Ecosystem recovery of Tampa bay following the 2021 release of phosphate mine wastewater from the Piney Point facility

Marcus W Beck1,✉, Edward T Sherwood1, Sarina J Ergas2, Jeffrey A Cunningham2, and David A Tomasko3

1 Tampa Bay Estuary Program, 263 13th Ave S., Suite 350, St. Petersburg, Florida 33701 USA  
2 University of South Florida, Department of Civil and Environmental Engineering, 4202 East Fowler Avenue, ENG 030, Tampa, Florida 33620 USA  
3 Sarasota Bay Estuary Program, Sarasota, Florida 34236 USA

✉ Correspondence: [Marcus W Beck <mbeck@tbep.org>](mailto:mbeck@tbep.org)

## Abstract (150-250 words)

Mining activities can support local and global economies, yet also impose significant consequences for the natural environment. Phosphate mining in central Florida has been ongoing for decades and many facilities present risks to freshwater and coastal aquatic environments in the state. In 2021, a breach in the liner of a wastewater holding pond at Piney Point, a legacy phosphate processing facility, resulted in the emergency discharge of ~815 million liters of highly acidic and nutrient-laden (nitrogen, phosphorus) process water into Tampa Bay. A multi-agency, event-response monitoring program resulted, which documented ecosystem impacts within several months. Short-term declines in water quality were observed, with a notable harmful algal bloom and substantial fish kills occurring three months after the initial wastewater release. Acute spills like the 2021 event threaten past successes, while efforts to mitigate and prevent these negative outcomes in the future are ongoing. This chapter will present the historical context and management of Piney Point as a precursor to the events of 2021, while providing quantitative examples of the bay’s response for interpretation relative to the long-term recovery of the bay. The role of the Tampa Bay Estuary Program as a non-regulatory institution that works to build public and private partnerships for bay management will also be explored, with emphasis on its role coordinating monitoring efforts and disseminating open science communication products.

## 1 Introduction (500-1500 words)

The contemporary history of Tampa Bay, Florida is an exemplary model for how collaborative efforts among public and private entities can lead to long-term improvements in the environment. In February 1974, a news segment airing on Sixty Minutes drew national attention on the effects of population growth and unchecked development in the Tampa Bay region. Noxious macroalgal blooms, loss of seagrass, and a decline in fisheries were evidence of the effects of this growth as the bay’s natural resources were stressed by an increasing human population in the watershed. The discharge of untreated wastewater into Tampa Bay was a culprit for many of these maladies. Over the following decades, efforts to restore Tampa Bay were successful in reducing nutrient loads from wastewater and other external sources by 2/3 (Greening et al., 2014; Greening & Janicki, 2006). By 2016, seagrasses had recovered to an all-time recorded high of 41,656 acres, exceeding the management goal by several thousand acres (Sherwood et al., 2017).

Efforts contributing to the recovery of Tampa Bay were the product of multiple factors, some opportune while others more intentional. In the 1960s, a growing nationwide environmental movement influenced public sentiment on how unregulated economic growth and development can severely harm the environment. Notable events such as the Cuyahoga River catching on fire and widely read texts like “Silent Spring” were influential factors that motivated change in a national environmental ethic. These sentiments trickled down to Tampa Bay communities as local environmental disasters combined with massive population growth led to public calls for regulatory reform and environmental restoration (Bennett, 2024). Focus was primarily on the discharge of untreated sewage directly to the bay, as legislation was ultimately passed that required all wastewater treatment plants to upgrade to advanced technologies to remove excess nutrients before the water was returned to the environment (Johansson, 1991). Additional state legislation led to tighter controls on stormwater pollution to remediate additional sources of nutrients. These efforts were reinforced at the federal level with enactment of the Clean Water Act in 1972. Gradually and over several decades, tighter regulation of pollution motivated by public concern over the effects of population growth had its intended outcomes as water quality in the bay improved and the seagrasses returned. Bay recovery was also supported by hundreds of habitat and infrastructure restoration projects lead by numerous entities (Beck et al., 2019).

Local public and private environmental groups were and continue to be key players in coalescing public support to improve water quality in Tampa Bay (Gross & Hagy III, 2017; Sherwood et al., 2016). The Tampa Bay Estuary Program (TBEP), in particular, has been a consistent voice over the last three decades that has worked to build partnerships to restore and protect the bay’s resources. This work is implemented through a scientifically sound, community-based management plan that outlines distinct actions to take related to water quality, fish and wildlife, and the community. The TBEP is part of a broader National Estuary Program consisting of 28 similar programs around the country that have been established at Congressionally recognized “estuaries of national significance”, each with their own locally-specific mission. Since 1991, the TBEP has worked to engage communities, private businesses, and local governments to work towards the common goal of a healthy Tampa Bay. The TBEP also manages the Tampa Bay Nitrogen Management Consortium (TBNMC) with representatives from public and private entities that have a shared responsibility to control sources of pollution to Tampa Bay. The TBNMC has worked to reduce nitrogen loads as a key water quality pollutant, with primary sources being wastewater and stormwater. The management approach is simple; reduced nitrogen loads will produce less algal growth, promoting a light environment in the water that is supportive of seagrass growth (Janicki et al., 2000; Johansson & Greening, 1999). The TBNMC has quantified and allocated sources of nitrogen among entities that directly or indirectly discharge to the bay, with totals not to exceed based on the capacity of the Bay to assimilate these nutrients (Janicki & Wade, 1996). The Florida Department of Environmental Protection (FDEP) maintains regulatory oversight.

Despite the nationally recognized story of Tampa Bay, current challenges have emerged that threaten past successes and bring into question the effectiveness of existing management paradigms. From 2016 to 2022, seagrasses declined baywide by over 11,000 acres, falling well below the management target of 40,000 acres (Beck et al., 2024). These declines were notable because water quality goals were met in successive years of seagrass decline, suggesting that additional factors were driving this loss. Recent interest has shifted towards climate change as a potential culprit as extreme temperatures and changes in precipitation may be stressing seagrasses beyond their optimal tolerance ranges (Beck et al., 2024; Oliver et al., 2018; Sherwood & Greening, 2013). These additional stressors mean that further reductions in nutrient loads may be needed to account for external climate factors that are difficult, if not impossible, to control at the local scale (Stantec Consulting Services, Inc., 2025). Resilience of the bay to assimilate nutrient inputs has likely been reduced as shifting baselines from climate change cause regional managers to reconsider the effectiveness of past targets and thresholds.

Reduced resilience of Tampa Bay to respond to management efforts threatens to undo the years of collaborative work in restoring seagrasses. Unanticipated events may push the bay beyond a tipping point to undesirable conditions similar to the past as the bay may no longer have the capacity to process excess nutrient inputs. Events in 2021 were a substantial test for the management of Tampa Bay that provided an unintentional system-wide experiment for how the bay’s resources respond to acute nutrient inputs. The Piney Point facility is located on the southeast shoreline of Tampa Bay and is a legacy phosphorus fertilizer processing facility that has been inactive for over twenty years ([Figure 1](#fig-map)). Large amounts of wastewater as a byproduct of historical processing are stored on site, with no useful application given the chemical characteristics of the water and the logistics of its removal. Central Florida has had a long and complicated history with fertilizer mining (Nelson et al., 2021). While these activities support economic growth, there are often unintended consequences for the natural environment. Piney Point embodies this relationship, as fertilizer export outside of the region has had economic benefits, whereas wastewater stored on site has made its way to Tampa Bay on more than one occasion ([Figure 1](#fig-map)).

In April 2021, a tear in the plastic liner of the southeastern holding pond (NGS-S) at Piney Point was detected and the release of wastewater into Tampa Bay was authorized by FDEP to prevent catastrophic failure of the pond walls (Beck et al., 2022; Morrison et al., 2023; Nelson et al., 2021). The decision to discharge millions of gallons of wastewater into Tampa Bay from Piney Point was intentional to safeguard property and human life near Piney Point, despite the anticipated environmental consequences. Over 215 millions gallons of wastewater were released, introducing 205 tons of nutrients to lower Tampa over a ten day period, exceeding the amount that is typically introduced annually from other sources. The TBEP, in collaboration with multiple local, regional, and state entities, coordinated a response-based monitoring effort to document the effects of this release on the bay’s resources. Several dramatic effects were observed over the months following the initial release, the most notable being a massive bloom of the red-tide organism *Karenia brevis* that was likely fueled by the nutrient-rich wastewater from Piney Point (Chen et al., 2023). Red tide blooms produce a potent neurotoxin that is fatal for wildlife exposed for sustained periods. As a result, 1800 tons of dead fish were recovered from Tampa Bay in July 2021.

This chapter will provide an overview of the history of the Piney Point facility and the effects on the bay during and after the wastewater release, including past incidents before 2021. This information is presented in the context of the long-term recovery of Tampa Bay, the effects on seagrass resources, and how the history of local partnerships were important for the response-based effort. The reader should have an understanding of how past events, both historically and leading up to 2021, influenced the decision to release wastewater to Tampa Bay and what actions can be taken in the future to prevent similar events from occurring. The role of TBEP as a facilitator for bay management will be emphasized and the reader should reflect on how past activities of the program were important for responding to the Piney Point event, in addition to future challenges for managing bay resources in light of the details presented here.

## 2 Background (1000-2000 words)

The “Bone Valley” in central Florida has supported a multi-billion dollar mining industry for several decades (Henderson, 2004). Its namesake refers to the geological characteristics of the region, also called Karst geology, where fossilized marine organisms have created a limestone base overlying a freshwater aquifer. This limestone is rich in phosphorus as a main ingredient used in commercially available fertilizer, either for residential use or large-scale agricultural production. Consequently, Tampa Bay waters have relatively high concentrations of phosphorus that aquatic organisms have adapted to over geologic time scales (Wang et al., 1999). Additions of historically scarce nutrients, like nitrogen, can substantially alter the balance and pace of biological growth in the estuary. Because Tampa Bay is “nitrogen-limited”, water quality improvements in previous decades have focused on mitigating external sources of nitrogen (Greening et al., 2014). However, byproducts from fertilizer production can be rich in both phosphorus and nitrogen. Fertilizer processing facilities are often located near distribution centers like marine ports and the export of fertilizer is a primary function that the ports of Tampa Bay support. As such, both the production and export of fertilizer present substantial risks for water quality in Tampa Bay.

The production and distribution of fertilizer is a waste intensive process. For every 1 part useful fertilizer that is produced from raw phosphorus ore, five parts waste are created (U.S. Environmental Protection Agency, 2025). This waste is called phosphogypsum and it has minimal commercial applications, owing primarily to its radioactive characteristics. Phosphogypsum is stored on-site as large stacks (or gypstacks) that are visible miles away and are often the only topographical features on the flat Florida landscape. Phosphogypsum is initially produced as a slurry during fertilizer production. The gypstacks are formed as the solid materials settle out of the slurry, leaving wastewater with similar chemical characteristics as the phosphogypsum. Piney Point historically produced diammonium phosphate ((NH)HPO) and the wastewater stored on site is high in both nitrogen and phosphorus. This wastewater also has no practical use and its disposal through treatment or export elsewhere can be cost-prohibitive. As a result, phosphogypsum stacks and their wastewater persist long-after fertilizer production stops, with 17 such examples in the Tampa Bay watershed (25 total in Florida, Florida Department of Environmental Protection, 2025). Distribution of fertilizer at port facilities can also introduce substantial nutrients to surface waters primarily through losses during physical transport. Although regulation and adoption of best practices has greatly reduced “material losses” from these activities, nutrient loads from fertilizer transport at ports are still estimated as a non-negligible portion of the overall nutrient budget for Tampa Bay (Janicki Environmental, Inc., 2023).

The Piney Point facility has a long and complicated history of ownership and management (see supplement to Beck et al., 2022; Henderson, 2004). Fertilizer production began in 1966 when the land was purchased by Borden Chemicals. Early reports described environmental concerns related to surface water contamination in Bishop Harbor immediately adjacent to Piney Point, suspected groundwater contamination from industrial solvents, and air pollution from emissions produced during production. Mulberry Phosphates, Inc. acquired the facility in 1993 and operated it until 2001 when the company declared bankruptcy, after which regulatory oversight was transferred to FDEP. Mulberry Phosphates was a prominent fertilizer production company in Florida at the time and was also responsible for an unintentional spill in 1997 of fertilizer process water into the Alafia River, the second largest tributary to Tampa Bay, that resulted in a massive fish kill (DiPinto et al., 2001). Wastewater from Piney Point was released to Bishop Harbor in 2001 due to tropical storm activity and again in November 2003 to October 2004 to ease pressure on the gypstacks. The impacts of these events were not well studied, although Garrett et al. (2011) documented occurrences of potentially harmful algal species near the discharge site and Switzer et al. (2011) noted increased macroalgal blooms. Wastewater was also barged offshore to the Gulf of Mexico during this time as another attempt at maintaining integrity of the facility. HRK Holdings, LLC purchased Piney Point in August 2006 through an administrative agreement with FDEP. With oversight by the latter, HRK agreed to maintain Piney Point such that any future uses must protect and be compatible with integrity of stack closure and long-term care, as defined in their agreement.

Over the course of its ownership, site management decisions by HRK, as approved by FDEP, contributed to further decline in the holding capacity of the gypstacks at Piney Point. A port expansion project at Port Manatee produced dredge material that HRK agreed to store in the NGS-S holding pond ([Figure 1](#fig-map)), further reducing holding capacity of the facility. Wastewater was released in 2011 again to Bishop Harbor as a result of compromised plastic liner in NGS-S, where the addition of dredge material and seawater was suspected as the cause. HRK Holdings filed for Chapter 11 bankruptcy in 2012 citing expenses associated with the port expansion project and the fallout from the environmental impacts. Although HRK maintained majority ownership of the site, portions of the property were sold to third parties to alleviate some of the financial burden from the bankruptcy settlement. By 2021, the inability of NGS-S to continue to hold wastewater and dredge material was evident as a leak was identified in NGS-S and later confirmed as being caused again by a tear in the plastic liner of the holding pond. Concerns of public safety and potential damage to property motivated the decision to release untreated wastewater from NGS-S directly to Tampa Bay near Port Manatee, as authorized by an emergency order from FDEP.

From March 30th to April 9th, 2021, over 215 million gallons of wastewater were released from Piney Point into Tampa Bay from a discharge point at Port Manatee(Beck et al., 2022). A year’s worth of external nutrient inputs entered lower Tampa Bay during this ten day period. Given the environmental impacts that were expected, the TBEP coordinated a multi-agency response to document the effects on the bay’s natural resources. Public, private, and academic partners collected thousands of water quality samples, measured seagrass and macroalgae coverage, documented changes in sediment quality and the organisms that live on the bay bottom, and assessed algal community changes. Monitoring efforts were guided by a hydrodynamic flow simulation model developed by the College of Marine Science at the University of South Florida (Liu et al., 2024). This model provided an assessment of where the released water was likely to travel, thus providing guidance on where sampling should occur each week. The TBEP provided support for these efforts by having regular meetings with partner agencies to coordinate sampling, serving as a data warehouse for synthesizing monitoring information, creating a public dashboard to communicate changes to the public in near real time, and disseminating monthly one-pagers to communicate results to date (Beck et al., 2023; Tampa Bay Estuary Program, 2022). In addition, TBEP staff provided dozens of interviews for local and national media outlets as expert commentary on the event.

Monitoring of bay resources continued for six months following the initial release. Throughout this period, several impacts were observed (Beck et al., 2022; Morrison et al., 2023). First, an immediate and expected response in the algal community near the discharge point was observed as a bloom of commonly-occurring diatoms quickly utilized the nutrients ([Figure 2](#fig-wqchange)). The bloom was short-lived and dissipated by the end of April, after which blooms of filamentous cyanobacteria (*Dapis* spp.) were observed near the port and at locations south, often covering seagrasses or floating on the surface. Increases in macroalgal species were also observed along seagrass monitoring transects (Scolaro et al., 2023). The cyanobacteria blooms decreased in abundance by July, when concentrations of the red-tide organism *Karenia brevis* increased dramatically in the bay. Red tide was first observed outside of Tampa Bay on April 20th, first measured at bloom concentrations in the bay proper on May 23rd, increased to high bloom concentrations (> 1 million cells / L) by late June, and peaked on July 4th at greater than 10 million cells / L in the middle of Tampa Bay ([Figure 2](#fig-wqchange)). Red tide is typically limited in Tampa Bay as freshwater inputs from major rivers lower salinity below the optimal tolerance range. However, low rainfall during the first half of 2021 contributed to higher than normal salinity that produced favorable conditions for red tide, in addition to increased availability of nutrients from the Piney Point discharge. As a result, brevetoxins produced by the red tide caused a massive fish kill throughout the bay, where an estimated 1800 tons of dead fish were recovered. The effects of red tide on fish in Tampa Bay were also reflected in notable increases in public reports during July to a state fish kill hotline ([Figure 3](#fig-fishkill)). Compared to other years, 2021 was a distinct outlier in the number of reported fish kills. Numerous reports of marine mammal mortalities were also received during this time.

By September 2021, conditions in the bay were visibly similar to those prior to the release from Piney Point ([Figure 2](#fig-wqchange)), although monitoring and additional research continued to better understand long-term effects. A study published two years later demonstrated that wastewater from Piney Point dispersed much further than anticipated, with water having a chemical signature similar to the discharge being observed at a control site over 30 miles to the north of the mouth of Tampa Bay (Morrison et al., 2023). Seagrasses, although not showing any notable changes in 2021, had declined in total cover on the eastern shore of Tampa Bay based on a comparison of estimates from aerial imagery obtained during the winter of 2020 and 2022 (i.e., pre- and post-discharge, [Figure 4](#fig-seagrasschange)). However, seagrasses consistently declined baywide since 2016 and it is difficult to assess the role of Piney Point in the 2022 decline. Further work has demonstrated that phosphorous and nitrogen from wastewater discharge from Piney Point, 2021 and previous, can be stored in bay bottom sediments as a potential future source of nutrients (Chappel et al., 2025). These findings highlight the need to better quantify sediment nutrient sources that have likely been influenced by Piney Point discharge, especially when nutrients can be made biologically available in the water column during storm events that resuspend sediments. Lastly, the fate and effects of lesser studied contaminants from Piney Point have also been a concern. Microplastic particles were observed near the Skyway Bridge at the mouth of Tampa Bay shortly after the initial wastewater release, possibly from degradation of the plastic liner in the holding ponds (S. Gowans, Eckerd College, personal communication, April 2025). Microplastics have widespread distribution in Tampa Bay and future efforts should focus on source mitigation to prevent further negative impacts on bay habitats and wildlife (Gowans & Siuda, 2023; Vandale et al., 2023).

Public response to the events of 2021 was a significant factor influencing future plans for Piney Point. Motivated by public concerns on the environmental impacts, a lawsuit was filed against HRK holdings by several prominent local conservation groups shortly after the discharge was authorized for release in 2021. Litigation occurred in the years following and on September 18th, 2024 a US District federal judge ruled that [HRK was in violation](https://biologicaldiversity.org/programs/environmental_health/pdfs/Default-Jugment-Order_HRK_Piney-Point.pdf) of the US Clean Water Act, despite receiving a permit from FDEP to discharge the wastewater in 2021. This ruling ordered HRK to pay $56,460 for each day wastewater was released to public waters, totaling $846,900 for the duration of the event. FDEP concurrently agreed to fund additional future monitoring to assess long-term impacts, with $75,000 paid to the TBEP to organize these efforts. During litigation, public calls for the closure of Piney Point lead to the development and implementation of a [closure plan](https://content.govdelivery.com/attachments/FLDEP/2022/03/31/file_attachments/2118832/ConceptualClosurePlan03252022_revisedsmall.pdf) for the facility as adopted and implemented by FDEP. These plans included using an independent third-party as a court-appointed receiver to oversee the closure process, with specific actions to treat the wastewater onsite prior to pumping the water underground using a newly constructed deep well injection site that was fully functioning By April 2023. Wastewater was also sent to local treatment plants to expedite the process. Once all wastewater is removed, the remaining gypstacks will be filled and capped to reduce future stormwater management needs at the site. As an example of closure progress, [Figure 5](#fig-capacity) shows the removal of water from NGS-S over time, as well as the ability of Piney Point to accommodate additional rainfall contributing to stormwater capacity onsite as wastewater is treated and/or removed. As of writing, only one of the four holding ponds at Piney Point has been successfully filled.

## 3 Student Activities (500-1000 words)

### 3.1 Classroom discussion questions

This chapter has focused on the long-term recovery of Tampa Bay and its recent challenges, often evaluating the change in seagrasses as a means to evaluate the bay’s response to chronic and acute stressors. Seagrass cover in Tampa Bay has changed dramatically over time

Include at least 3 discussion questions based on the case study that can be used in a classroom situation.

My notes:

Something about communication/transparency of information

Something about history of past partnerships, why were they so important

Something about reactive v proactive, i.e., Piney Point was a disaster waiting to happen, but somethign was only done once it happened. What are the forces at play that prevent proactive action?

### 3.2 Individual student responses

Include at least 3 questions/prompts based on the case study that can be used in a homework assignment or on an exam. These could include further reading (be sure to provide references to readily available materials) or personal reflections.

My notes:

Something about interpretation of the figures/tables in this chapter

## 4 Conclusion (500-1000 words)

Include a discussion of key take-aways.

My notes:

long-term closure plan for piney point, other facilities in the region - deep well injection, disposal of phosphogypum via road construction? Piney Point well may be precedent for future activities, but still a lot of unknowns, related to groundwater/drinking water?

Bring everybody to the table (highlight Mosaic’s role in the TBNMC)

Something about resiliency and the bay’s ability to recover from this event

## Figures

|  |
| --- |
| Fig. 1: The Tampa Bay watershed and Piney Point. Bay segments, holding ponds, and other relevant locations are shown. County boundaries are labeled with paired county names. NGS-N: New Gypsum Stack North; NGS-S: New Gypsum Stack South; OGS-N: Old Gypsum Stack North; OGS-S: Old Gypsum Stack South. Basemap credits: Esri, HERE, Garmin, OpenStreetMap, Maxar, and Earthstar Geographics. |

|  |
| --- |
| Fig. 2: Water quality changes from March to September 2021 near Port Manatee at the discharge point. Monitoring data are shown for (a) total nitrogen, (b) chlorophyll-a, and (c) Secchi depth as a measure of water clarity. Monthly baseline ranges are shown in blue as an estimate of normal conditions from the past fifteen years. Notable algal bloom events as shown by increases in chlorophyll-a are shown in (b). Data sources described in Beck et al. (2022). |

|  |
| --- |
| Fig. 3: Fish kill reports for Hillsborough, Manatee, and Pinellas Counties that border Tampa Bay. Plot (a) shows reports by year and plot (b) shows reports by week for 2021. Data from Florida Fish and Wildlife Commission fish kill hotline. |

|  |
| --- |
| Fig. 4: Seagrass change from 2020 to 2022 for selected seagrass management areas identified by the Tampa Bay Estuary Program. Map (a) shows the overall acreage change by management area and map (b) shows the areas where seagrass was lost or gained. See [Figure 1](#fig-map) for the locational context. Data from the Southwest Florida Water Management District. |

|  |
| --- |
| Fig. 5: Progress to date closing the NGS-S holding pond at Piney Point. The top plot shows the volume of water in the pond and the bottom plot shows the overall capacity of Piney Point to accommodate additional stormwater, affected by both the volume of water onsite and rainfall. Key events affecting the closure process are shown by the horizontal lines. Data from the Florida Department of Environmental Protection. |

## References

Beck, M. W., Altieri, A., Angelini, C., Burke, M. C., Chen, J., Chin, D. W., Gardiner, J., Hu, C., Hubbard, K. A., Liu, Y., Lopez, C. B., Medina, M., Morrison, E. F., Phlips, E. J., Raulerson, G. E., Scolaro, S., Sherwood, E. T., Tomasko, D. A., Weisberg, R. H., & Whalen, J. (2022). Initial estuarine response to inorganic nutrient inputs from a legacy mining facility adjacent to Tampa Bay, Florida. *Marine Pollution Bulletin*, *178*, 113598. <https://doi.org/10.1016/j.marpolbul.2022.113598>

Beck, M. W., Burke, M. C., Raulerson, G. E., Scolaro, S., Sherwood, E. T., & Whalen, J. (2023). Coordinated monitoring of the Piney Point wastewater discharge into Tampa Bay. *Florida Scientist*, *86*(2), 288–300.

Beck, M. W., Flaherty-Walia, K., Scolaro, S., Burke, M. C., Furman, B. T., Karlen, D. J., Pratt, C., Anastasiou, C. J., & Sherwood, E. T. (2024). Hot and fresh: Evidence of climate-related suboptimal water conditions for seagrass in a large Gulf Coast estuary. *Estuaries and Coasts*, *47*(6), 1475–1497. <https://doi.org/10.1007/s12237-024-01385-0>

Beck, M. W., Sherwood, E. T., Henkel, J. R., Dorans, K., Ireland, K., & Varela, P. (2019). Assessment of the cumulative effects of restoration activities on water quality in Tampa Bay, Florida. *Estuaries and Coasts*, *42*(7), 1774–1791. <https://doi.org/10.1007/s12237-019-00619-w>

Bennett, E. P. (2024). *Tampa Bay: The story of an estuary and its people*. University Press of Florida.

Chappel, A. R., Kenney, W. F., Waters, M. N., Fisher, C. B., Amaral, J. H., Phlips, E. J., & Morrison, E. S. (2025). Coastal sediments record decades of cultural eutrophication in Tampa Bay, Florida, USA. *Ecological Indicators*, *172*, 113329. <https://doi.org/10.1016/j.ecolind.2025.113329>

Chen, Y., Li, M., Glibert, P. M., & Heil, C. (2023). Mu*rK*y waters: Modeling the succession from *r* to *k* strategists (diatoms to dinoflagellates) following a nutrient release from a mining facility in Florida. *Limnology and Oceanography*, *68*(10), 2288–2304. <https://doi.org/10.1002/lno.12420>

DiPinto, L., Penn, T., Iliff, J., & Peterson, C. (2001). Determing the scale of restoration for a fish kill in the Alafia River, Florida. *International Oil Spill Conference*, *2001*, 1511–1516.

Florida Department of Environmental Protection. (2025). *Florida Gypsumstacks*. Florida Department of Environmental Protection Geospatial Open Data. <https://ca.dep.state.fl.us/arcgis/rest/services/OpenData/GYPSUMSTACKS/MapServer/0>

Garrett, M., Wolny, J., Truby, E., Heil, C., & Kovach, C. (2011). Harmful algal bloom species and phosphate-processing effluent: Field and laboratory studies. *Marine Pollution Bulletin*, *62*(3), 596–601. <https://doi.org/10.1016/j.marpolbul.2010.11.017>

Gowans, S., & Siuda, A. N. (2023). Microplastics in large marine herbivores: Florida manatees (*Trichechus manatus latirostris*) in Tampa Bay. *Frontiers in Ecology and Evolution*, *11*, 1143310. <https://doi.org/10.3389/fevo.2023.1143310>

Greening, H. S., & Janicki, A. J. (2006). Toward reversal of eutrophic conditions in a subtropical estuary: Water quality and seagrass response to nitrogen loading reductions in Tampa Bay, Florida, USA. *Environmental Management*, *38*(2), 163–178. <https://doi.org/10.1007/s00267-005-0079-4>

Greening, H. S., Janicki, A. J., Sherwood, E. T., Pribble, R., & Johansson, J. O. R. (2014). Ecosystem responses to long-term nutrient management in an urban estuary: Tampa Bay, Florida, USA. *Estuarine, Coastal and Shelf Science*, *151*, A1–A16. <https://doi.org/10.1016/j.ecss.2014.10.003>

Gross, C., & Hagy III, J. D. (2017). Attributes of successful actions to restore lakes and estuaries degraded by nutrient pollution. *Journal of Environmental Management*, *187*, 122–136. <https://doi.org/10.1016/j.jenvman.2016.11.018>

Henderson, C. S. (2004). *Piney Point phosphate plant: An environmental analysis. University of South Florida St. Petersburg, Florida*.

Janicki, A. J., & Wade, D. L. (1996). *Estimating critical nitrogen loads for the Tampa Bay Estuary: An empirically based approach to setting management targets* (06-96). Tampa Bay Estuary Program. <https://drive.google.com/file/d/1kZkvuprvsMyN9nPS5PHYvXHyo1KQxKTr/view?usp=drivesdk>

Janicki, A. J., Wade, D., & Pribble, J. R. (2000). *Developing and establishing a process to track the status of chlorophyll-a concentrations and light attenuation to support seagrass restoration goals in Tampa Bay* (04-00). Tampa Bay Estuary Program. <https://drive.google.com/file/d/1XMULU8w4syWcSv_ciOUOhnC_G4xt6GIF/view?usp=drivesdk>

Janicki Environmental, Inc. (2023). *Estimates of total nitrogen, total phosphorus, total suspended solids, and biological oxygen demand loadings to Tampa Bay, Florida: 2017-2021* (06-23; p. 83). Tampa Bay Estuary Program. <https://drive.google.com/file/d/1KARuSC5fGx05MuT1wiOQFWNXysBokkQl/view?usp=share_link>

Johansson, J. O. R. (1991). Long-term trends in nitrogen loading, water quality and biological indicators in Hillsborough Bay, Florida. In S. F. Treat & P. A. Clark (Eds.), *Proceedings of the Tampa Bay Area Scientific Information Symposium 2* (pp. 157–176). Tampa Bay Regional Planning Council.

Johansson, J. O. R., & Greening, H. S. (1999). Seagrass restoration in Tampa Bay: A resource-based approach to estuarine management. In S. A. Bartone (Ed.), *Seagrasses: Monitoring, Ecology, Physiology, and Management* (pp. 297–312). CRC Press.

Liu, Y., Weisberg, R. H., Zheng, L., Sun, Y., Chen, J., Law, J. A., Hu, C., Cannizzaro, J. P., & Frazer, T. K. (2024). A tracer model nowcast/forecast study of the Tampa Bay, Piney Point effluent plume: Rapid response to an environmental hazard. *Marine Pollution Bulletin*, *198*, 115840. <https://doi.org/10.1016/j.marpolbul.2023.115840>

Morrison, E. S., Phlips, E., Badylak, S., Chappel, A. R., Altieri, A. H., Osborne, T. Z., Tomasko, D., Beck, M. W., & Sherwood, E. (2023). The response of Tampa Bay to a legacy mining nutrient release in the year following the event. *Frontiers in Ecology and Evolution*, *11*, 1144778. <https://doi.org/10.3389/fevo.2023.1144778>

Nelson, N. G., Cuchiara, M. L., Hendren, C. O., Jones, J. L., & Marshall, A.-M. (2021). Hazardous spills at retired fertilizer manufacturing plants will continue to occur in the absence of scientific innovation and regulatory enforcement. *Environmental Science & Technology*, *55*(24), 16267–16269. <https://doi.org/10.1021/acs.est.1c05311>

Oliver, E. C. J., Donat, M. G., Burrows, M. T., Moore, P. J., Smale, D. A., Alexander, L. V., Benthuysen, J. A., Feng, M., Sen Gupta, A., Hobday, A. J., Holbrook, N. J., Perkins-Kirkpatrick, S. E., Scannell, H. A., Straub, S. C., & Wernberg, T. (2018). Longer and more frequent marine heatwaves over the past century. *Nature Communications*, *9*(1324). <https://doi.org/10.1038/s41467-018-03732-9>

Scolaro, S., Beck, M. W., Burke, M. C., Raulerson, G. E., & Sherwood, E. T. (2023). Piney Point, seagrass, and macroalgae: Impact assessment and a case for enhanced macroalgae monitoring. *Florida Scientist*, *86*, 2.

Sherwood, E. T., & Greening, H. S. (2013). Potential impacts and management implications of climate change on Tampa Bay estuary critical coastal habitats. *Environmental Management*, *53*(2), 401–415. <https://doi.org/10.1007/s00267-013-0179-5>

Sherwood, E. T., Greening, H. S., Janicki, A. J., & Karlen, D. J. (2016). Tampa Bay estuary: Monitoring long-term recovery through regional partnerships. *Regional Studies in Marine Science*, *4*, 1–11. <https://doi.org/10.1016/j.rsma.2015.05.005>

Sherwood, E. T., Greening, H. S., Johansson, J. O. R., Kaufman, K., & Raulerson, G. E. (2017). Tampa Bay (Florida, USA): Documenting seagrass recovery since the 1980’s and reviewing the benefits. *Southeastern Geographer*, *57*(3), 294–319. <https://doi.org/10.1353/sgo.2017.0026>

Stantec Consulting Services, Inc. (2025). *Old Tampa Bay assimilative capacity study: Task 2 evaluation of eutrophication indicator targets, thresholds, and numeric nutrient criteria and proposed adjustments* (05-25; p. 107). Tampa Bay Estuary Program. <https://drive.google.com/file/d/12xYfSs-4bxhLa1ZVQbmhQSv5Jo4Jf-oY/view?usp=sharing>

Switzer, T. S., Tyler-Jedlund, A. J., Rogers, K. R., Grier, H., McMichael Jr, R. H., & Fox, S. (2011). *Response of estuarine nekton to the regulated discharge of treated phosphate-production process water* (p. 24). Florida Fish; Wildlife Conservation Commission, Fish; Wildlife Research Institute.

Tampa Bay Estuary Program. (2022). *Piney Point Monitoring*. Tampa Bay Estuary Program. <https://tbep.org/piney-point/>

U.S. Environmental Protection Agency. (2025). *TENORM: Fertilizer and Fertilizer Production Wastes*. United States Environmental Protection Agency. <https://www.epa.gov/radiation/tenorm-fertilizer-and-fertilizer-production-wastes>

Vandale, N., Gowans, S., & Siuda, A. N. (2023). Monitoring microplastics in Tampa Bay. *Florida Scientist*, *86*(2), 91–94.

Wang, P., Martin, J., & Morrison, G. (1999). Water quality and eutrophication in Tampa Bay, Florida. *Estuarine, Coastal and Shelf Science*, *49*(1), 1–20. <https://doi.org/10.1006/ecss.1999.0490>