Introduction

Effective management of coastal ecosystems to sustain current status or to mitigate impacts requires information on how these systems have changed over time. Estuaries, the natural buffer zone between rivers and ocean, are often some of the most vulnerable ecosystems as their watersheds are much larger than their area. The problem of nutrient enrichment and pollution in coastal environments is growing worldwide, particularly as populations increase in these watersheds and more of the upland habitats are developed for residential, urban, or industrial complexes (Freeman et al. 2019; Kyzar et al. 2021). **Nutrient enrichment alters coastal ecosystems often first with increases in algal production and biomass (CITATION?)** and the response of these systems is quite variable over space and time (Cloern and Jassby 2010). Anthropogenic impacts are not the only the primary drivers in these systems as climate also plays a large role in long-term conditions. In the Chesapeake Bay, precipitation and tropical cyclone activity results in variable phytoplankton production coupled with underlying increases in chlorophyll *a* due to eutrophication (Harding et al. 2016). In the Indian River Lagoon, variability in phytoplankton blooms have been attributed to cyclical patterns (e.g. El Niño/La Niña periods) and tropical cyclone events (Phlips et al. 2020). There are also systems, like the San Francisco estuary which, though nutrient-enriched, do not experience water quality impacts common to other enriched systems (like frequent phytoplankton blooms or low dissolved oxygen) attributed to a variety of variables such as strong tidal flushing and heavy phytoplankton grazing pressure from bivalves (Jassby 2008; Cloern and Jassby 2010; Cloern 2019). Therefore the use of observational information from long-term research and monitoring programs provides the most valuable information for place-based and adaptive strategies in the management of coastal ecosystems.

The System-Wide Monitoring Program (SWMP) of the National Estuarine Research Reserve System (NERRS) is an established long-term monitoring program that has been a cornerstone of the NERRS since its inception in 1995. The SWMP utilizes standardized equipment and protocols to collect high-frequency and continuous water quality and meteorological data in a variety of estuarine environments across the United States and Puerto Rico. Due to the standardization of the program, and its well-developed and documented data management protocols for quality assurance and quality control, it serves as an excellent resource for helping to identify trends, patterns, and scales of variability in phytoplankton dynamics as well as their potential drivers within estuarine environments (System 2022).

One of thirty NERRS nationwide, three of which exist in Florida, the Guana Tolomato Matanzas National Estuarine Research Reserve (GTMNERR) has collected long-term data on water quality and meteorological conditions in the Guana-Tolomato-Matanzas (GTM) estuary since 2002. The GTM is a bar-built estuary with enclosed lagoons “rivers” (the Guana, Tolomato, and Matanzas) that trifurcate at the St. Augustine Inlet. The St. Augustine Inlet is one of two inlets in this system and it is stabilized with a jetty and maintained by the US Army Corps of Engineers to a depth of 5-m and the other, the Matanzas Inlet, is one of Florida’s few remaining unstructured inlets on the Atlantic Coast (Dean and O’Brien 1987). Overall, the GTM estuary is a well-mixed and well-flushed estuary with an absence of a freshwater river and a short residence time of approximately 12.6 days (Phlips et al. 2004; Sheng et al. 2008; Gray et al. 2021).

The last study to have performed any trend or status of the GTM estuary was performed almost 20 years ago in 2004 using monitoring data collected by the St. Johns River Water Management District (Winkler and Ceric 2004). Their assessment encompassed a suite of water quality indicators which included chlorophyll *a*. At that time, the Northern Coastal Basin, which includes the GTM estuary, was found to have some of the best water quality out of all the basins in the District; however, many of the sites, though deemed of good water quality, provided insufficient data (did not have at least 10 years of data) or had insignificant results for trend tests (Winkler and Ceric 2004).

The estuary is within the ecotone of salt marsh and mangrove habitats with diverse habitats such as intertidal oyster reefs, tidal creeks, mud flats, and open water (Williams et al. 2014; Bacopoulos et al. 2019). The GTM estuary hosts exceptionally intact and robust populations of eastern oysters (*Crassostrea virginica*) that filter ~60% of the estuary’s volume within a single residence time (Gray et al. 2021). It is likely these filtration services coupled with the short residence times keep phytoplankton biomass low (Dix et al. 2013; Hart et al. 2015).

Given the lack of recent information regarding the status of water quality or nutrients within this system, the access of a robust water quality time series, and the continued increase in coastal population density pressure in the region (Kyzar et al. 2021), this study uses the established long-term continuous monitoring framework of the NERRS SWMP to establish trends, patterns, and scales in variability of chlorophyll *a* for a 20-year time period (2003-2022) while providing some potential drivers of that variation.

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