days at 28 and 56 cells/L on 11-May-2022 and 16-May-2022, respectively (Fig. 1B). *D. acuminata* peaked at 17,332 cells/L on 23-May-2022 (Fig. 1B). There was a second peak of 5,012 cells/L on 13-June-2022 (Fig. 1B). Three Mile Harbor had low density blooms below 1,000 cells/L with a peak on 7-June-2022 at 2,422 cells/L (Fig. 1B).

*Cochlodinium*

In 2022, *Cochlodinium polykrikoides* was monitored from 5-July-2022 to 28-September-2022 and appeared at relatively low densities at all five sites. *C. polykrikoides* appeared only once on 12-July-2022 at 50 cells/mL (Fig. 2). Meetinghouse Creek had consistent blooms throughout September and had a peak on 13-September-2022 at 145 cells/mL (Fig. 2). Reeves Bay had the highest bloom density of the five sites at 500 cells/mL on the first day of monitoring on 6-July-2022 (Fig. 2). Sag Harbor Cove had more consistent blooms throughout the monitoring with the second highest density bloom of the five sites at 318 cells/mL on 18-July-2022 (Fig. 2). At Three Mile Harbor, *C. polykrikoides* appeared twice at 10 and 4 cells/mL on 11-July-2022 and 18-July-2022, respectively (Fig. 2).

*Nutrients and Chlorophyll-a*

In 2022, Jockey Creek had higher concentrations of ammonium and nitrate, both at 46.98 uM, compared to the other five sites between May and June (Fig. 3B, 3C). Meetinghouse Creek has the second highest of all nutrients throughout the monitoring period (Fig. 3B, 3C, 3D). Reeves Bay had a higher concentration of nitrate at the beginning of May compared to ammonium and phosphate (Fig. 3B, 3C, 3D). Sag Harbor Cove had the lowest nutrient levels of all five sites (Fig. 3B, 3C, 3D). Jockey Creek had the highest chlorophyll-*a* concentrations in July at 205.5 ug/L on 20-July-2025 (Fig. 3A). Meetinghouse Creek and Reeves Bay had higher

chlorophyll-*a* in July and September, respectively, at 78.15 ug/L and 87.5 ug/L, respectively (Fig. 3A). Three Mile Harbor and Sag Harbor Cove had the lowest chlorophyll-*a* concentrations throughout the whole monitoring period (Fig. 3A).

*Experiments*

In 2022, results from chlorophyll-*a* data showed nutrient addition experiments performed with Meetinghouse Creek bloom water had four experiments that were nitrogen limiting on 25-May-2022, 30-May-2022, 6-June-2022, and 22-June-2022 ($p<0.05$, Fig. 30), Two experiments were co-limiting between nitrogen and phosphorus on 9-May-2022 and 15-June-2022 ($p<0.05$, Fig. 30), and one that had no response on 18-May-2022 (Fig. 30). All seven nutrient addition experiments performed with Reeves Bay bloom water were nitrogen limiting ($p<0.05$, Fig. 31). Nutrient addition experiments performed with Sag Harbor Cove bloom were similar to Reeves Bay bloom water where all seven experiments were nitrogen limiting ($p<0.05$, Fig. 32). Three Mile Harbor bloom water nutrient addition experiments had similar results as Reeves Bay and Sag Harbor Cove nutrient addition experiments where all seven were nitrogen limiting ($p<0.05$, Fig. 33). Nutrient addition experiments using Jockey Creek bloom water showed two nitrogen limitations on 11-May-2022 and 6-June-2022 ($p<0.05$, Fig. 34). Three experiments were phosphorus limiting on 18-May-2022, 1-June-2022, and 15-June-2022 ($p<0.05$, Fig. 34). Two experiments had no response on 25-May-2022 and 15-June-2022 (Fig. 34).

**2023**

*Alexandrium*

In 2023, *Alexandrium catenella* was monitored from 3-April-2023 to 26-June-2023. Jockey Creek had the highest density bloom of the five sites when it first appeared on 10-April-2023 at a peak bloom of 24,500 cells/L (Fig. 5A). *A. catenella* sustained at over 1,000 cells/L the two weeks after that at 8,610 and 6,300 cells/L on 17-April-2023 and 24-April-2023, respectively. Meetinghouse Creek first bloomed on 12-April-2023 over 1,000 cells/L at 1,610 cells/L (Fig. 5A). There were two sampling days that were over 100 cells/L on 19-April-2023 at 630 cells/L and 24-May-2023 at 238 cells/L (Fig. 5A). Reeves Bay had the second highest bloom of the five sites at its peak at 23,800 cells/L (Fig. 5A). *A. catenella* bloomed two more times in the next two weeks at 2,240 cells/L and 70 cells/L on 19-April-2023 and 26-April-2023, respectively (Fig. 5A). *A. catenella* bloomed once in Sag Harbor Cove on 3-April-2023 at 224 cells/L (Fig. 5A). Three Mile Harbor had a peak bloom over 1,000 cells/L on the first day at 3,444 cells/L on 3-April-2023 (Fig. 5A). The rest of the monitoring density was below 100 cells/L on 24-April-2023, 1-May-2023, and 8-May-2023 at 140, 70, 70, cells/L, respectively (Fig. 5A).

*Dinophysis*

In 2023, *Dinophysis acuminata* was monitored from 3-April-2023 to 5-July-2023. In Jockey Creek, *D. acuminata* had the highest density bloom of the five sites on 15-May-2023 at 57,582 cells/L (Fig. 5B). There was a second high density bloom over 10,000 cells/L on 30-May-2023 at 10,962 cells/L (Fig. 5B). In Meetinghouse Creek, there was a bloom over 10,000 cells/L

on 17-May-2023 at 10,262 cells/L (Fig. 5B). On 24-May-2023, there was a bloom of 27,706 cells/L, which was the second highest bloom of the five sites (Fig. 5B). Reeves Bay had its highest density bloom on 7-June-2023 at 7,182 cells/L (Fig. 5B). There was another bloom over 1,000 cells/L a week prior to 2,856 cells/L on 31-May-2023 (Fig. 5B). In Sag Harbor Cove, the peak bloom was on 22-May-2023 at 3,038 cells/L (Fig. 5B). There was a second peak bloom on 5-June-2023 at 2,282 cells/L (Fig. 5B). In Three Mile Harbor, the peak bloom was on 5-June-2023 at 7,056 cells/L (Fig. 5B).

*Cochlodinium*

In 2023, *Cochlodinium polykrikoides* was monitored from 20-July-2023 to 21-September-2023 (Fig. 6). *C. polykrikoides* did not bloom throughout the monitoring period until the last day on 21-September-2023 at a very low density of 4 cells/mL (Fig 6). In Meetinghouse Creek, *C. polykrikoides* appeared once in July on 24-July-2023 at a low density of 15 cells/mL (Fig. 6). Throughout September there were low density blooms of 44, 65, and 35 cells/mL on 7-September-2023, 14-September-2023, and 21-September-2023, respectively. In Reeves Bay, *C. polykrikoides* appeared in very low densities sporadically throughout the monitoring period. On 20-July-2023, *C. polykrikoides* first appeared at 35 cells/mL and again a week later at 3 cells/mL on 27-July-2023 (Fig. 6). In August, *C. polykrikoides* was detected on 31-August-2023 at 20 cells/mL (Fig. 6). In September, it was detected at 8 and 4 cells/mL on 5-September-2023 and 11-September-2023, respectively (Fig. 6). *C. polykrikoides* in Sag Harbor Cove was detected sporadically and had the second highest bloom of the five sites on 19-September-2023 at 89 cells/mL (Fig. 6). Three Mile Harbor peaked on 31-July-2023 at 178 cells/mL, which was also the highest density bloom of the five sites (Fig. 6).

*Nutrients and Chlorophyll-a*

Meetinghouse Creek had the highest nitrate and phosphate levels of the five sites (Fig. 7B, 7C, 7D). The highest nitrate level was on 12-April-2023 at 222 uM and the highest phosphate level was on the same date at 38 uM (Fig. 7B, 7D). Reeves Bay had the highest ammonium concentration of the five sites at 146.71 o 31-August-2023 (Fig. 7C). All other sites had lower concentrations compared to Meetinghouse Creek and Reeves Bay (Fig. 7B, 7C, 7D). Chlorophyll-*a* concentrations at all sites increased from June to September (Fig. 7A). Jockey Creek had the highest chlorophyll-*a* concentration on 15-May-2023 at 184.3 ug/L (Fig. 7A). Reeves Bay had its highest chlorophyll-*a* in September at 116.6 ug/L (Fig. 7A).

*Experiments*

In 2023, Meetinghouse Creek *A. catenella* bloom water on 12-April-2023 cell density data showed that nutrient addition experiments were co-limiting ($p<0.05$, Fig. 35) and that 75% and 90% dilutions with artificial seawater were significantly lower density ($p<0.05$, Fig. 35). Similarly, an experiment using *D. acuminata* bloom water on 26-April-2023 also showed co-limitation ($p<0.05$, Fig. 36) in nutrient addition as well as significantly lower density in 75% and 90% dilutions with artificial seawater ($p<0.05$, Fig. 36). In an experiment on 15-Spetember-2023 using *C. polykrikoides* bloom water, nutrient addition experiment did not have a response, but the 90% dilution with artificial seawater was significant ($p<0.05$, Fig. 37). Reeves Bay *D. acuminata*

bloom water experiment performed on 2-June-2023 showed no response in the nutrient addition experiment, but significance in both 75% and 90% dilution with artificial seawater ($p<0.05$, Fig. 38). Another Reeves Bay *D. acuminata* bloom water experiment performed on 9-June-2023 showed no response in the nutrient addition experiment, but significance in all three dilutions: 50%, 75%, and 90% ($p<0.05$, Fig. 39). Three Mile Harbor *D. acuminata* bloom water experiment performed on 1-June-2023 showed that there was nitrogen limiting in the nutrient addition experiment ($p<0.05$, Fig. 40), and the 75% and 90% dilution with artificial seawater were significant ($p<0.05$, Fig. 40). *D. acuminata* bloom water experiment from Sag Harbor Cove on 7-June-2023 and 14-June-2023 both had the same results, showing nitrogen limitation ($p<0.05$, Fig. 41; Fig. 42), and that 75% and 90% dilution with artificial seawater were both significant ($p<0.05$, Fig. 41; Fig. 42). An experiment with *C. polykrikoides* bloom water from Sag Harbor Cove 20-Septmeber-2023 showed that it was co-limiting in the nutrient addition experiment, and significant when diluted by 75% and 90% with artificial seawater ($p<0.05$, Fig. 43). Another experiment with Jockey Creek *A. catenella* bloom water on 3-May-2023, showed that nutrient addition was co-limiting ($p<0.05$, Fig. 44), and that again 75% and 90% dilutions with artificial seawater were significant ($p<0.05$, Fig. 44). An experiment with *D. acuminata* bloom water on 1-June-2023 showed no response in nutrient addition, but 75% and 90% dilutions with artificial seawater were significant ($p<0.05$, Fig. 45).

**2024**

*Alexandrium*

In 2024, *Alexandrium catenella* was monitored from 18-March-2024 to 24-June-2024. *A. catenella* in Jockey Creek was consistently blooming over 1,000 cells/L throughout the monitoring period except for one day on 13-May-2024 at 233 cells/L (Fig. 9A). The peak bloom was on 24-April-2024 at 157,500 cells/L, which was also the highest density bloom of the five sites (Fig. 9A). There was a second peak bloom on 22-May-2024 at 27,475 cells/L (Fig. 9A). Meetinghouse Creek had the second highest bloom of the five sites on 29-May-2024 at its peak of 11,200 cells/L (Fig. 9A). Reeves Bay had consistent high blooms first on 17-April-2024 at a peak of 8,867 cells/L and a week later on 24-April-2024 at 7,408 cells/L. The second peak was on 22-May-2024 at 1,750 cells/L (Fig. 9A). Sag Harbor Cove had a peak bloom on 29-April-2024 at 1,108 cells/L (Fig. 9A). There was a higher second bloom on 22-May-2024 at 6,125 cells/L (Fig. 9A). Three Mile Harbor had a peak bloom on 22-May-2024 at 8,050 cells/L (Fig. 9A).

*Dinophysis*

In 2024, *Dinophysis acuminata* was monitored from 18-March-2024 to 24-June-2024. In Jockey Creek, *D. acuminata* bloomed consistently over 1,000 cells/L from May through June (Fig. 9B). The peak bloom was on 10-June-2024 at 395,500 cells/L, which was the second highest bloom of all five sites (Fig. 9B). At Meetinghouse Creek, *D. acuminata* bloomed from May through mid-June and peaked on 29-May-2024 at 65,450 cells/L (Fig. 9B). Reeves Bay had its most intense peak bloom on 4-June-2024 at 57,800,000 cells/L, which was the highest bloom of all five sites (Fig. 9B). Sag Harbor Cove had its peak on 28-May-2024 at 6,475 cells/L (Fig.

9B). Three Mile Harbor had two peak blooms first on 28-May-2024 at 18,900 cells/L and the second on 10-June-2024 at 9,392 cells/L (Fig. 9B).

*Cochlodinium*

In 2024, *Cochlodinium polykrikoides* was monitored from 3-July-2024 to 25-September-2024. Jockey Creek had the second highest bloom of the five sites on 24-July-2024 at 792 cells/mL (Fig. 10). Meetinghouse Creek had the highest bloom of the five sites on 18-July-2024 at 2500 cells/mL (Fig. 10). Reeves Bay bloomed over 100 cells/mL on 21-August-2024 at 625 cells/mL (Fig. 10). Sag Harbor Cove had one bloom on 26-August-2024 at 100 cells/mL (Fig. 10). Three Mile Harbor did not have any *C. polykrikoides* blooms throughout the whole monitoring period.

*Nutrients and Chlorophyll*

In 2024, Meetinghouse Creek had the highest ammonium, phosphate, and nitrate levels compared to the other five sites from late April to July (Fig. 11B, 11C, 11D). Jockey Creek had a high concentration of ammonium at the start of the monitoring period on 24-April-2024 at 10.5 uM then dropped and had another high on 10-July-2024 at 7.2 uM (Fig. 11C). Jockey Creek also had high levels of nitrate at the beginning of the monitoring period at 105 uM on 24-April-2024 (Fig. 11A). Phosphate levels were low compared to nitrate and ammonium (Fig. 11B, 11C, 11D). Chlorophyll-*a* concentrations increased throughout the monitoring period (Fig 11A). Reeves Bay had its peak on 1-August-2024 at 154.5 ug/L (Fig. 11A). Jockey Creek had several peaks throughout the monitoring period but had its highest concentration on 1-August-2024 at 96.07 ug/L (Fig. 11A). Sag Harbor Cove and Three Mile Harbor had the lowest concentrations of chlorophyll throughout the monitoring period (Fig. 11A).

**2025**

*Alexandrium*

In 2025, *Alexandrium catenella* was monitored from 4-March-2025 to 8-July-2025. *A. catenella* in Jockey Creek was consistently blooming over 1,000 cells/L throughout the monitoring period (Fig. 13). There was a record-breaking bloom on 17-April-2025 at 10,312,500 cells/L (Fig. 13). This bloom started on 7-April-2025 and persisted until 29-April-2025 (Fig. 13). Meetinghouse Creek had a peak bloom of 280 cells/L on 6-May-2025 (Fig. 13). Reeves Bay had consistent blooms over 1,000 cells/L with the peak on 6-May-2025 at 3,696 cells/L (Fig. 13). Three Mile Harbor had consistent high blooms first on 28-April-2025 at a peak of 3,080 cells/L and a week later 6-May-2025 at 1,736 cells/L (Fig. 13). Sag Harbor Cove had a peak bloom on 28-April-2025 at 560 cells/L (Fig. 13).

*Dinophysis*

In 2025, *Dinophysis acuminata* was monitored from 4-March-2025 to 8-July-2025. In Jockey Creek, *D. acuminata* bloomed consistently over 1,000 cells/L from May through June (Fig. 14). The peak bloom was on 2-June-2025 at 39,200 cells/L (Fig. 14). At Meetinghouse Creek, *D. acuminata* bloomed from May through mid-June and peaked on 25-June-2025 at

1,344,000 cells/L, which was the highest bloom of all five sites (Fig. 14). Reeves Bay peaked on 3-June-2025 at 219,100 cells/L (Fig. 14). Sag Harbor Cove had two peaks first on 21-May-2025 at 3.696 cells/L and the second one on 4-June-2025 at 8,288 cells/L (Fig. 14). Three Mile Harbor had two peak blooms first on 9-June-2025 at 1,064 cells/L and the second on 30-June-2025 at 3,920 cells/L (Fig. 14).

*Cochlodinium*

In 2025, *Cochlodinium polykrikoides* was monitored from 20-August-2025 to 16-September-2025. Compared to previous years *C. polykrikoides* did not bloom for much longer than a month and were in very low densities. The highest density was in Jockey Creek on 28-August-2025 at 96 cells/mL (Fig. 15). The second highest density was in Meetinghosue Creek on 28-August-2025 at 56 cells/mL (Fig. 15). All the other three sites had very low densities below 25 cells/mL (Fig. 15).

*Nutrients and Chlorophyll-a*

Nutrient levels (nitrate, ammonium, and phosphate) at Meetinghouse Creek were the highest amongst all five sites (Fig. 16B, 16C, 16D). Jockey Creek had higher levels of nitrate compared to ammonium and phosphate with the highest nitrate level on 28-May-2025 at 101.4 uM (Fig. 16B, 16C, 16D). Compared to Jockey Creek and Meetinghouse Creek, Reeves Bay, Sag Harbor Cove, and Three Mile harbor had lower levels of nutrients throughout the monitoring period (Fig. 16B, 16C, 16D). Reeves Bay did have one day in June where ammonium levels were higher than Meetinghouse Creek on 24-June-2025 at 11.1 uM (Fig. 16C). Chlorophyll-*a* concentrations were highest at Jockey Creek, and the peak was on 1-July-2025 at 555.85 ug/L (Fig. 16A). Meetinghouse Creek had a peak on 22-April-2025 at 125.26 ug/L (Fig. 16A). Reeves Bay, Sag Harbor Cove, and Sag Harbor Cove had the lowest chlorophyll-*a* levels (Fig. 16A).

*Spatial Surveys*

In 2025, spatial surveys were conducted at Jockey Creek and Meetinghouse Creek during high density blooms of *Alexandrium* and *Dinophysis*. Cell counts, nutrients, and chlorophyll-*a* samples were collected for all sites.

At Jockey Creek, spatial surveys were conducted during the peak of the bloom 17-April-2025 when *Alexandrium* density was at 10,312,500 cells/L, two weeks after on 30-April-2025, and a week after on 7-May-2025 (Fig. 22A). Site 5 was closest inland and had the densest *Alexandrium* densities and highest chlorophyll-a levels amongst the sites samples throughout each survey (Fig. 22A, 22B). In parallel, nitrate and ammonium levels were highest at Site 5 compared to all other sites on 17-April-2025 (Fig. 23A, 23B). The further east from site 5 to the Peconic Estuary there is a decrease in cell density, chlorophyll, and nutrients (Fig. 22A, 22B, 23A, 23B, 23C). Phosphate levels were relatively low in early spatial surveys compared to nitrate and ammonium levels (Fig. 23A, 23B, 23C). Chlorophyll-*a* concentrations reflect cell densities where site 5 had the highest concentrations, except for 22-April-2025 where the west bridge site had the highest concentrations (Fig. 22B).

At Meetinghouse Creek, spatial surveys were conducted pre-*Dinophysis* bloom on 12-May-2025 and at peak bloom on 25-June-2025 at 1,344,000 cells/L (Fig. 25A). From May to June all nutrient levels increased across all sites (Fig. 26A, 26B, 26C). Site 4 and Site 5 in June and May, respectively, had the highest nutrient levels (Fig. 26A, 26B, 26C). These two sites were closest in proximity when sampled (Fig. 24).

*Experiments*

In 2025, Meetinghouse Creek *D. acuminata* bloom water on 24-June-2025 cell density and chlorophyll-*a* data showed that nutrient addition experiments did not have a response (Fig. 46). Nutrients at Meetinghouse Creek were particularly high, which resulted in added nutrients to have no affect (Fig. 46). The dilution experiments showed that 75% and 90% dilutions with artificial seawater were significantly lower density and had significantly lower chlorophyll-*a* across all dilution levels ($p<0.05$, Fig. 46). Reeves Bay *A. catenella* bloom water experiment performed on 6-May-2025 showed no response in the nutrient addition experiment in chlorophyll-*a*, but decrease in cell density with nutrients ($p<0.05$, Fig. 47). Nutrient dilution experiments, however, did show significance in both 75% and 90% dilution with artificial seawater ($p<0.05$, Fig. 47). Another Reeves Bay *D. acuminata* bloom water experiment performed on 3-June-2025 showed no response in the nutrient addition experiment in both cell density and chlorophyll-*a*, but there was significance in 90% dilutions with artificial seawater only in chlorophyll-*a* ($p<0.05$, Fig. 48). Jockey Creek *A. catenella* bloom water on 15-April-2025, showed nutrient dilution experiments at 75% and 90% dilutions with artificial seawater showed most significance in decrease of cells ($p<0.05$, Fig. 49), and 50% and 90% dilutions with artificial seawater showed most significance in decrease of chlorophyll-*a* ($p<0.05$, Fig. 49).

*PSP Closures caused by Alexandrium catenella*

Cells densities of *A. catenella* were higher than normal in 2025 for all location and this translated into a large number of PSP-induced shellfish bed closures across Suffolk County. The most significant PSP event in more than 17 years occurred in the Peconic Estuary beginning in April. Jockey Creek has 12,000 cells per L in early April which rose to 240,000 cell per L the following week and more than 10 million cells per liter by late April (Fig. 28). This is the highest cell density ever recorded in NY with the prior record being 1 million cells per liter in Northport Harbor in 2008 (Hattenrath et al., 2010). This may also be the highest cell density ever recorded anywhere for this species. This spike in cell densities led to a shellfish bed closure of both Jockey Creek and Town Creek located just north of Jockey Creek on April 16 (Fig. 28). Two weeks later, Goose Creek, located just south of Jockey Creek, was closed to shellfishing by NYSDEC (Fig. 29). The bloom in Jockey Creek continued through the end of April, with >1.7 million cells per liter recorded in late April (Fig. 13). The shellfish closures in the region were completed justified, as shellfish removed from Jockey Creek contained more than 2 mg of saxitoxin per 100 grams of shellfish tissue, a record for New York State. The PSP closure in Jockey Creek continued until August, marking the longest PSP closure in the history of NYS.

## Figures

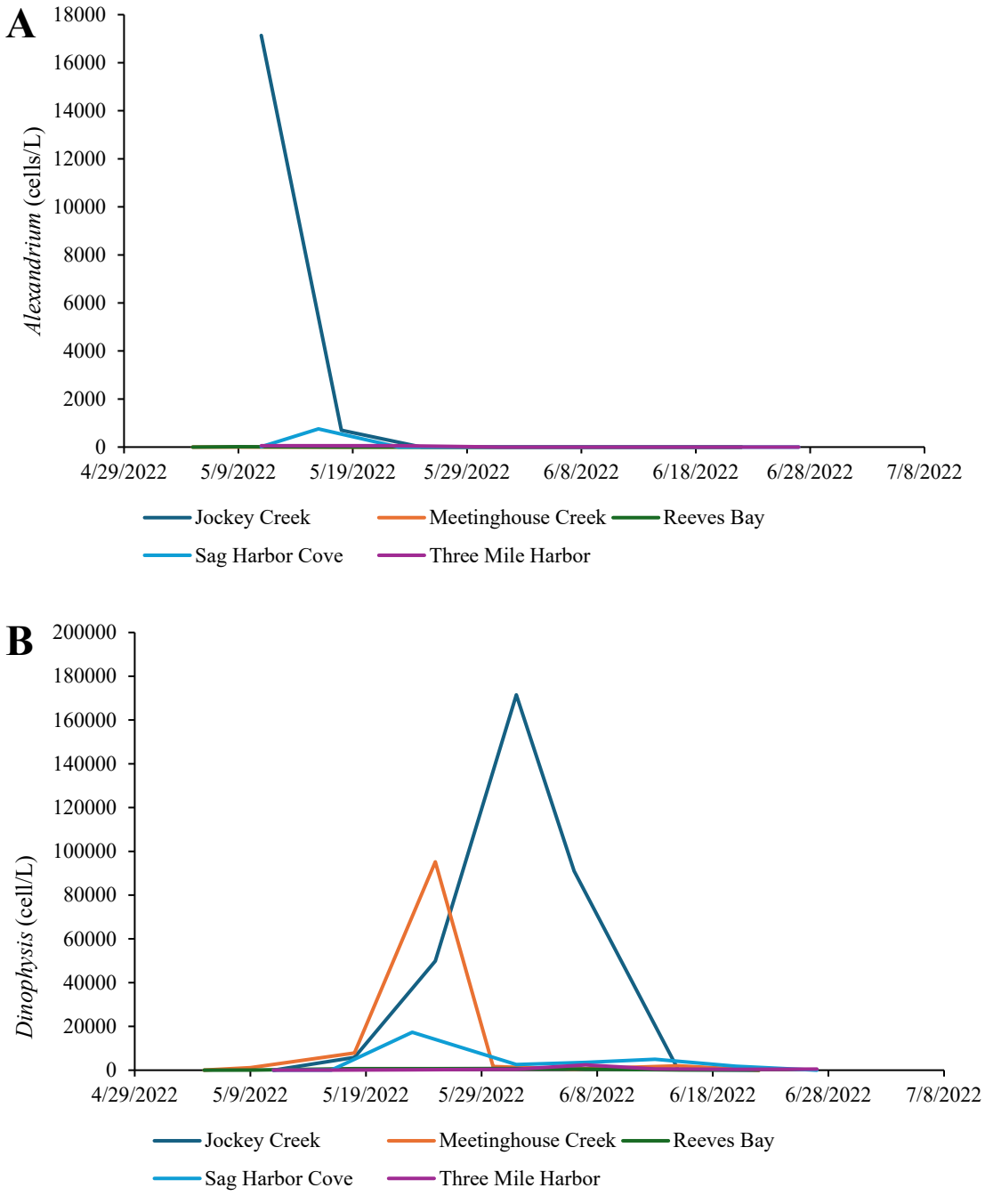



**Figure 1.** 2022 A) *Alexandrium* and B) *Dinophysis* density times series.

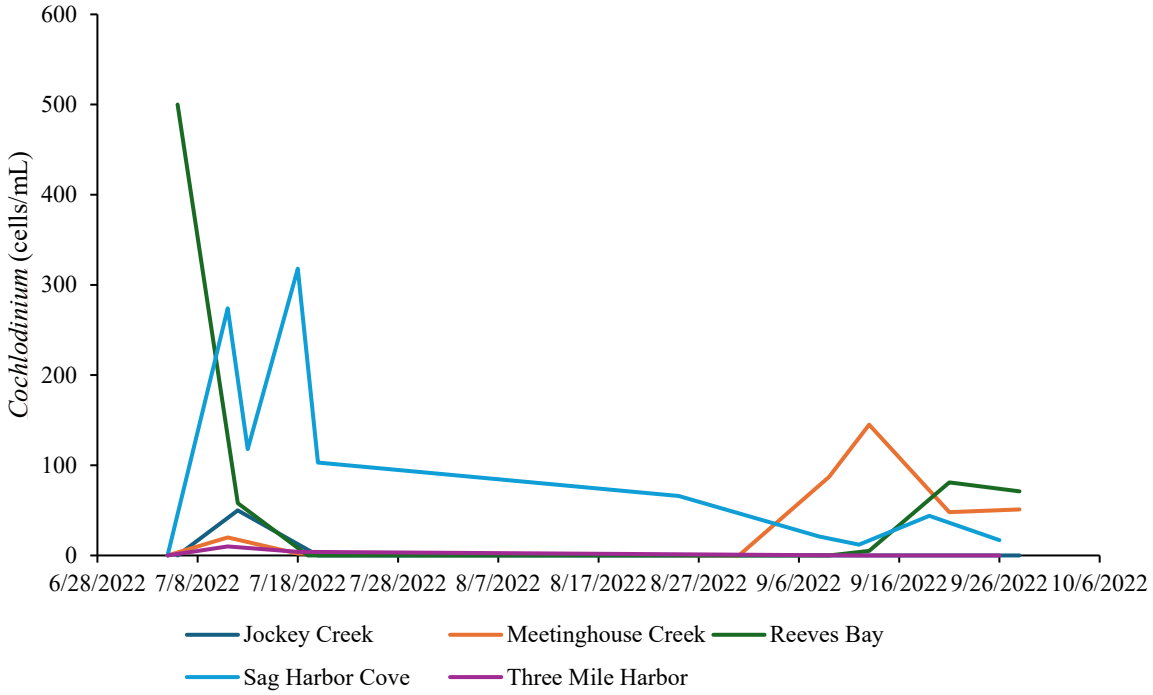



**Figure 2.** 2022 *Cochlodinium* density times series.

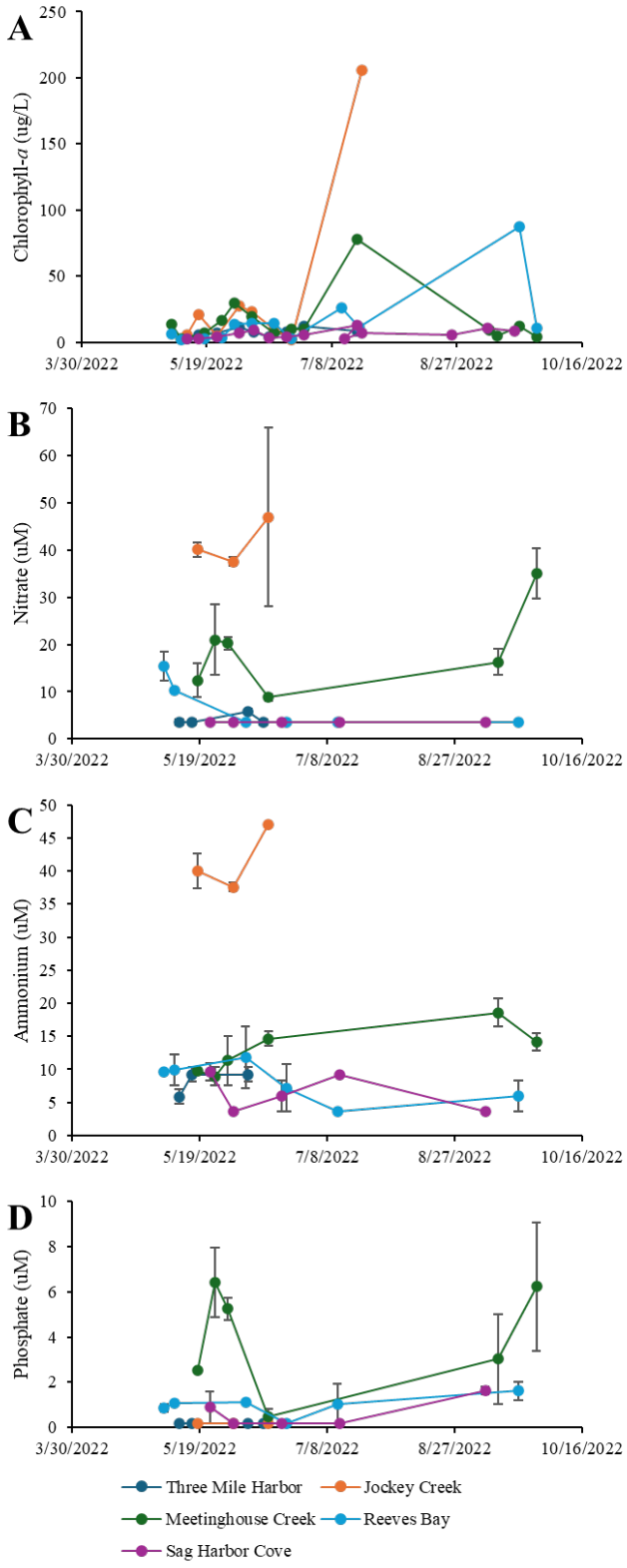



**Figure 3.** 2022 A) Chlorophyll-*a* B) nitrate C) ammonium and D) phosphate times series.

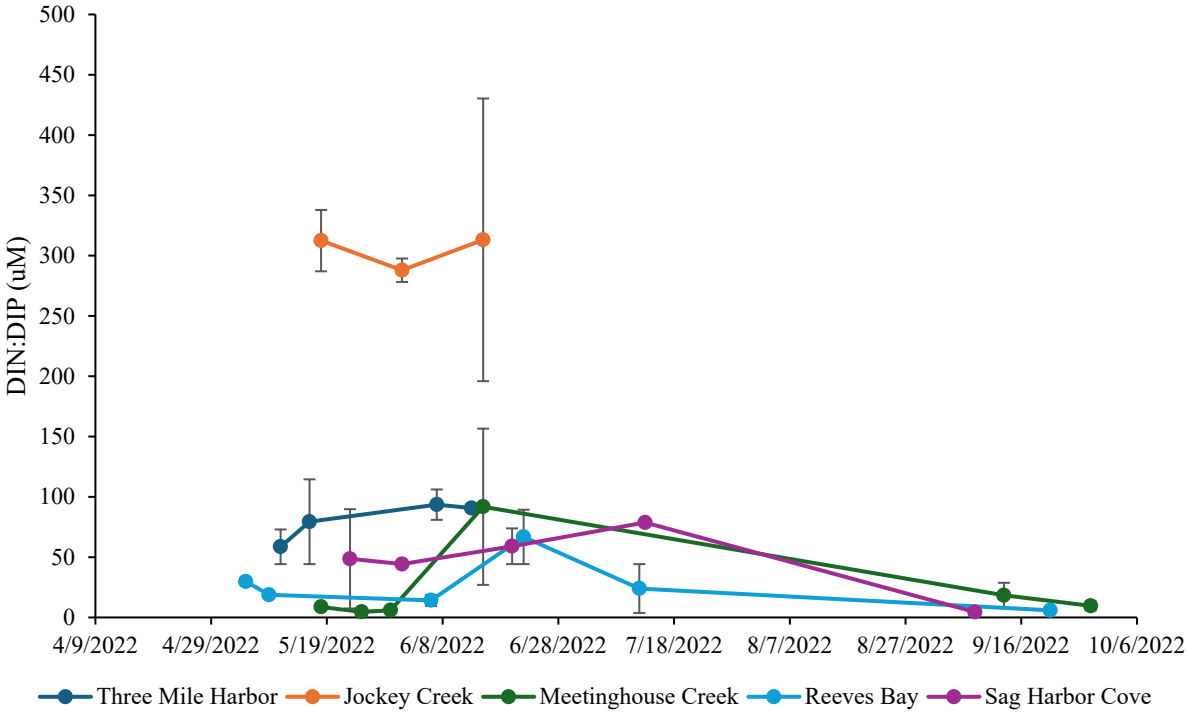



**Figure 4.** 2022 DIN:DIP time series.

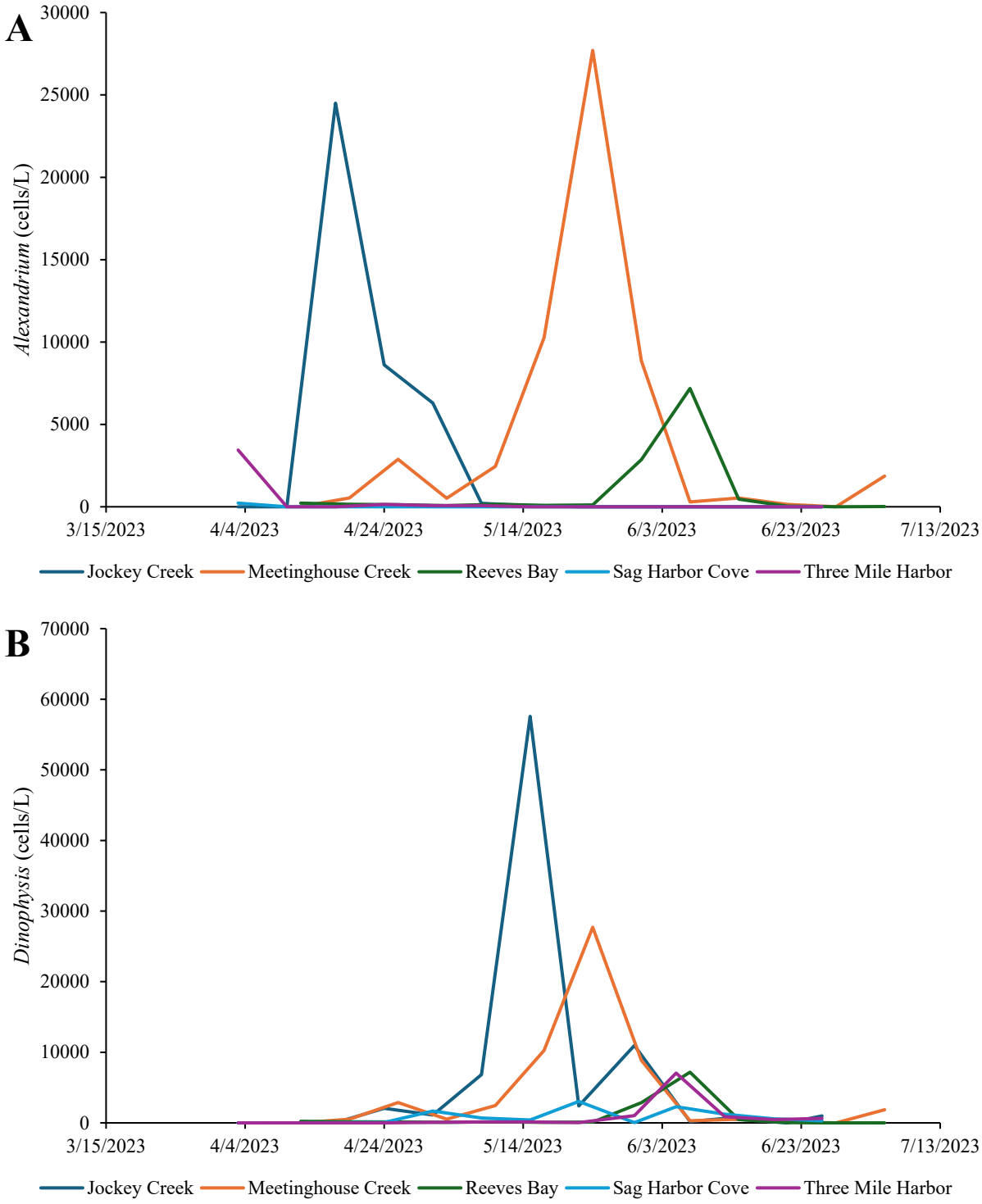



**Figure 5.** 2023 A) *Alexandrium* and B) *Dinophysis* density times series.

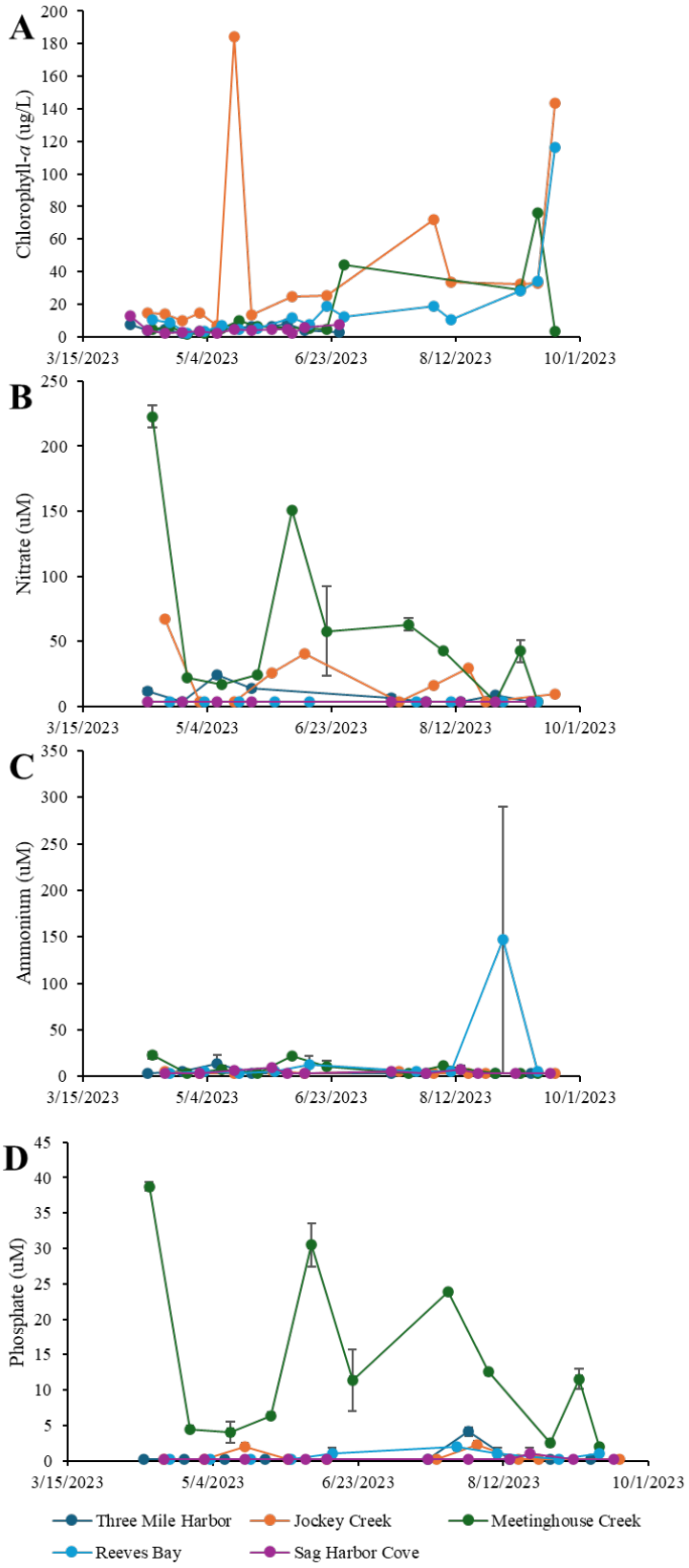



**Figure 7.** 2023 A) Chlorophyll-*a* B) nitrate C) ammonium and D) phosphate times series.

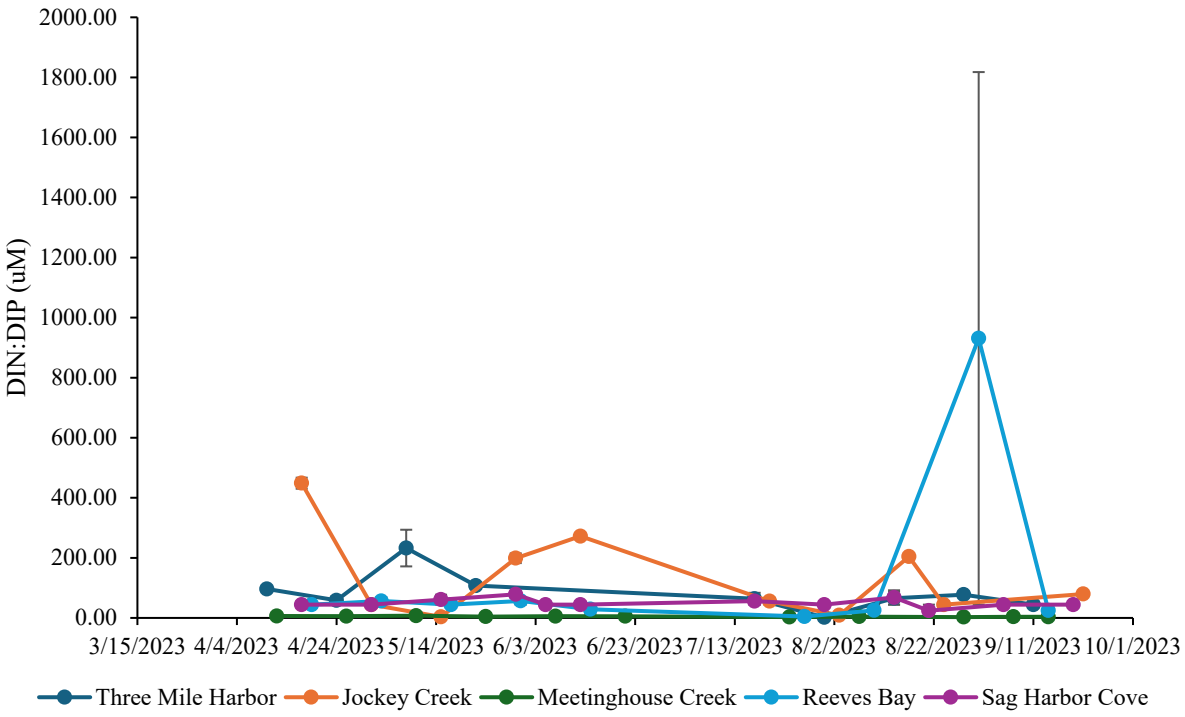



**Figure 8.** 2023 DIN:DIP time series.

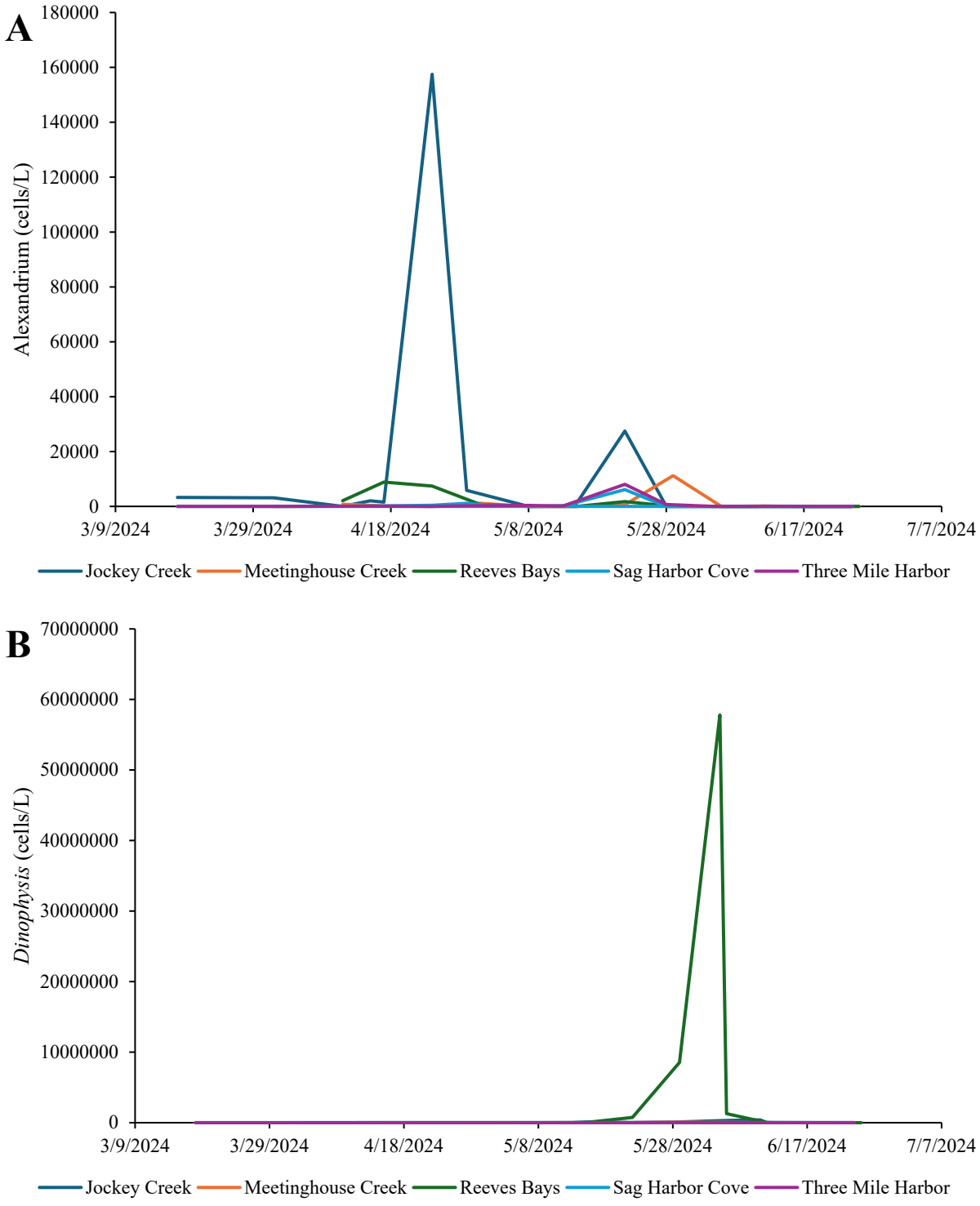



**Figure 9.** 2024 A) *Alexandrium* and B) *Dinophysis* density times series.

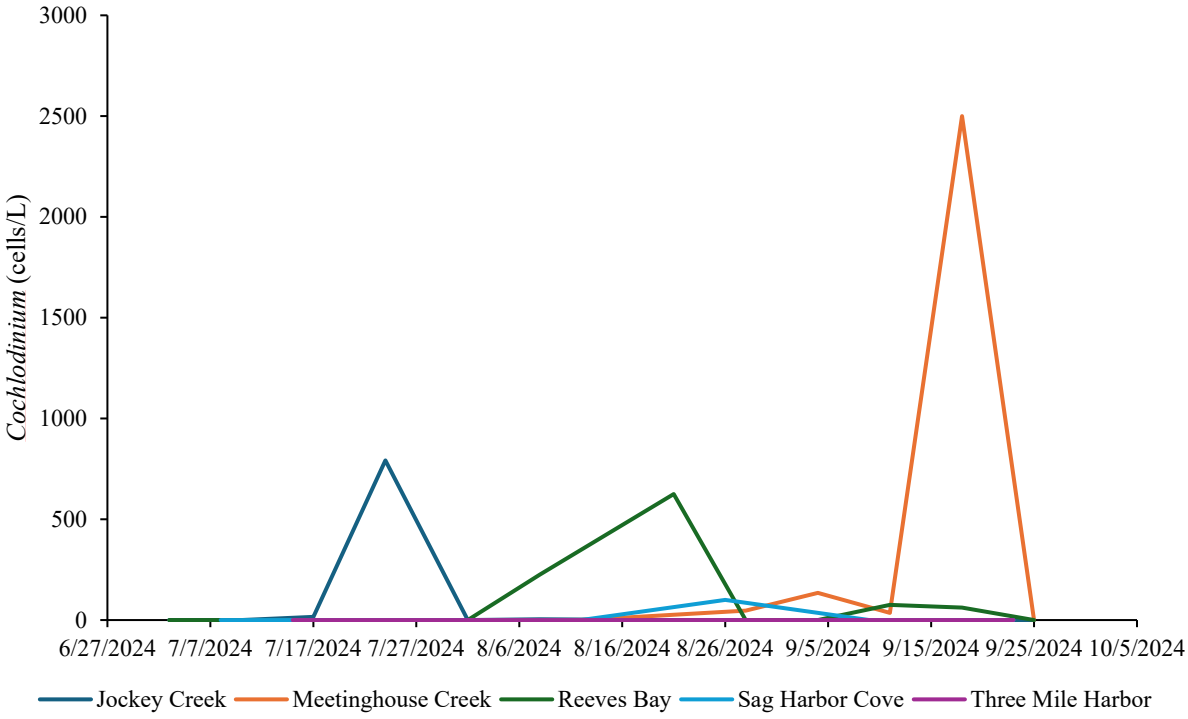



**Figure 10.** 2024 *Cochlodinium* density times series.

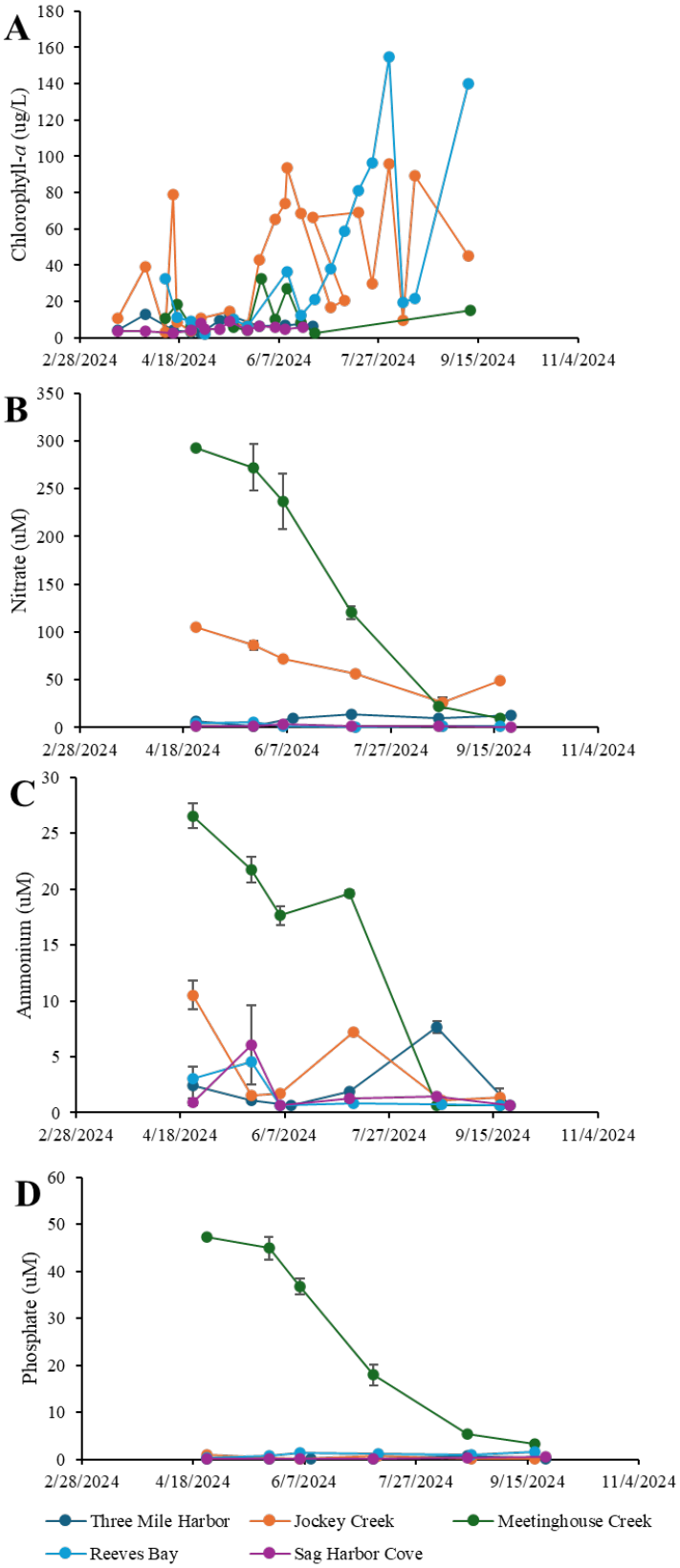



**Figure 11.** 2024 A) Chlorophyll-*a* B) nitrate C) ammonium and D) phosphate times series.

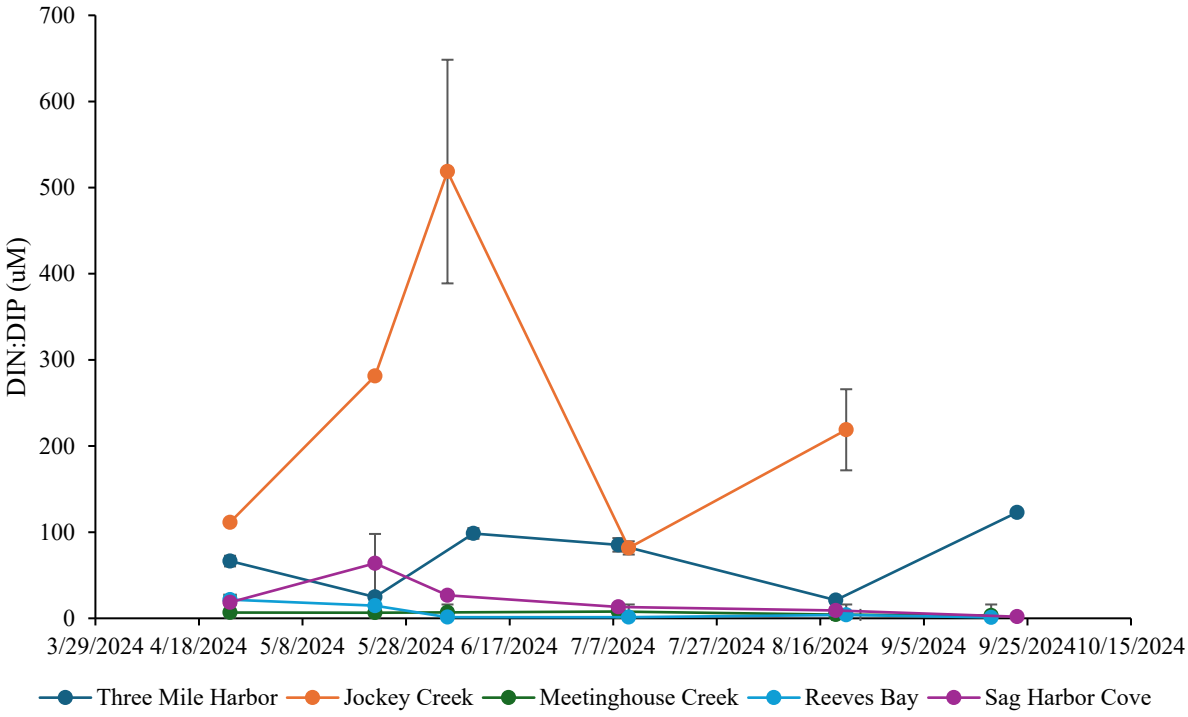



**Figure 12.** 2024 DIN:DIP time series.

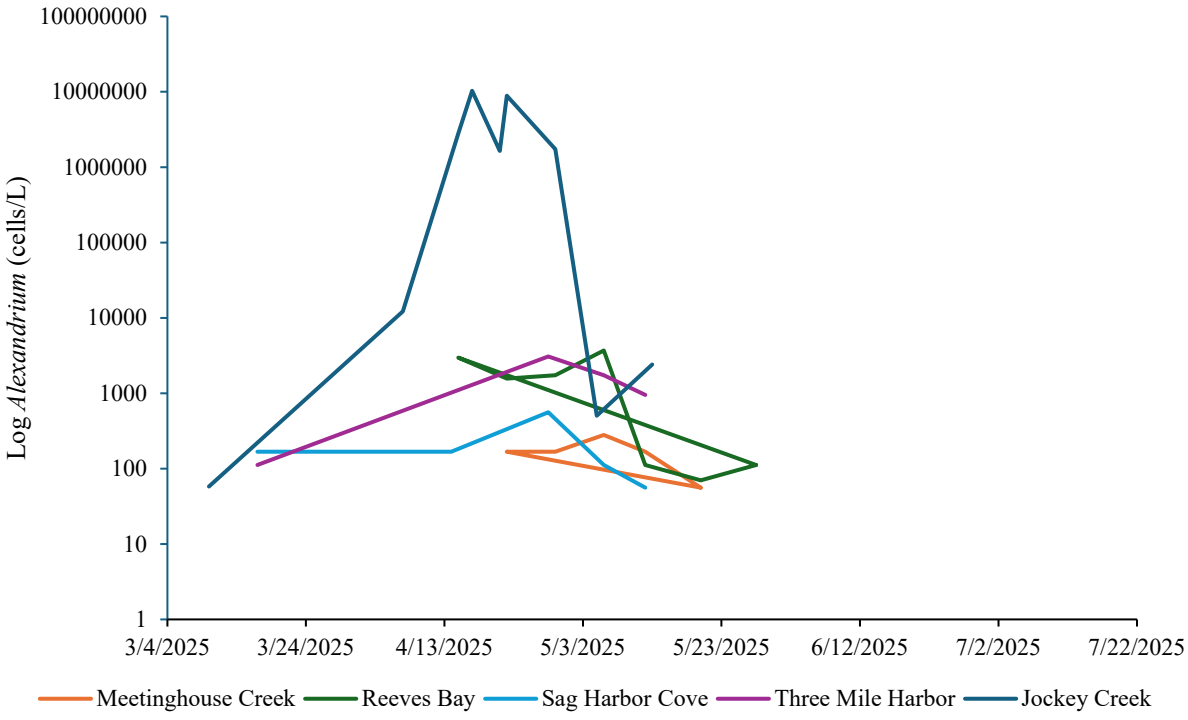



**Figure 13.** 2025 *Alexandrium* density times series.

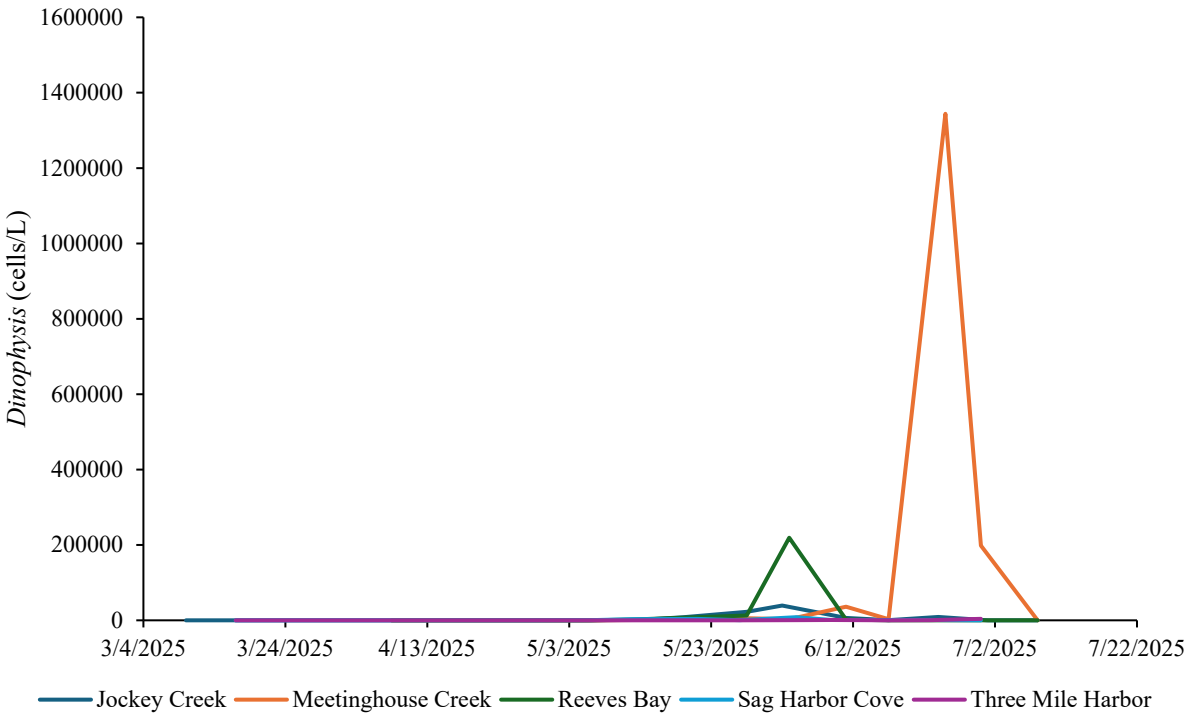



**Figure 14.** 2025 *Dinophysis* density times series.

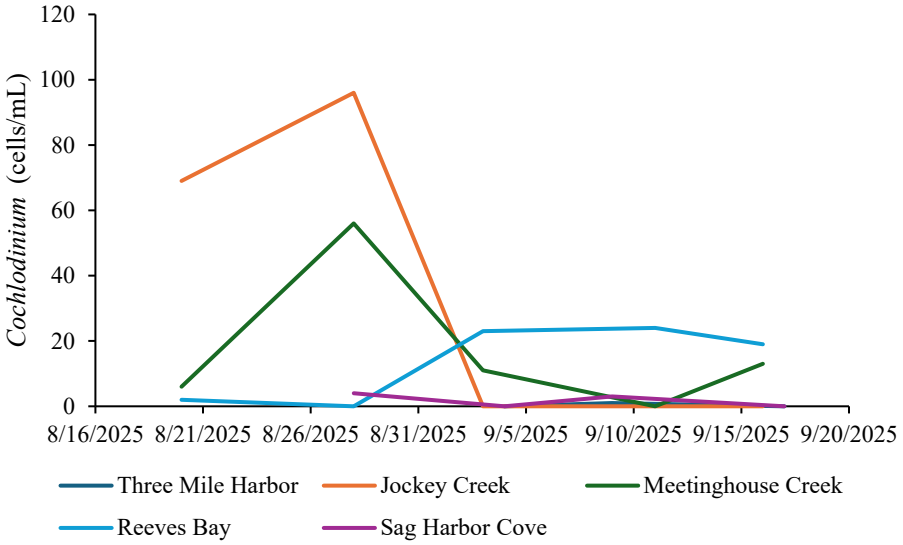



**Figure 15.** 2025 *Cochlodinium* density times series.

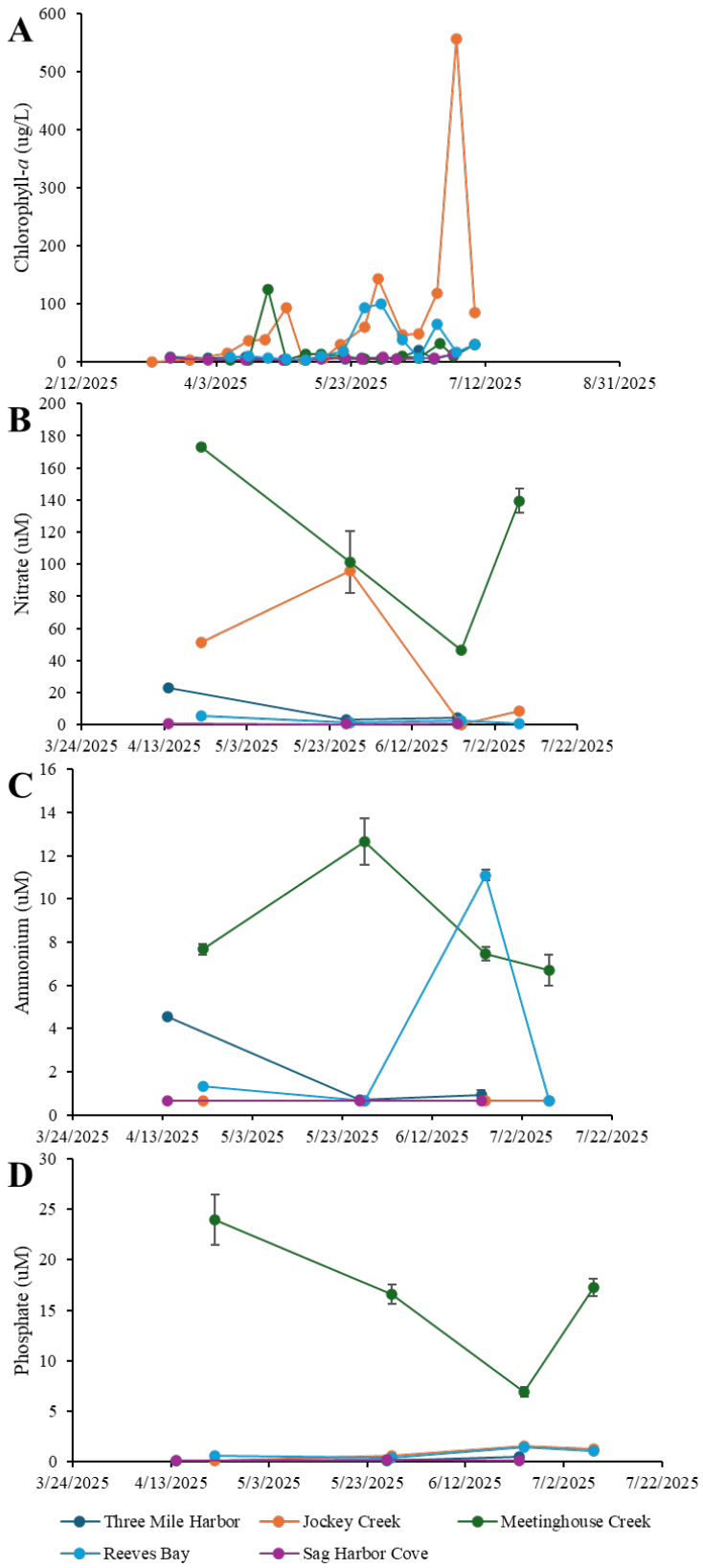



**Figure 16.** 2025 A) Chlorophyll-*a* B) nitrate C) ammonium and D) phosphate times series.

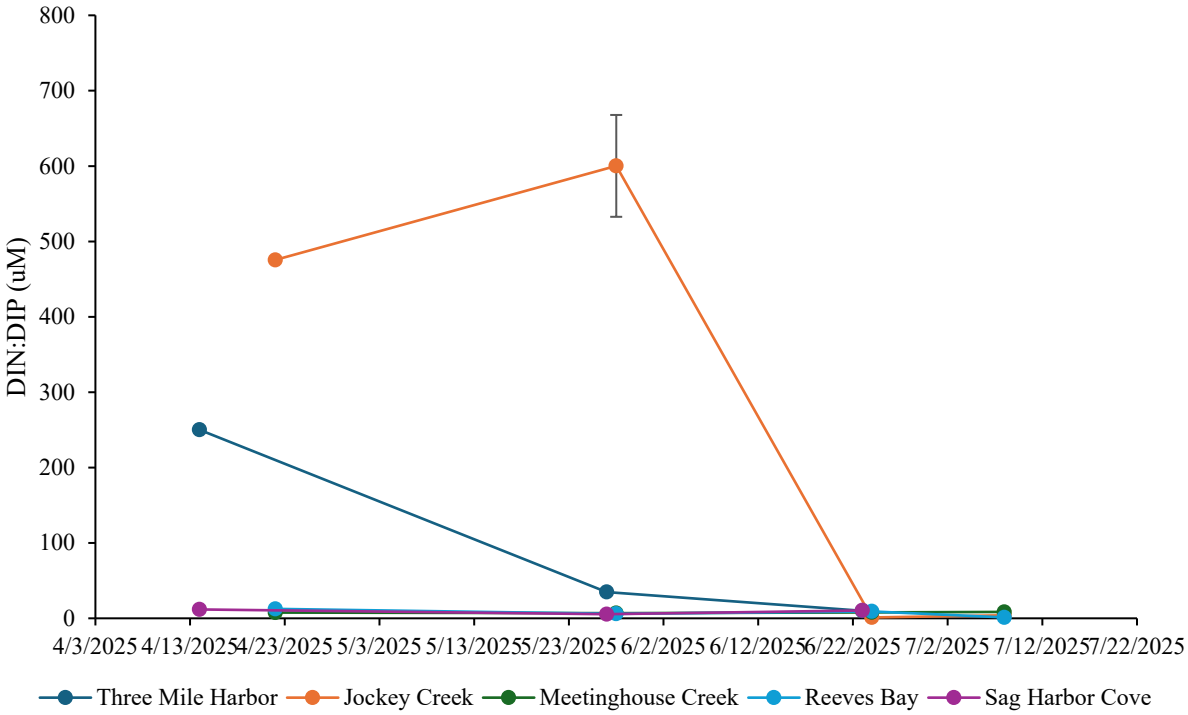



**Figure 17.** 2025 DIN:DIP time series.

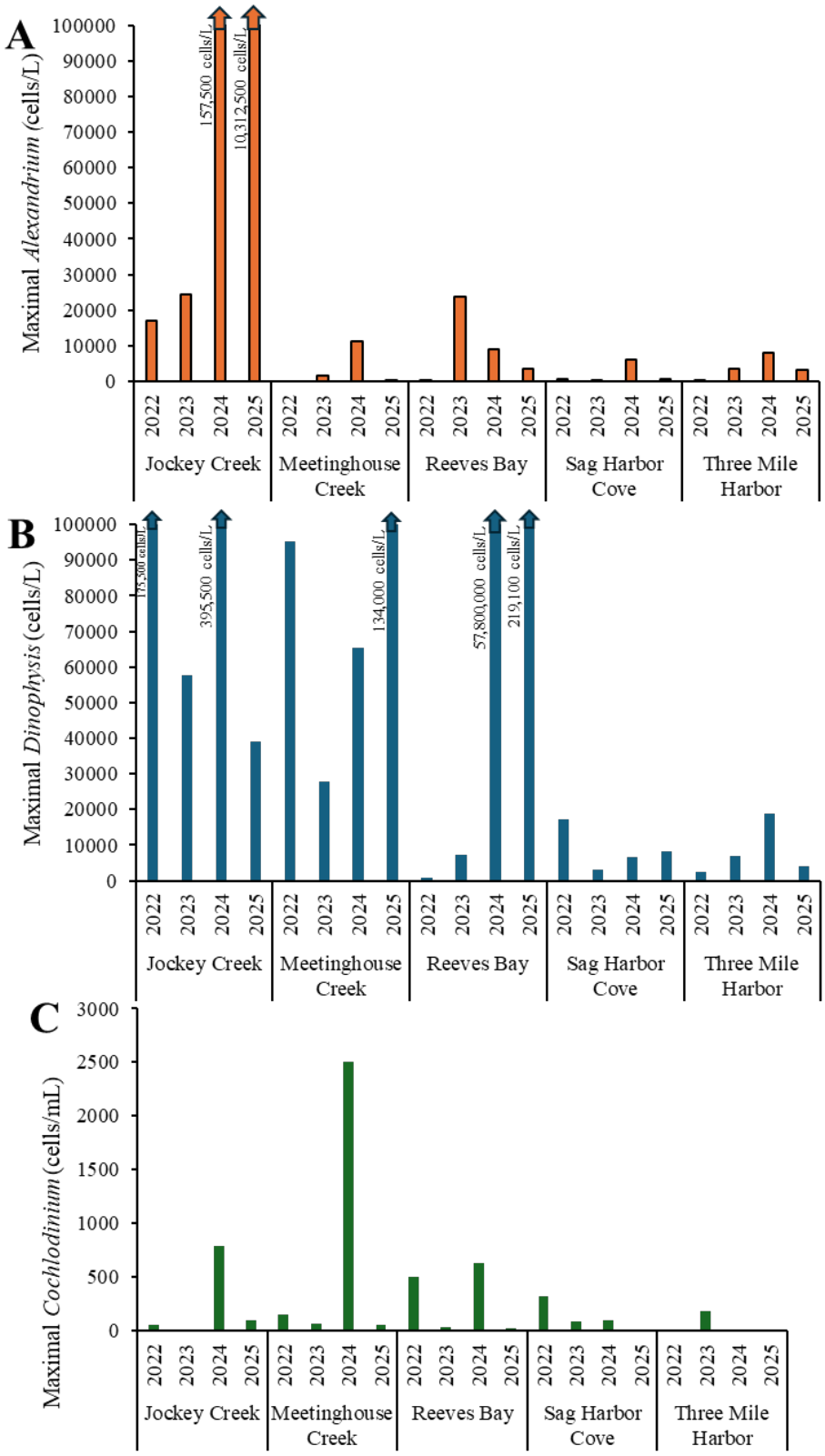



**Figure 18.** 2025 A) *Alexandrium* B) *Dinophysis* C) *Cochlodinium* maximal densities from 2022 to 2025.

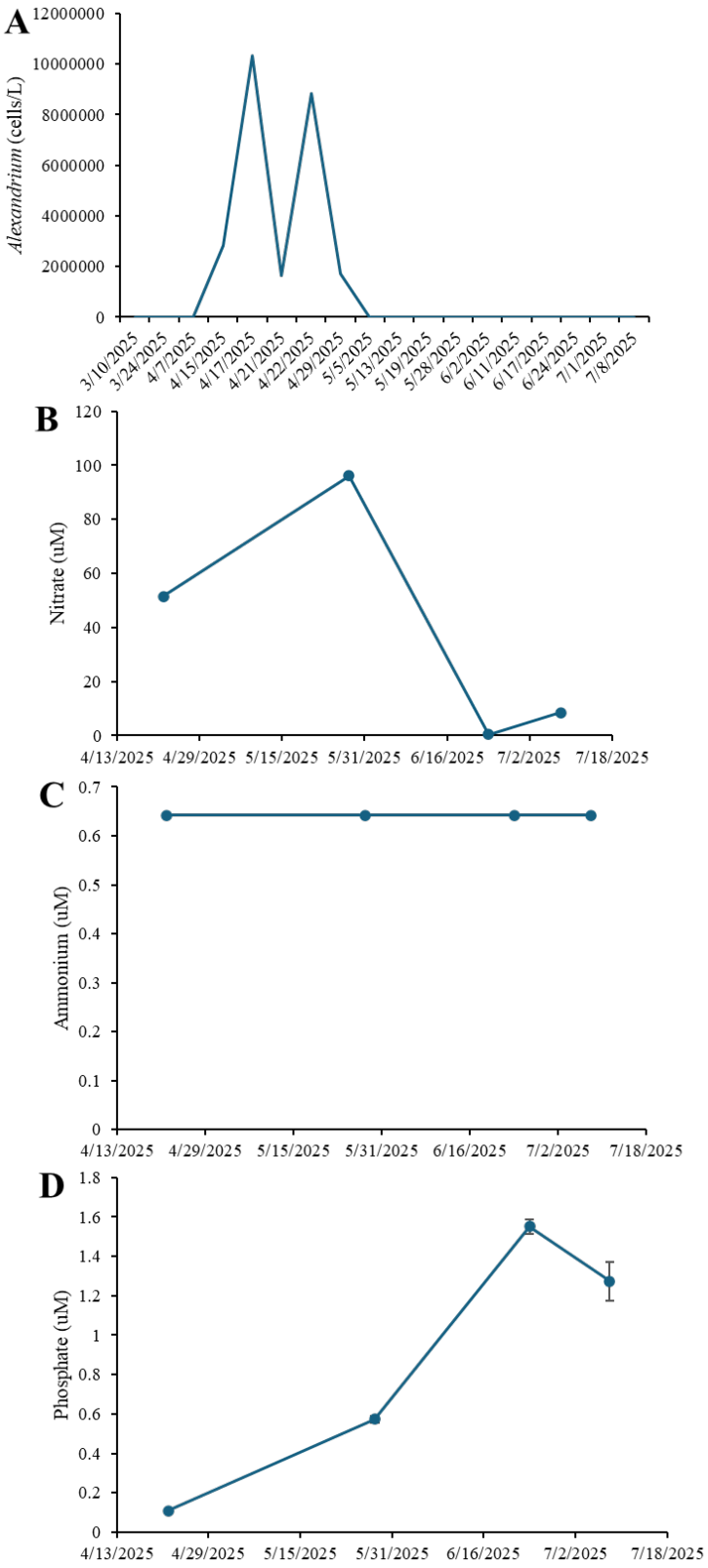



**Figure 19.** 2025 Jockey Creek A) *Alexandrium* B) nitrate C) ammonium D) phosphate times series.

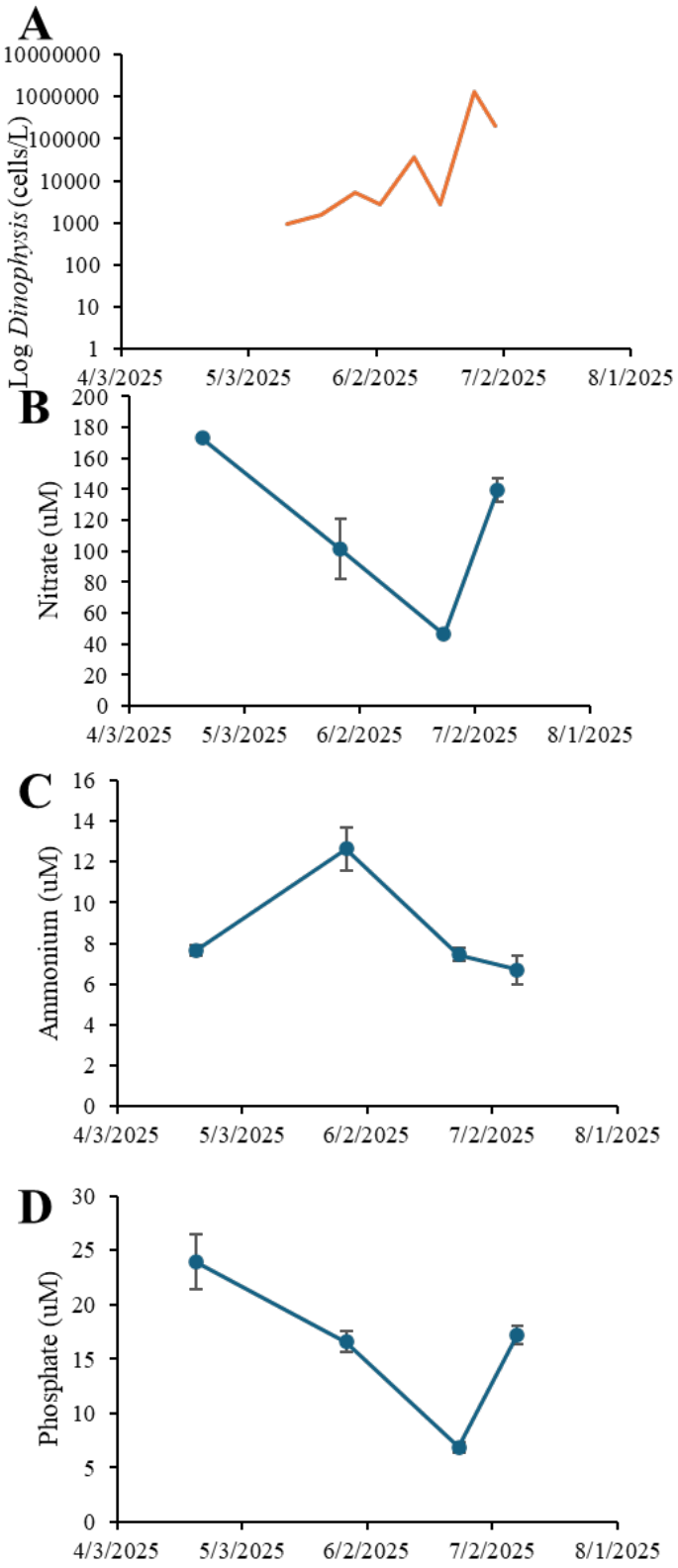



**Figure 20.** 2025 Meetinghouse Creek A) *Dinophysis* B) nitrate C) ammonium D) phosphate times series.

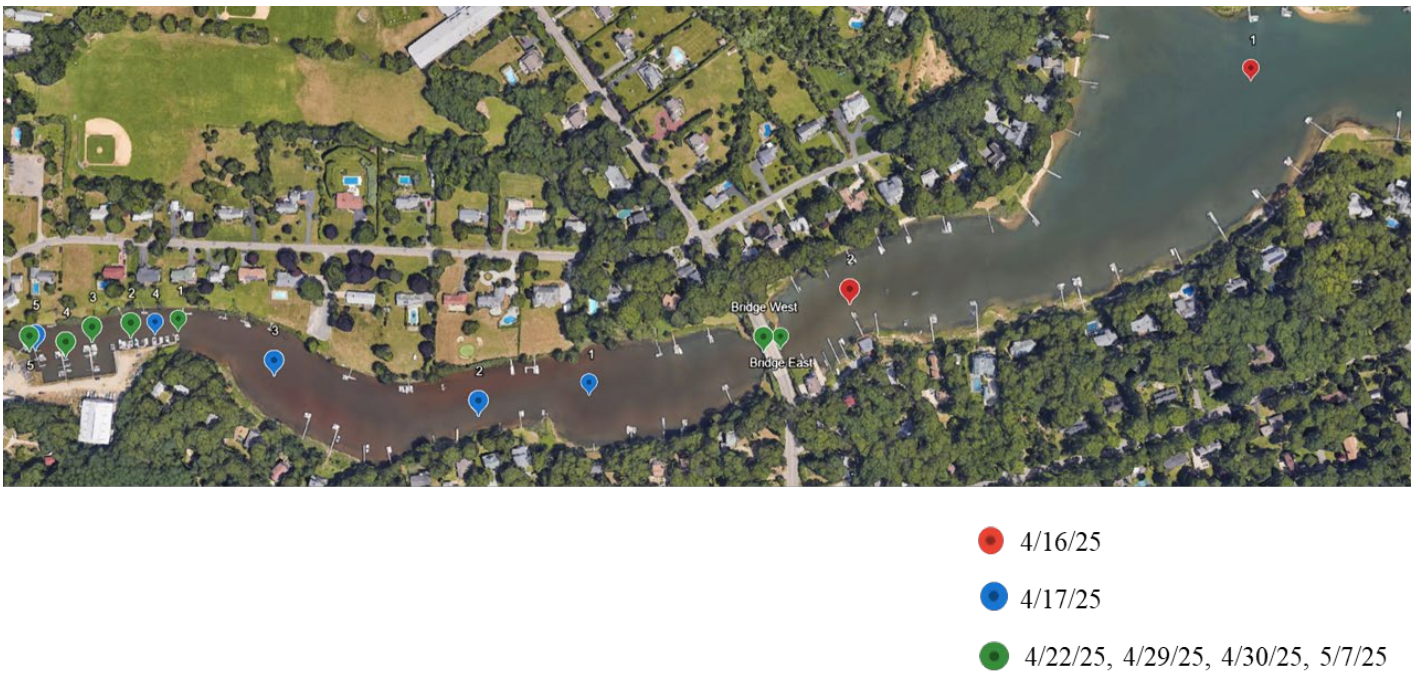



**Figure 21.** 2025 map of spatial surveys at Jockey Creek.

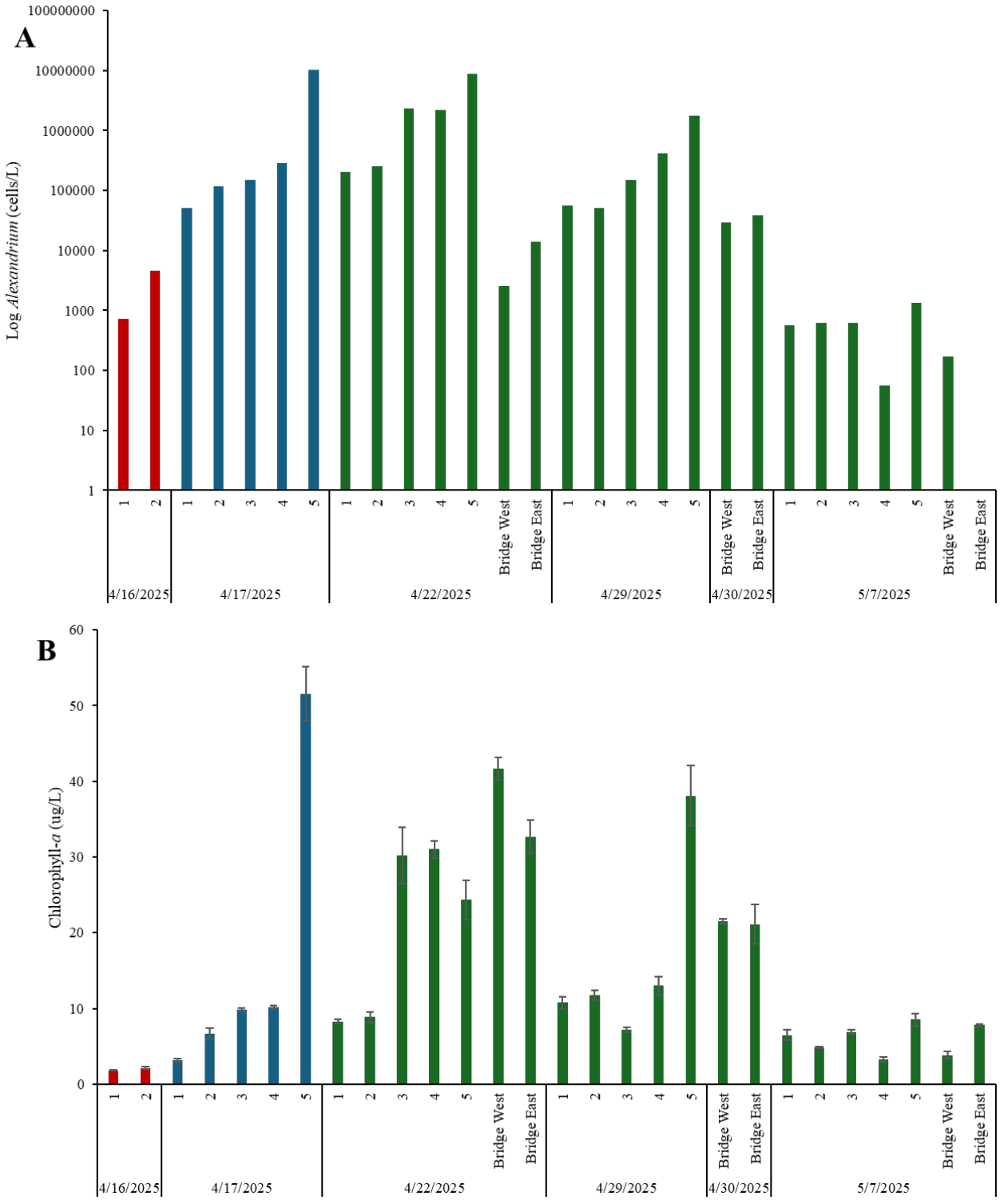



**Figure 22.** 2025 Jockey Creek spatial surveys A) *Alexandrium* and B) chlorophyll-*a densities*. Colors correspond to sites on map in Figure 19.

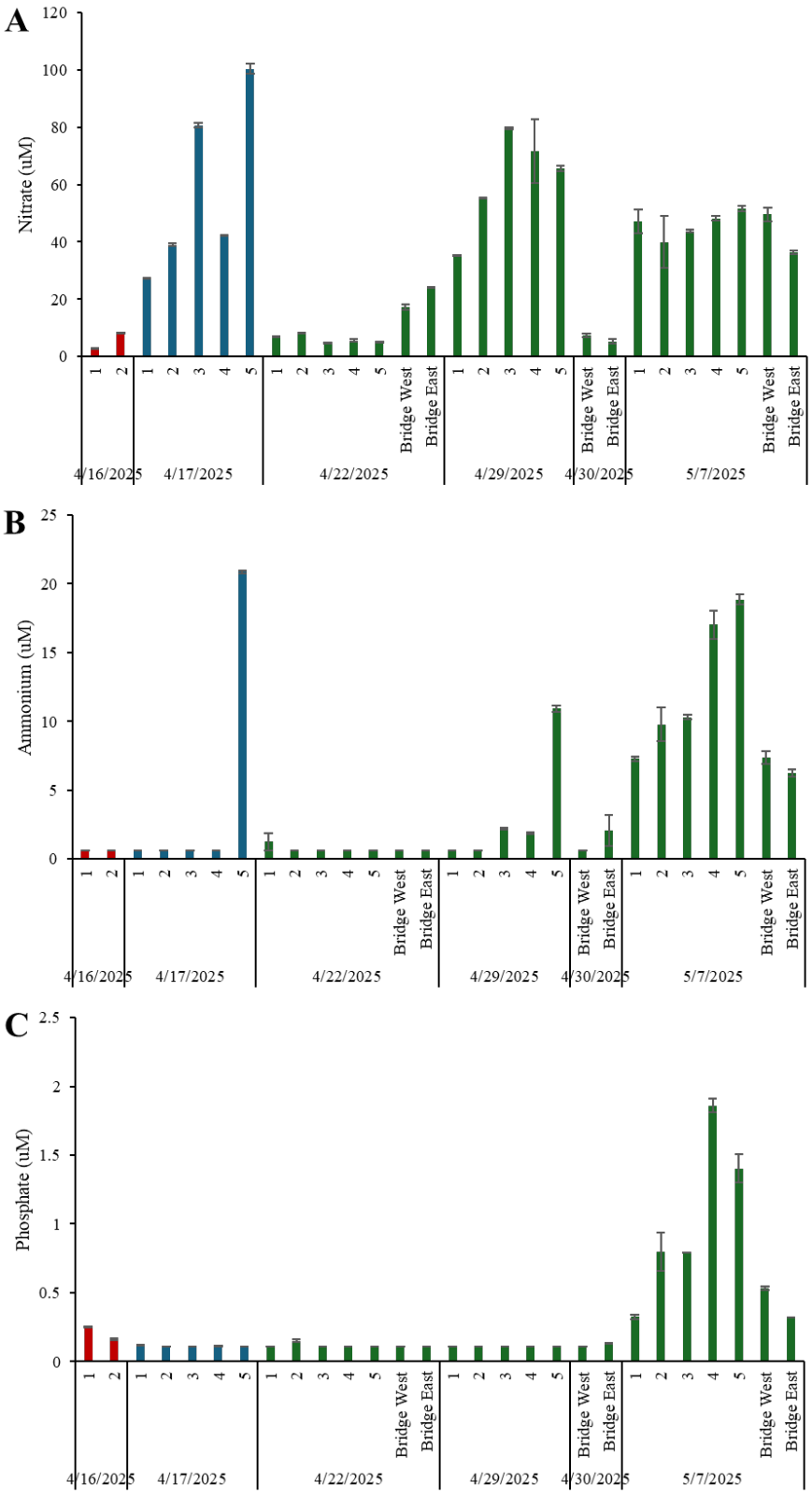



**Figure 23.** 2025 Jockey Creek spatial surveys ammonium concentrations. Colors correspond to sites on map in Figure 19.




**Figure 24.** 2025 Meetinghouse Creek spatial surveys map.

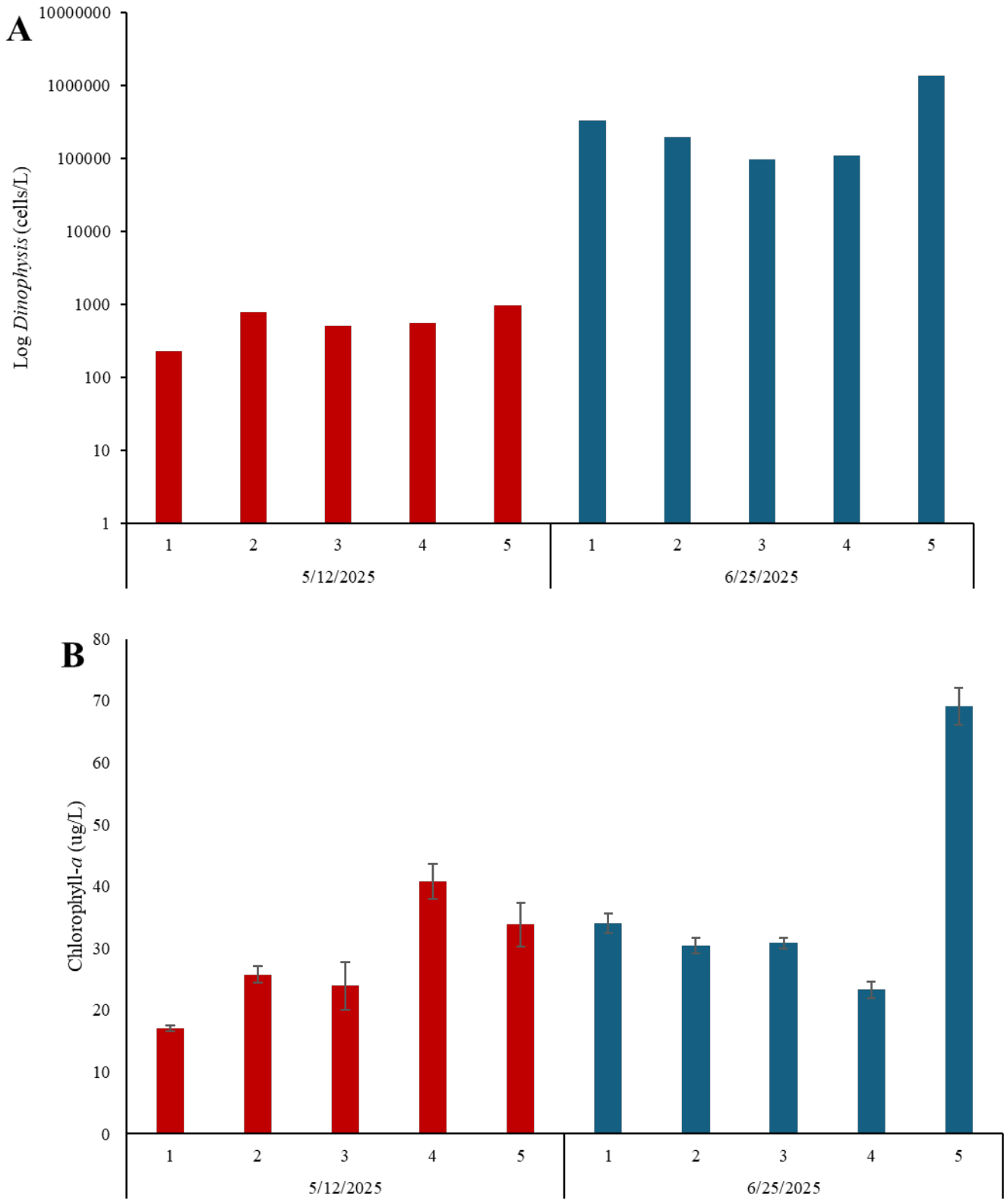



**Figure 25.** 2025 Meetinghouse Creek spatial surveys A) *Dinophysis* densities and B) chlorophyll-*a*. Colors correspond to sites on map in Figure 22.

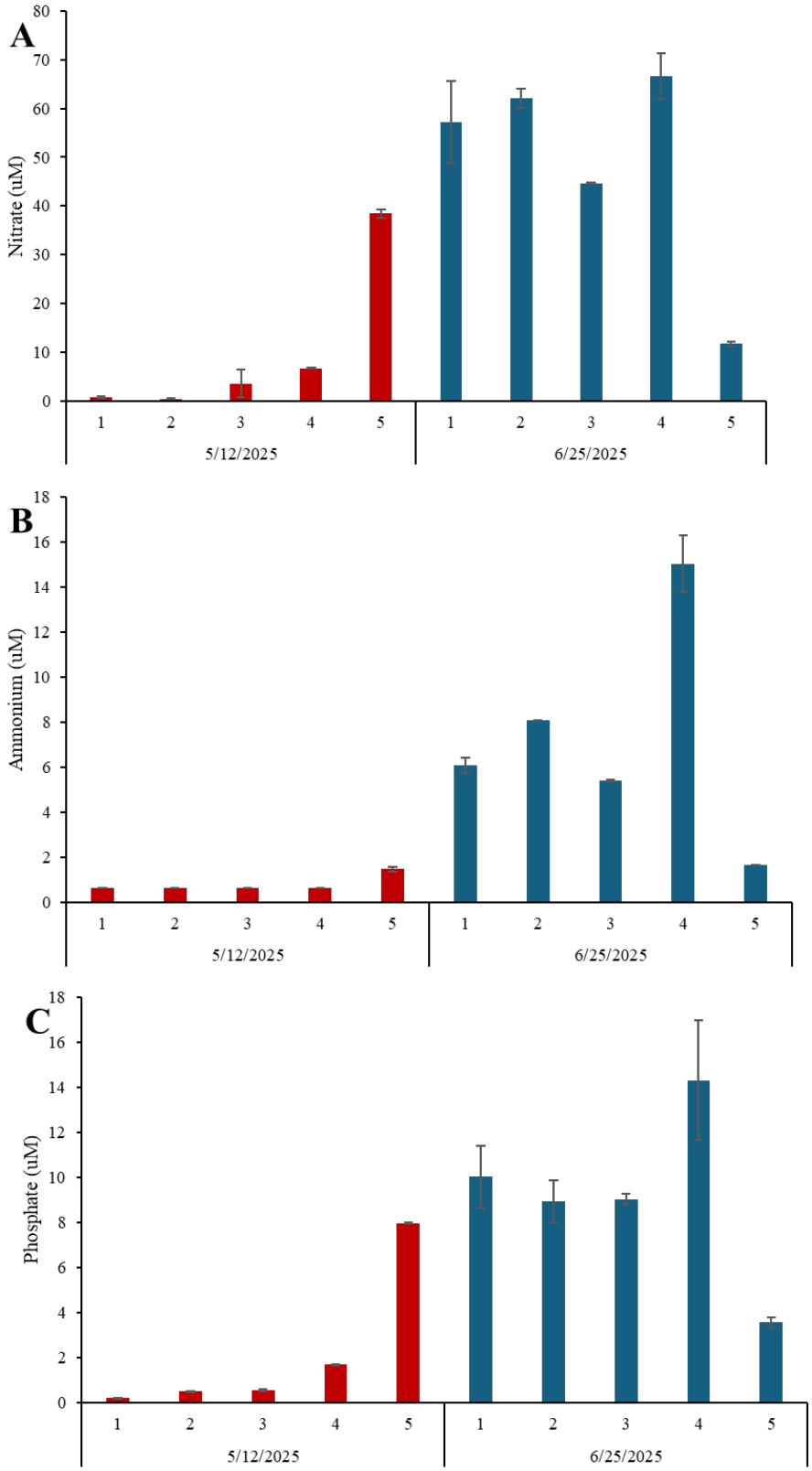



**Figure 26.** 2025 Meetinghouse Creek spatial surveys ammonium concentrations. Colors correspond to sites on map in Figure 22.

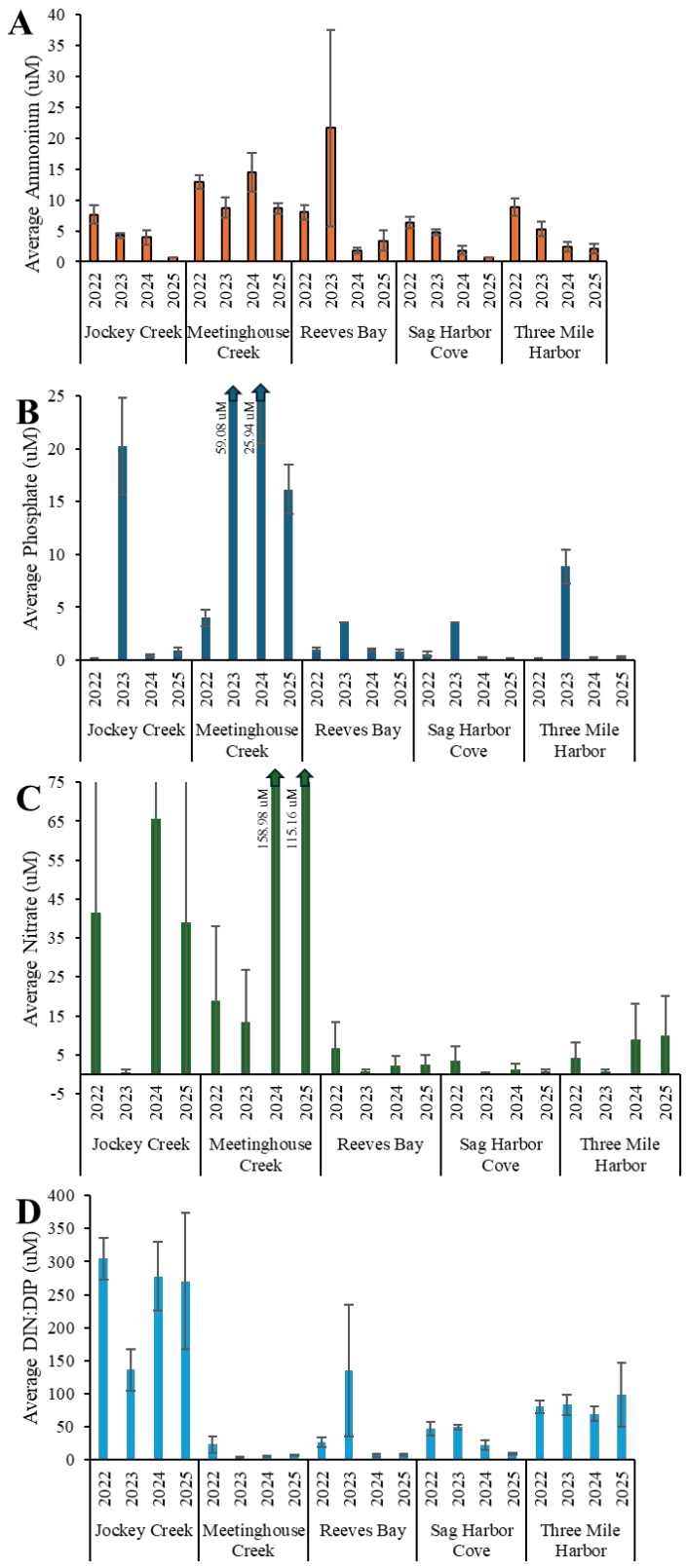



**Figure 27.** Average A) ammonium, B) phosphate, C) nitrate, and D) DIN:DIP from 2022 to 2025.

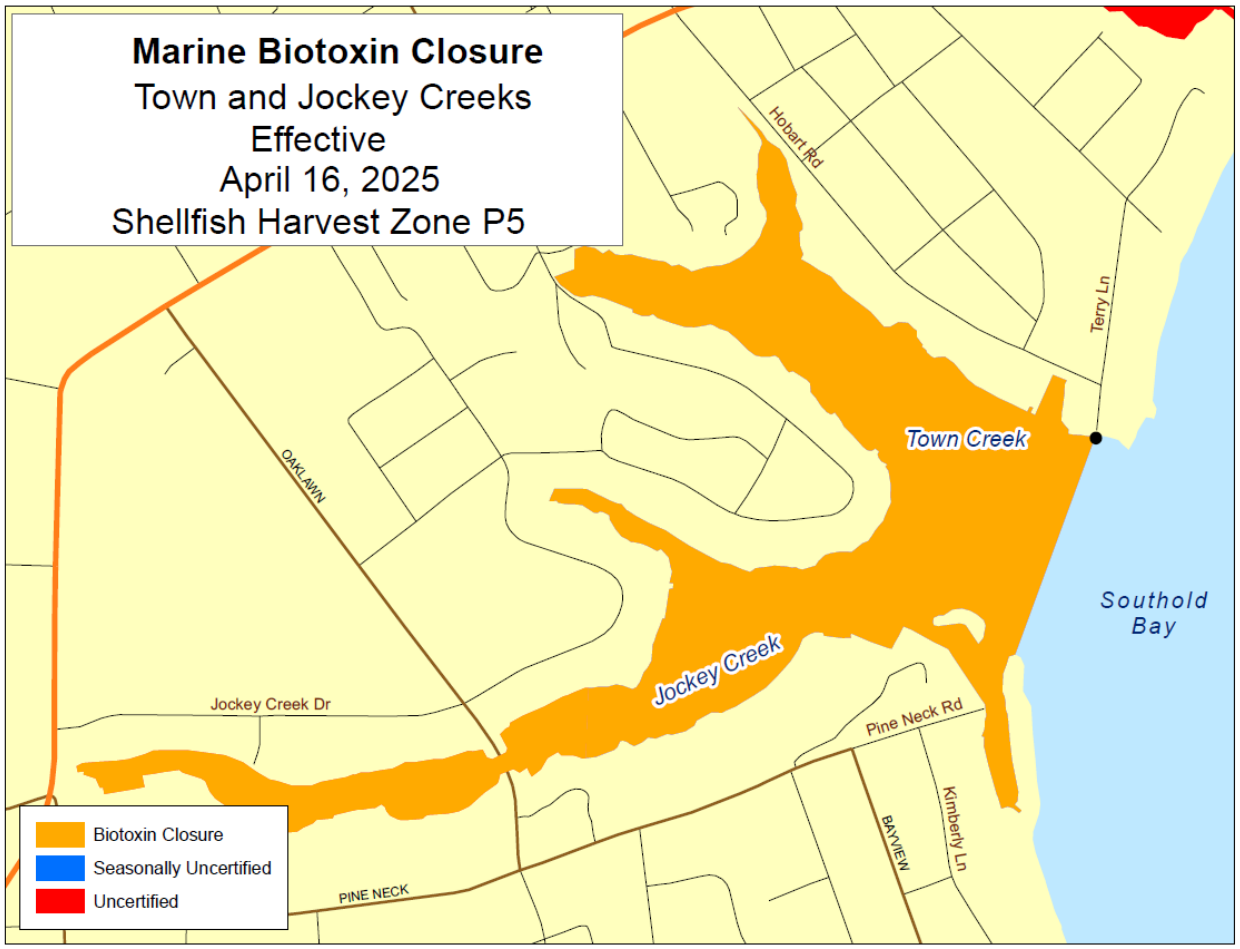



**Figure 28.** PSP closure of Jockey Creek and Town Creek initiated by NYSDEC in April 2025. This closure persisted until August 2025, the longest PSP closure in the history of NYS.

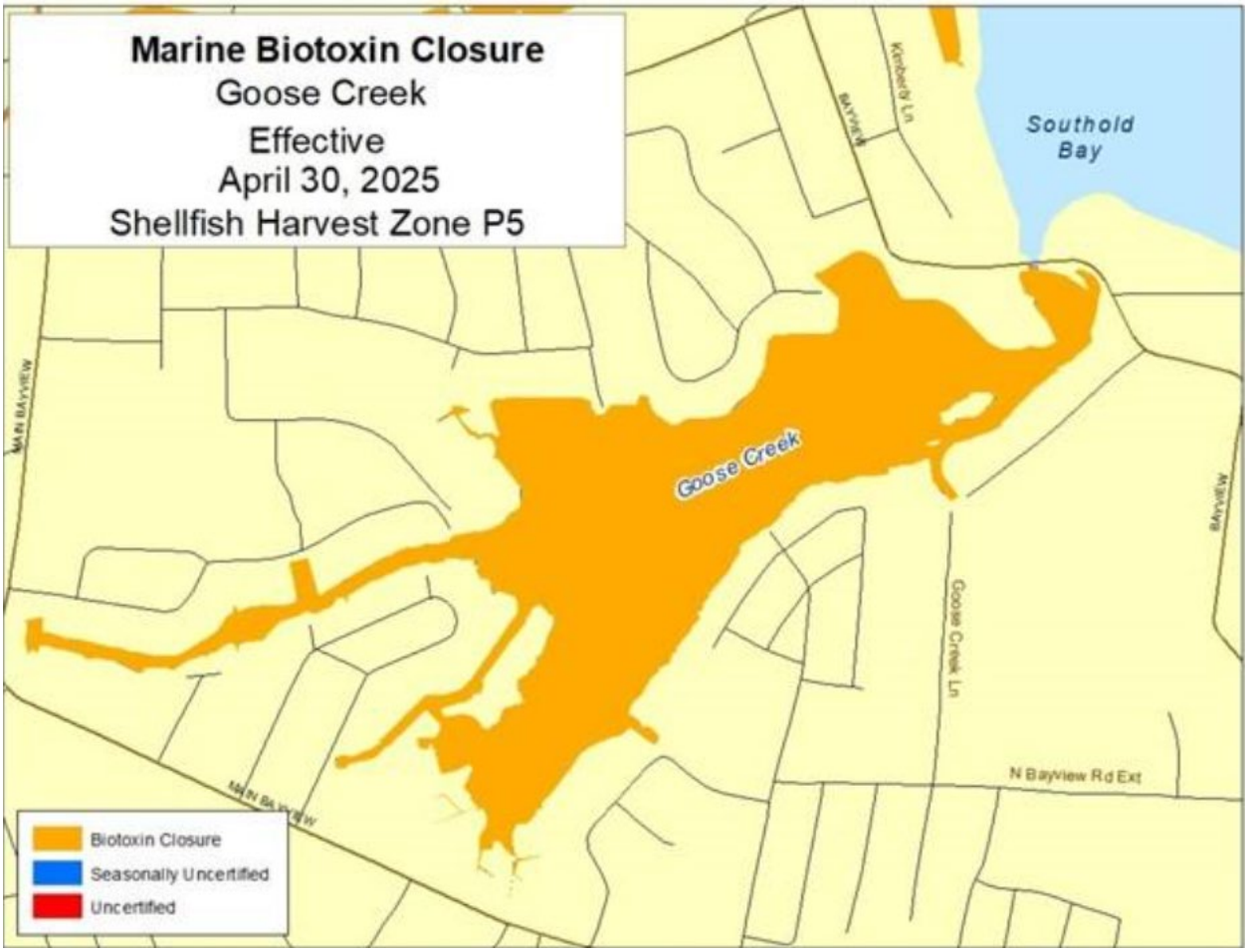



**Figure 29.** PSP closure of Goose Creek initiated bu NYSDEC in April, 2025, Goose Creek is adjacent to Jockey Creek in Southold.

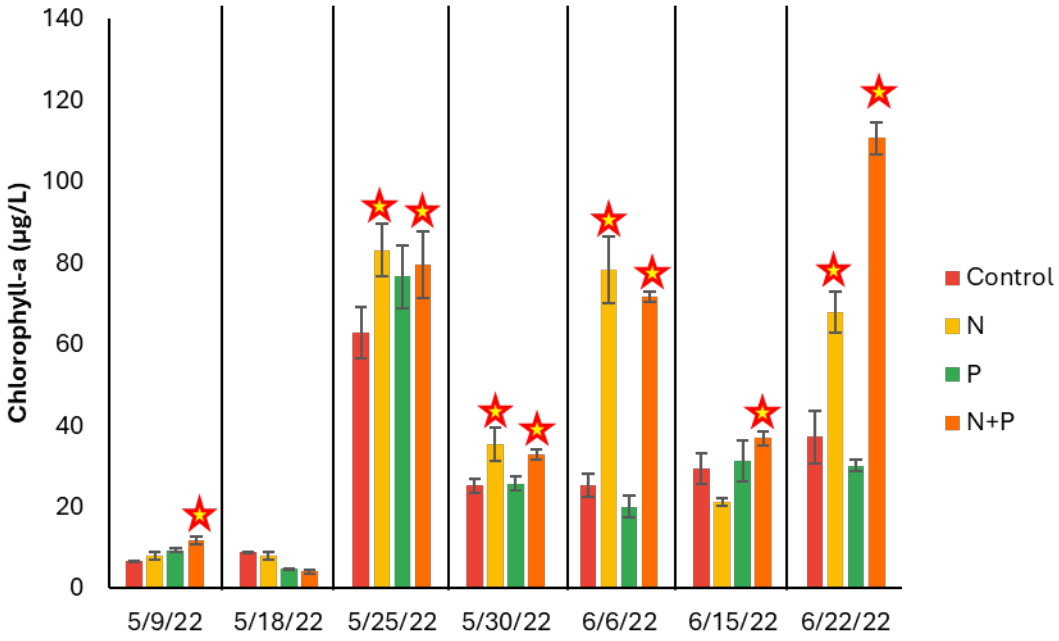



**Figure 30.** 2022 Meetinghouse Creek bloom water nutrient addition experiments. Stars represent significance.

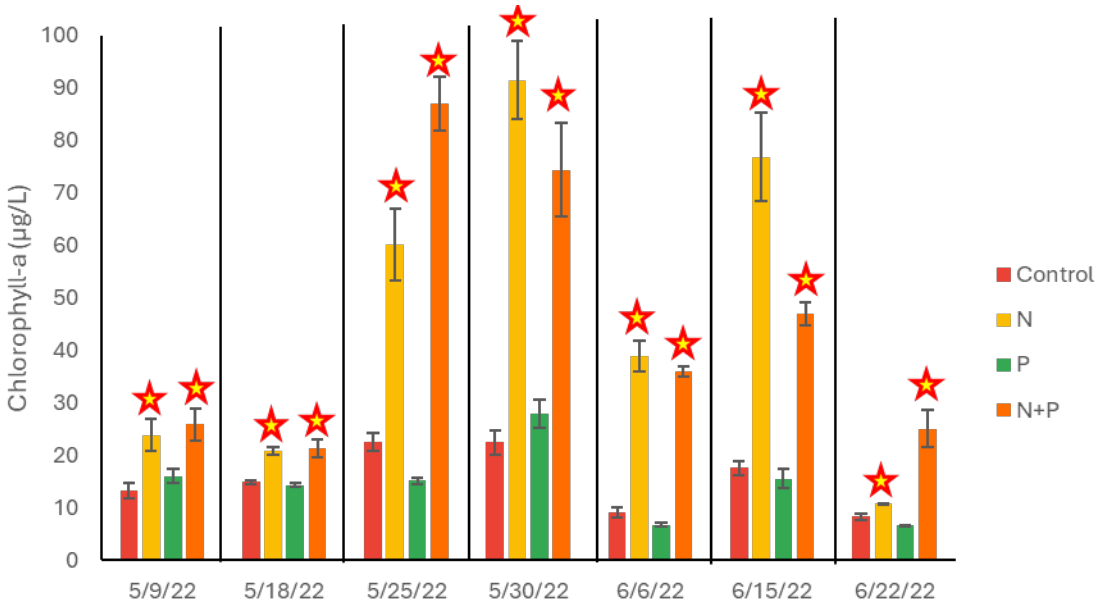



**Figure 31.** 2022 Reeves Bay bloom water nutrient addition experiments. Stars represent significance.

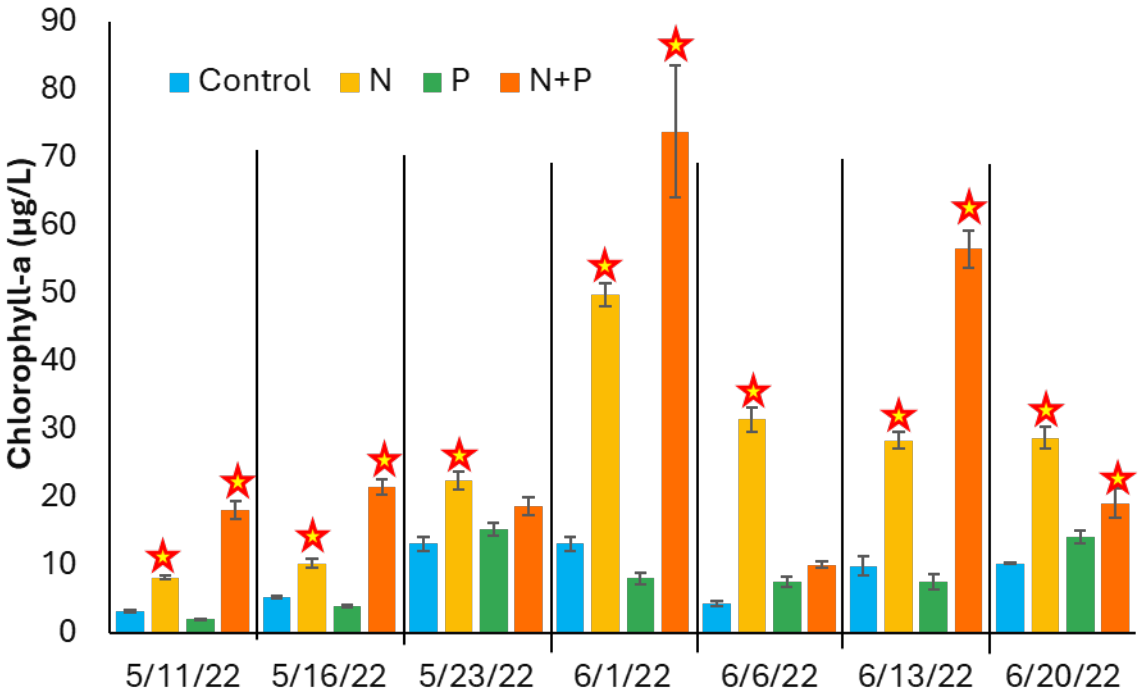



**Figure 32.** 2022 Sag Harbor Cove bloom water nutrient addition experiments. Stars represent significance.

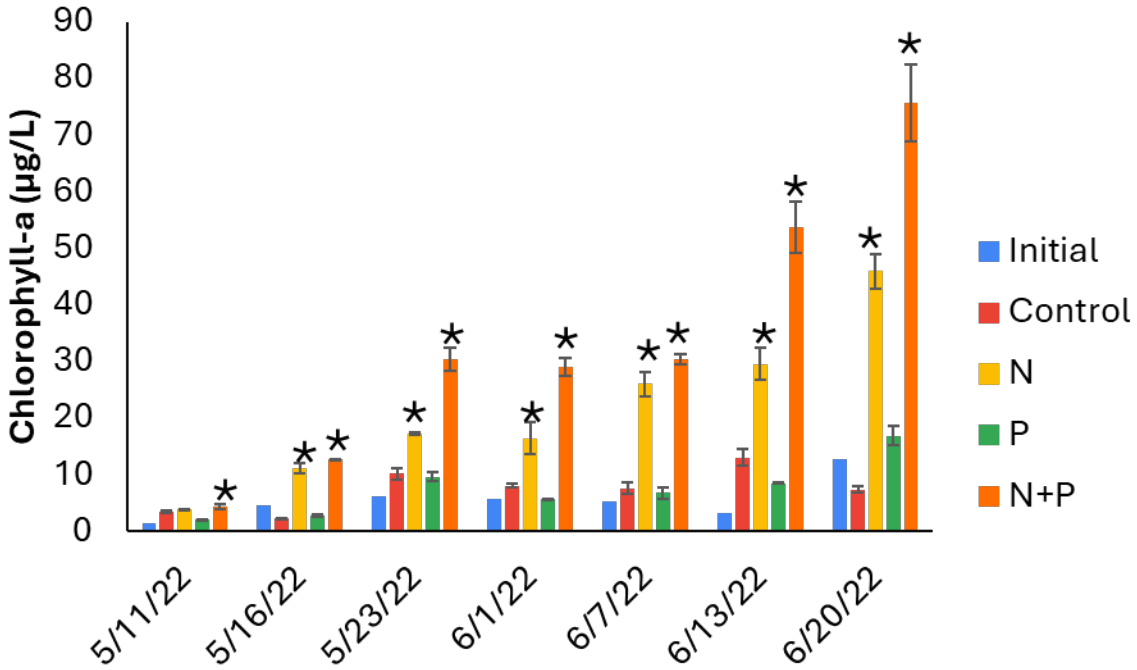



**Figure 33.** 2022 Three Mile Harbor water nutrient addition experiments. Stars represent significance.

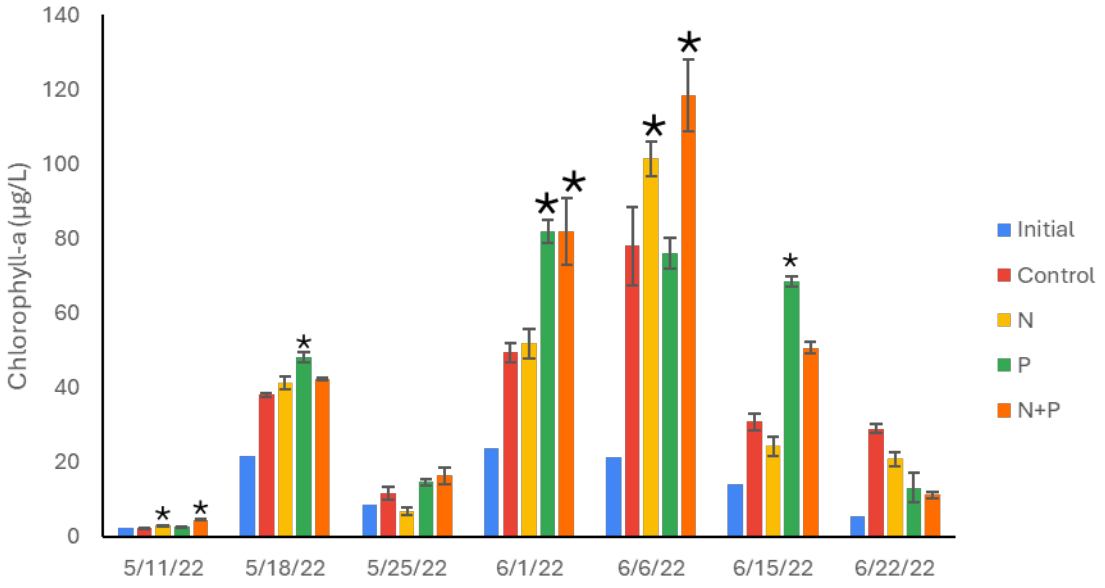



**Figure 34.** 2022 Jockey Creek water nutrient addition experiments. Stars represent significance.

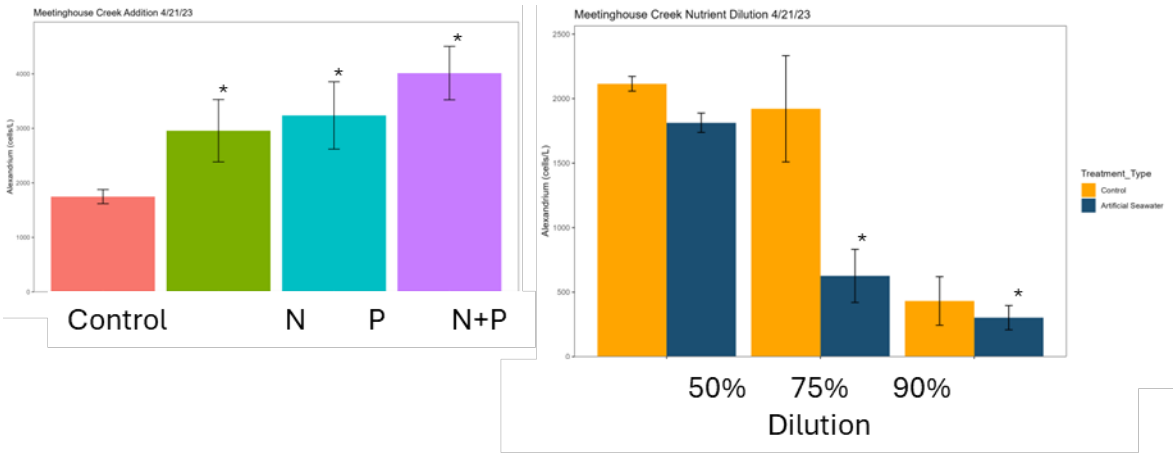



**Figure 35.** 2023 Meetinghouse Creek *Alexandrium* bloom water nutrient addition and dilution experiments. Stars represent significance.

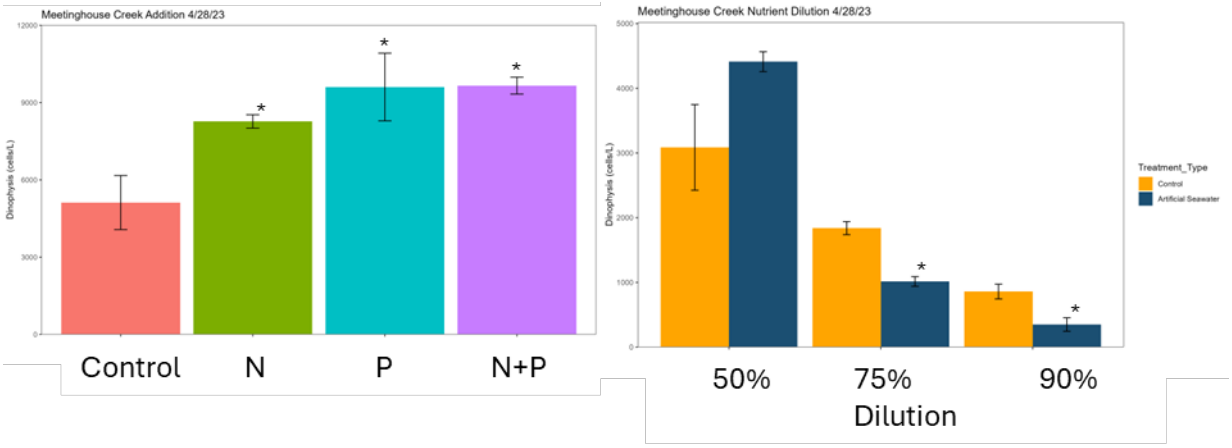



**Figure 36.** 2023 Meetinghouse Creek *Dinophysis* bloom water nutrient addition and dilution experiments. Stars represent significance.

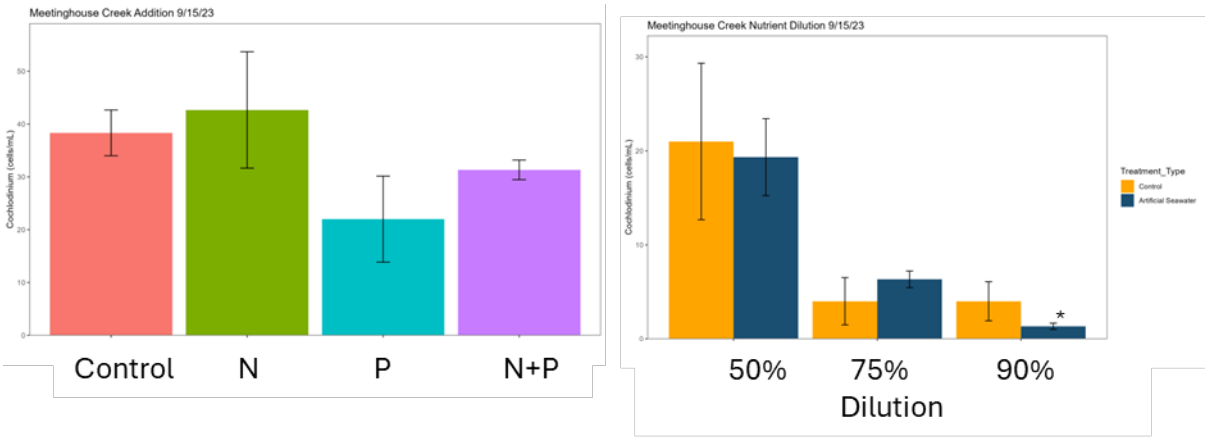



**Figure 37.** 2023 Meetinghouse Creek *Cochlodinium* bloom water nutrient addition and dilution experiments. Stars represent significance.

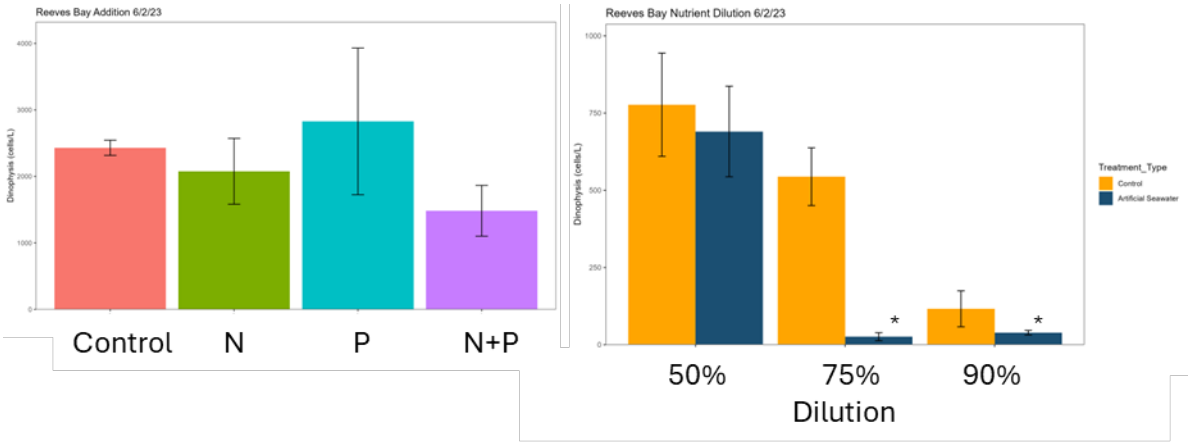



**Figure 38.** 2023 Reeves Bay *Dinophysis* bloom water nutrient addition and dilution experiments. Stars represent significance.

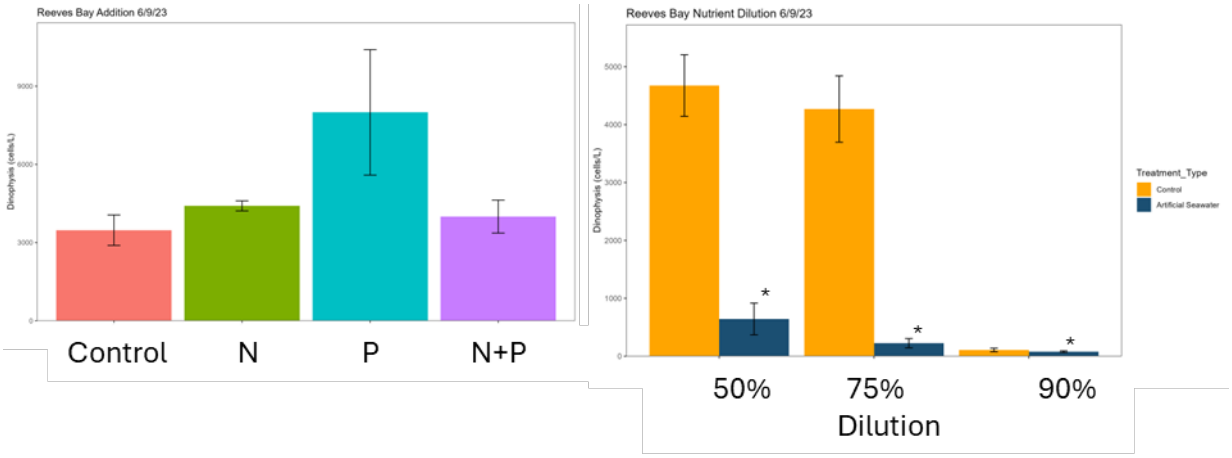



**Figure 39.** 2023 Reeves Bay *Dinophysis* bloom water nutrient addition and dilution experiments. Stars represent significance.

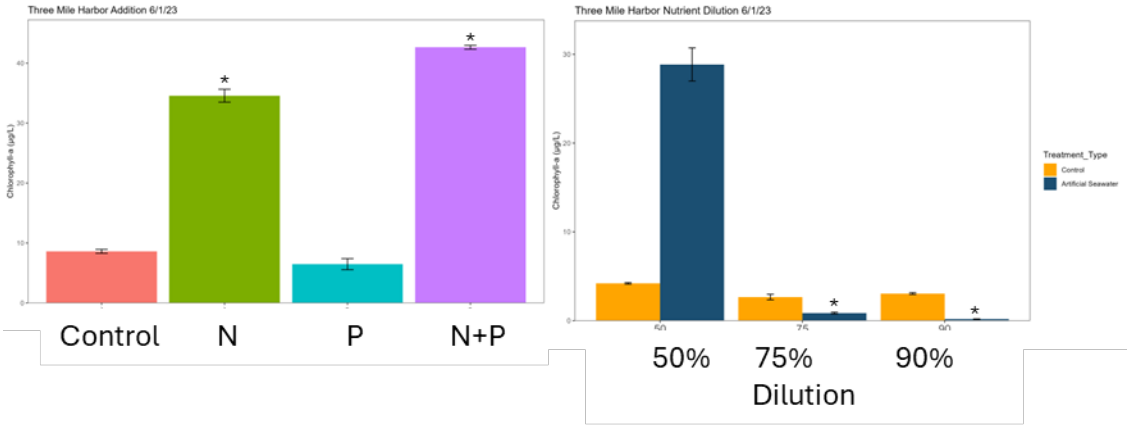



**Figure 40.** 2023 Three Mile Harbor *Dinophysis* bloom water nutrient addition and dilution experiments. Stars represent significance.

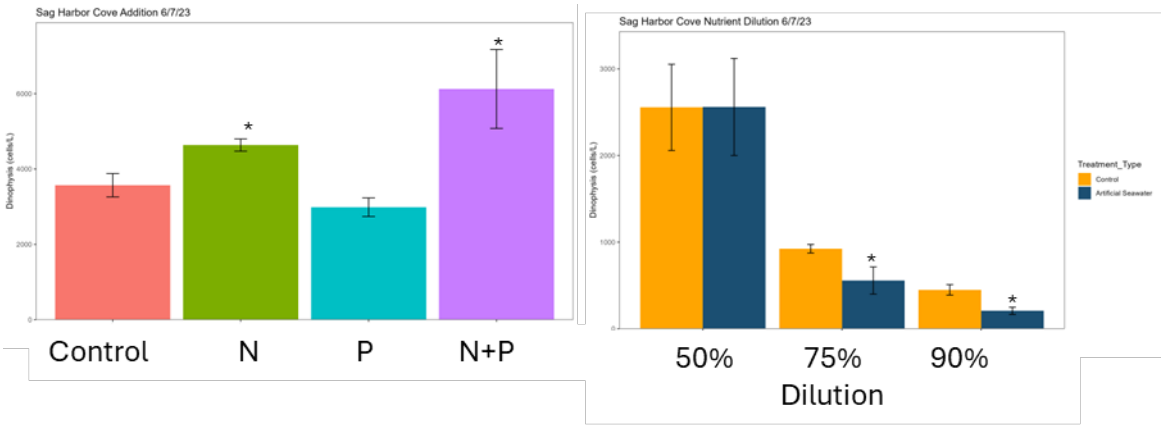



**Figure 41.** 2023 Sag Harbor Cove *Dinophysis* bloom water nutrient addition and dilution experiments. Stars represent significance.

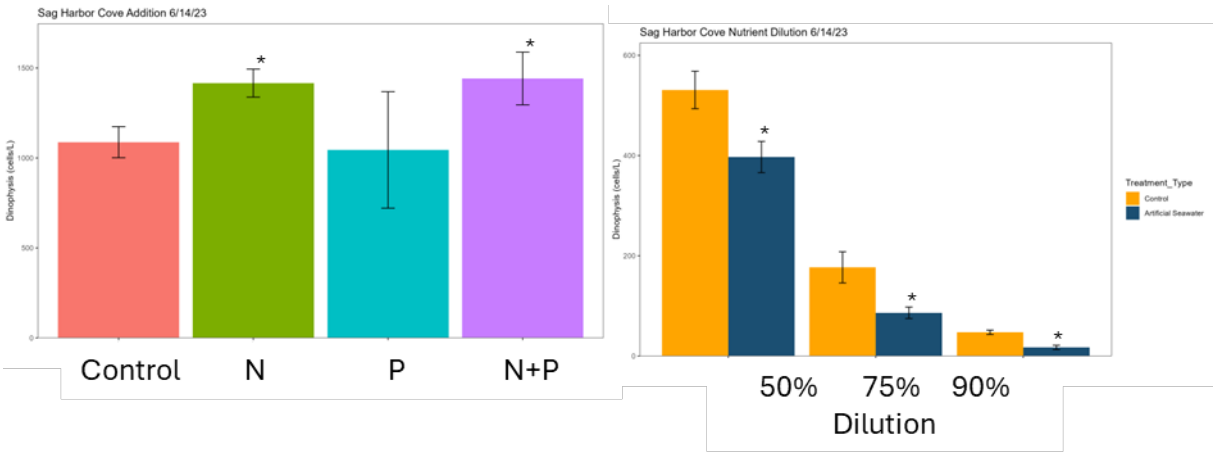



**Figure 42.** 2023 Sag Harbor Cove *Dinophysis* bloom water nutrient addition and dilution experiments. Stars represent significance.

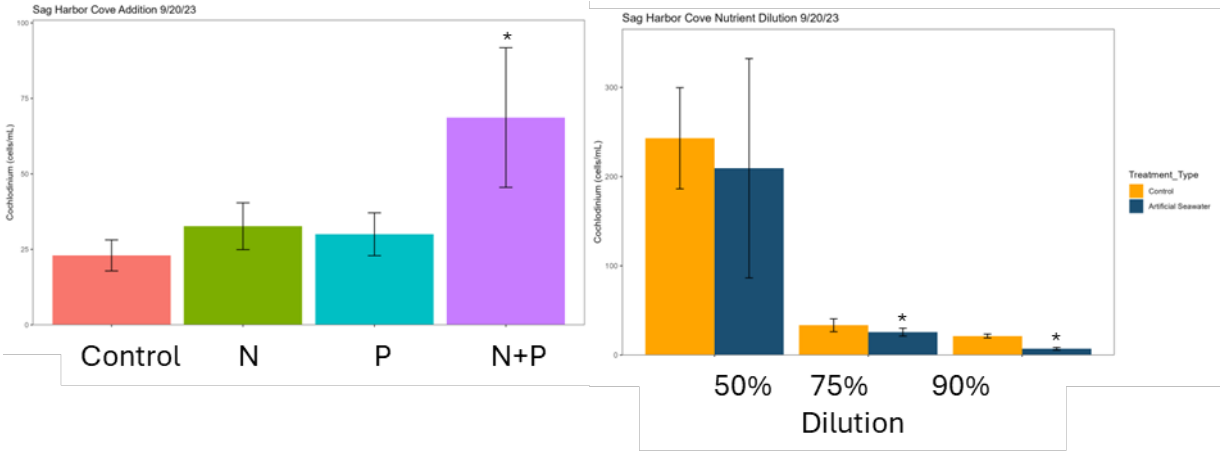



**Figure 43.** 2023 Sag Harbor Cove *Cochlodinium* bloom water nutrient addition and dilution experiments. Stars represent significance.

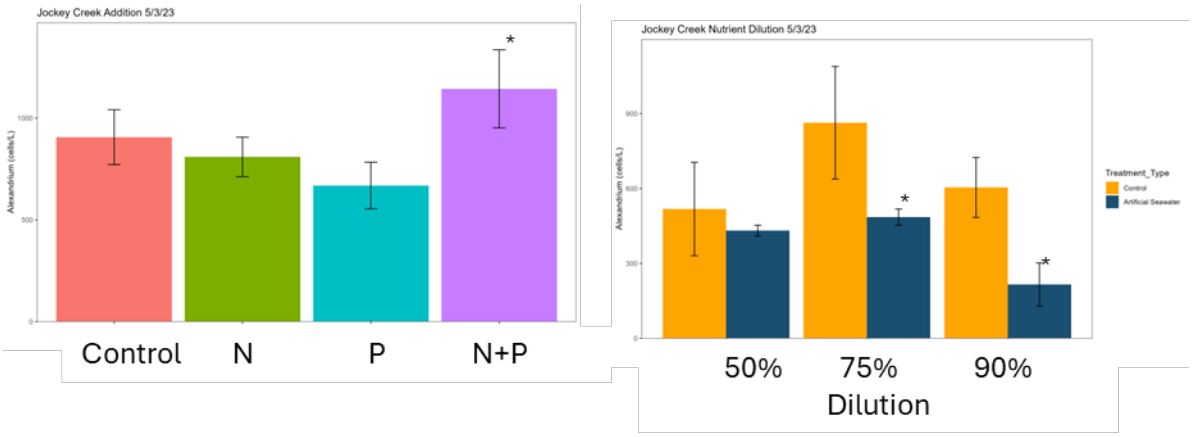



**Figure 44.** 2023 Jockey Creek *Alexandrium* bloom water nutrient addition and dilution experiments. Stars represent significance.

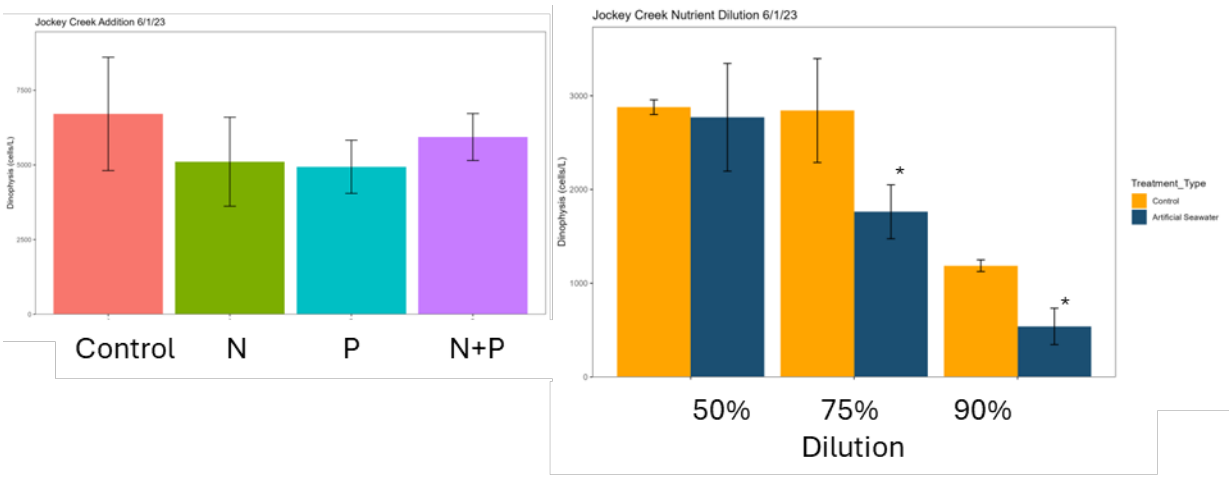



**Figure 45.** 2023 Jockey Creek *Alexandrium* bloom water nutrient addition and dilution experiments. Stars represent significance.

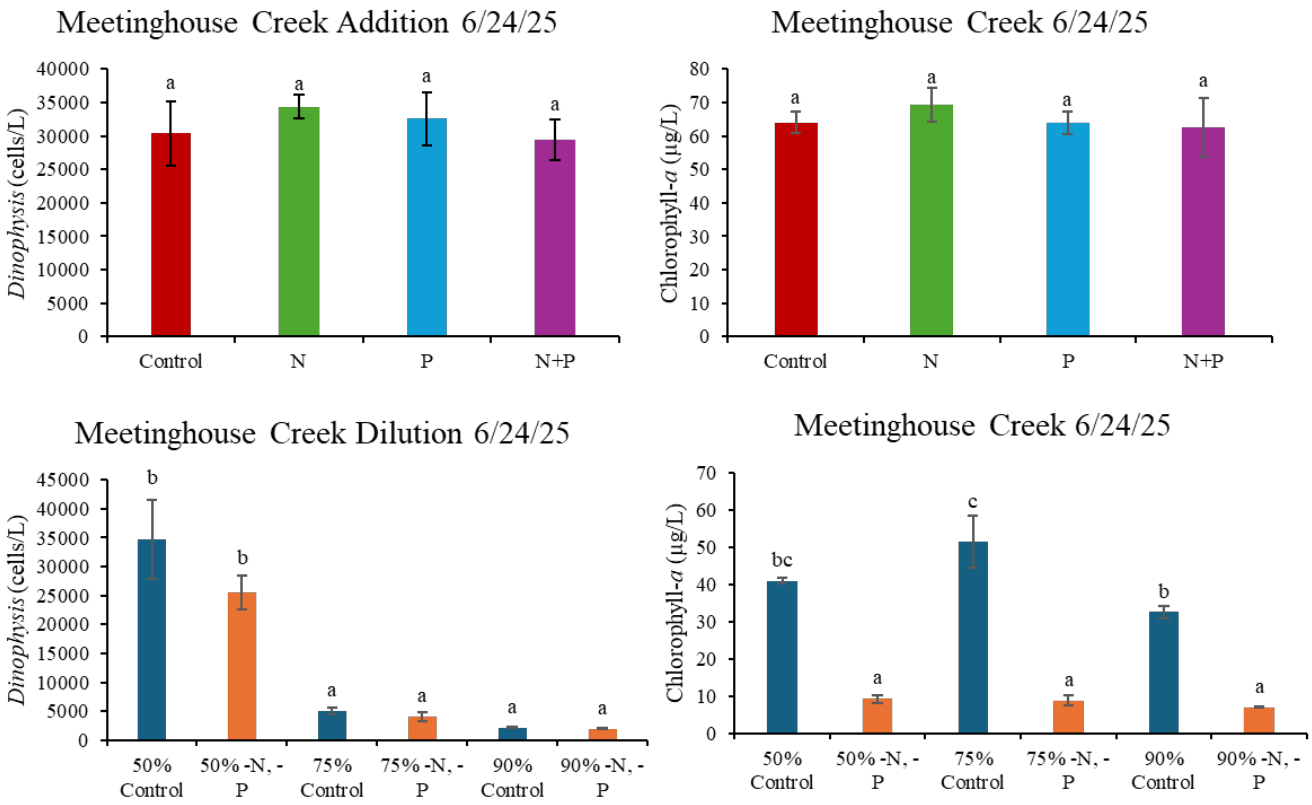



**Figure 46.** 2025 Meetinghouse Creek *Dinophysis* bloom water nutrient addition and dilution experiments.

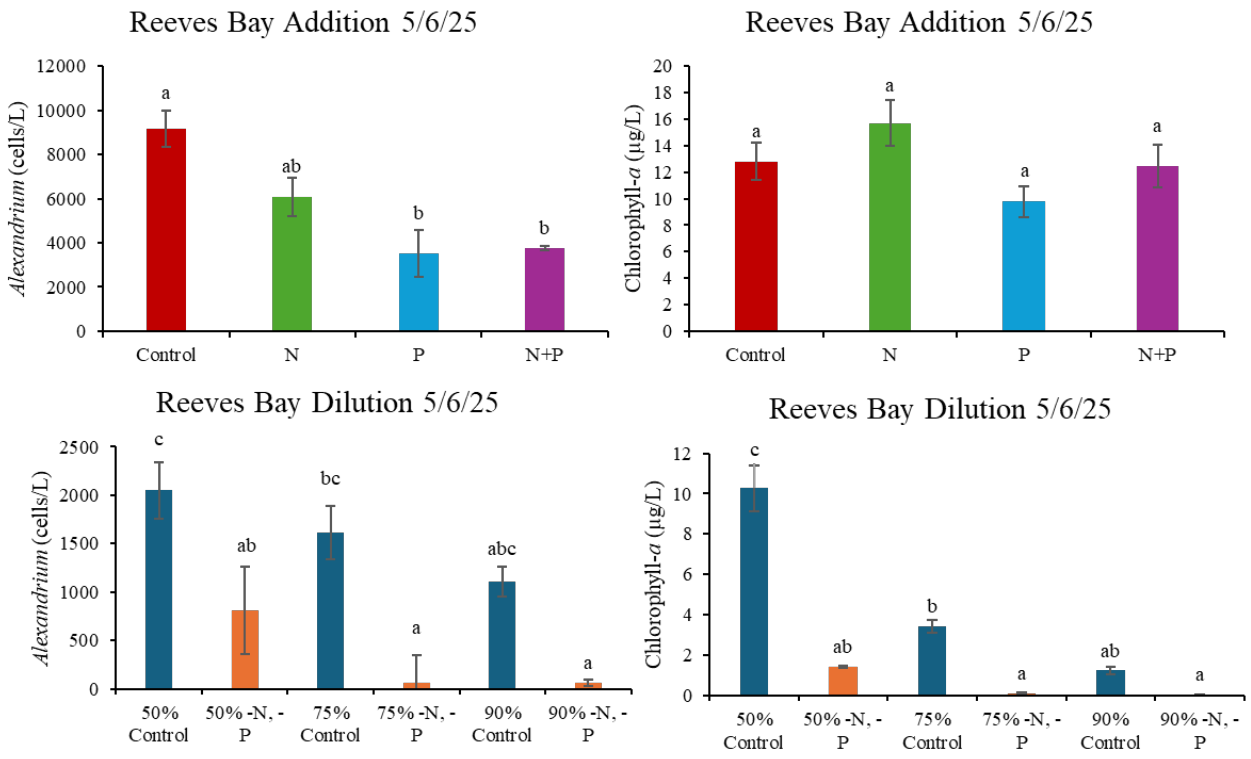



**Figure 47.** 2025 Reeves Bay *Alexandrium* bloom water nutrient addition and dilution experiments.

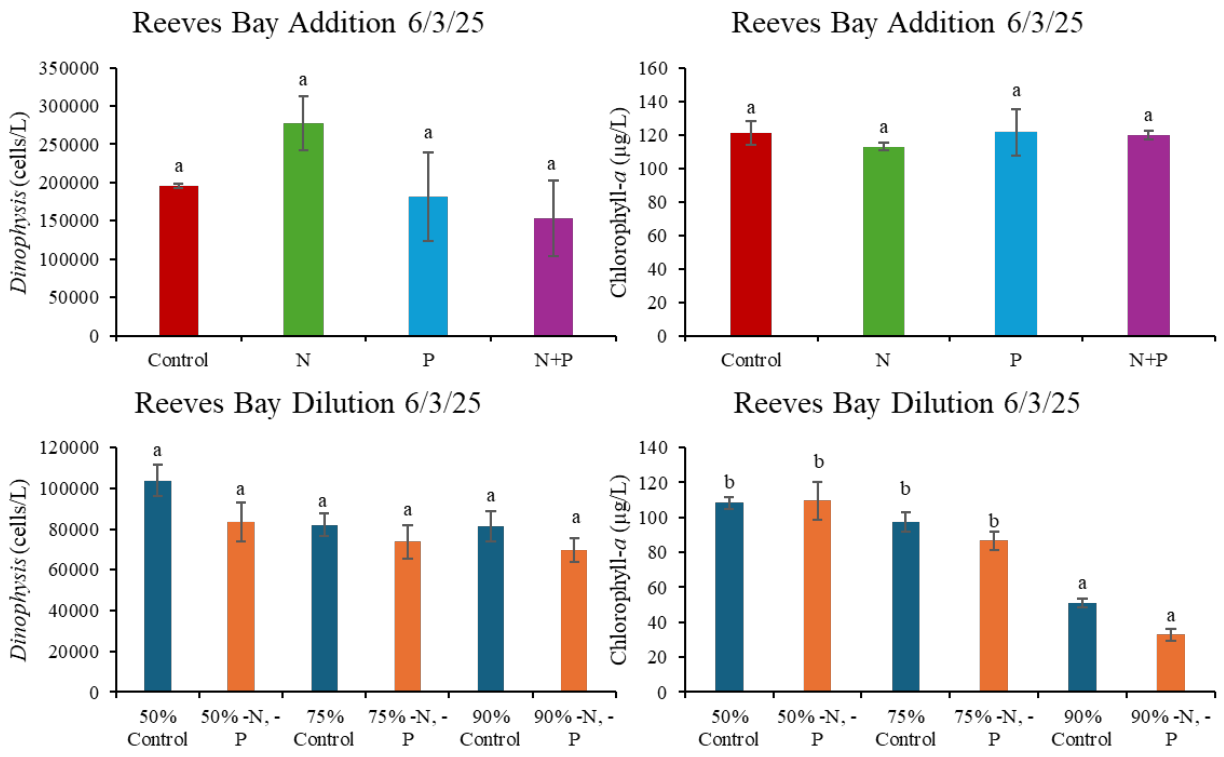



**Figure 48.** 2025 Reeves Bay *Dinophysis* bloom water nutrient addition and dilution experiments.

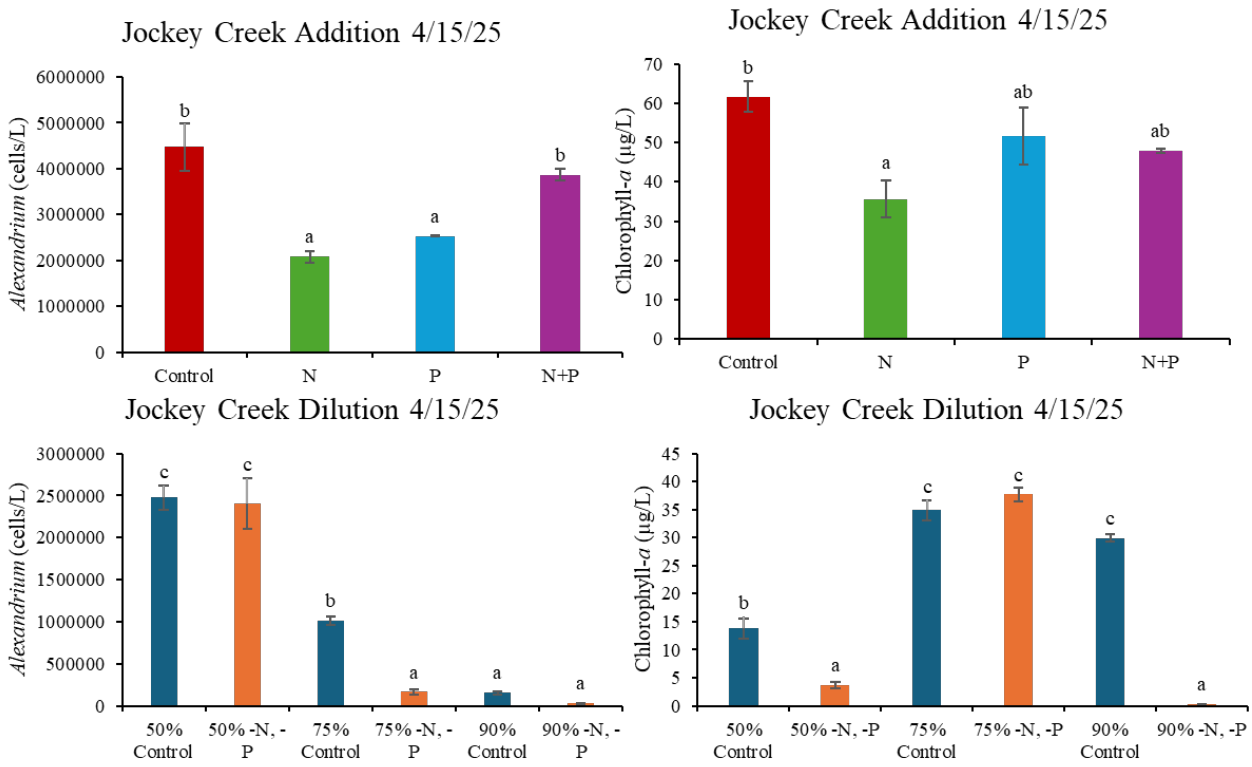



**Figure 49.** 2025 Reeves Bay *Dinophysis* bloom water nutrient addition and dilution experiments.