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# Nutrient concentrations in tidal creeks as indicators of the water quality role of mangrove wetlands in Southwest Florida

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ABSTRACT

Coastal mangroves have the potential to improve the water quality of urban and rural runoff before it is discharged into adjacent coastal bays and oceans; but they also can be impaired by excessive pollutants from upstream. Nutrients (phosphorus and nitrogen), salinity, and other water quality parameters were measured in five mangrove tidal creeks in different hydrogeomorphic and urbanization settings during high and low tides over a calendar year of wet (June and August 2015) and dry (February and April 2016) seasons in the Greater Naples Bay area in Southwest Florida, USA. Nutrient concentrations (ave. ± std error) in the tidal creeks were 0.055 ± 0.008 mg-P/L for total phosphorus (TP) and 0.610 ± 0.020 mg-N/L for total nitrogen (TN), with an average N:P ratio of 11.4:1. Average wet season TP (0.075 ± 0.010 mg-P/L) was significantly higher than the dry season TP (0.033 ± 0.003 mg-P/L; $p < 0.01$, $f = 15.17$, $f_{crit} = 3.89$) and the average wet season TN (0.75 ± 0.03 mg-N/L) was significantly higher than dry season TN (0.52 ± 0.02 mg/L; $p < 0.01$, $f = 64.14$, $f_{crit} = 3.89$), suggesting that urban stormwater runoff is directly or indirectly affecting the nutrient conditions in these mangroves. Significant differences in nutrient concentrations between low tide and high tide were not found for either TP ($p = 0.43$, $f = .63$, $f_{crit} = 3.88$) or TN ($p = 0.20$, $f = 1.66$, $f_{crit} = 3.89$). These differences were confirmed by a PCA and cluster analyses, which found differences to be seasonal. We could not conclude from these results whether these five mangrove wetlands were sources nor sinks of nutrients based simply on the measurement of nutrient concentrations. But we illustrated that nutrient concentrations were indicators of the mangroves' hydrogeomorphic settings, their tidal fluxes from Naples Bay, and the Bay's upstream watersheds, and less by direct urban runoff.

## 1. Introduction

### 1.1. Mangroves and water quality

Anthropogenic activity has increased nitrogen and phosphorus fluxes from terrestrial to oceanic systems world-wide by two and three fold, respectively (Howarth et al., 2002), leading to a number of problems such as harmful algal blooms (HAB) and hypoxic conditions estimated to exist in at least 762 coastal waters around the world (World Resources Institute, http://www.wri.org/our-work/project/eutrophication-and-hypoxia/interactive-map-eutrophication-hypoxia cited 27 April, 2017). Eutrophication caused by nutrient enrichment has been exacerbated by a dramatic population growth in many coastal zones. Approximately 40% of the human population now lives within 100 km of the coast (Wong et al., 2015). Southwest Florida experienced harmful algal blooms in the 2000s that were 13–18 times more prevalent than they were 50 years before (Brand and Compton, 2007). Harmful algal blooms exacerbated by water pollution cost the state of Florida $32 million per year (NOAA, 2012).

Mangrove swamps are a critical feature of tropical and subtropical coastlines around the world (Mitsch and Gosselink, 2015), and may play a significant role in improving the water quality of coastlines. Mangrove swamps have been shown to serve a myriad of other ecosystem services, including protection from the destructive force of hurricanes and tsunamis (Marois and Mitsch, 2015), nurseries for about 30% of the world's commercial fish species (Nagelkerken et al., 2008), and sinks for atmospheric carbon (Marchio et al., 2016). Mangrove wetlands often accumulate large quantities of organic matter, the result of their high productivity and anoxic soil conditions. It has been suggested that mangroves sequester an average of 174 $g\,C\,m^{-2}\,yr^{-1}$ (Alongi, 2014), with lower rates of 82–113 $g\,C\,m^{-2}\,yr^{-1}$ recently estimated in Florida mangroves that are part of this current water quality study (Marchio et al., 2016). Coastal wetlands, including mangroves, were estimated to provide services worth

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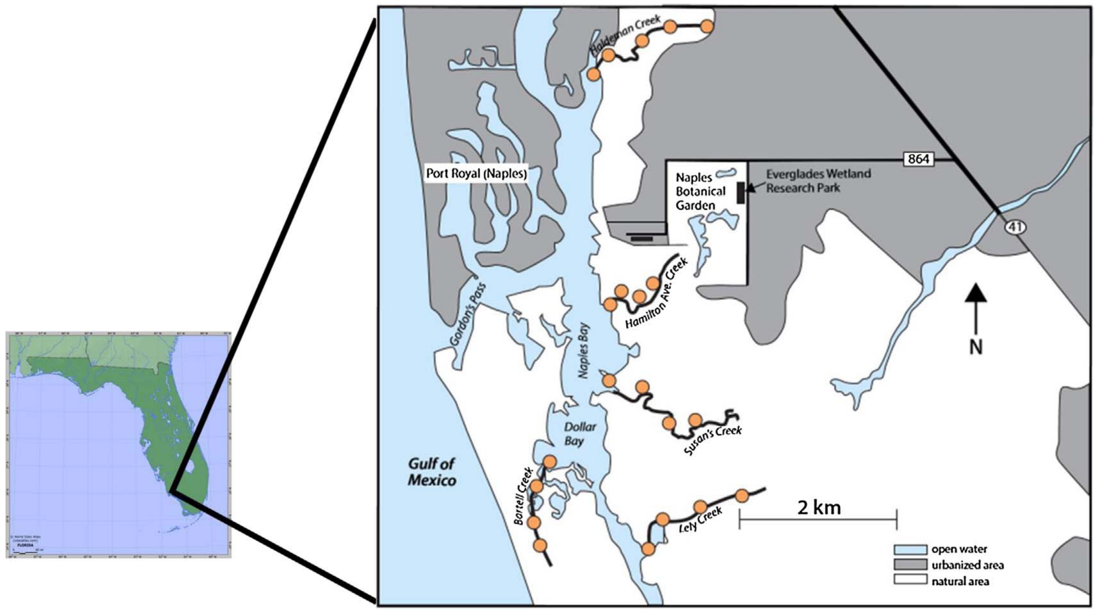


**Fig. 1.** Map detailing the five mangrove tidal creek study locations on the Greater Naples Bay area of southwest Florida. Also shown are locations of the specific water sampling sites on each tidal creek.

\$194,000 $ha^{-1} yr^{-1}$ in 2011, an order of magnitude greater than estimates from 1997 (Mitsch and Gosselink, 2015 from Costanza et al., 1997, 2014).

Despite providing valuable resources and protection, mangroves systems are on the decline around the world. As much as 35% of mangroves globally were destroyed in the last two decades of the 20th century (Valiela et al., 2001), with deforestation occurring at a faster rate in mangrove forests than in upland forests (Kauffman et al., 2014). Up to 64% of the world's remaining mangrove systems are within 25 km of large cities, making them vulnerable to nutrient pollution and other anthropogenic pressures (Millennium Ecosystem Assessment, 2005). This loss of mangrove wetland systems impacts water quality, erosion, and storm protection (Wong et al., 2015). To protect the remaining mangrove ecosystems in the world, efforts to quantify and understand its ecosystem services must continue and expand.

Mangrove wetlands may possess significant nutrient retentive abilities, trapping nutrient-laden sediments and sequestering pollution into permanent storage in soils, although published findings have not been consistent. Mangroves on a coastal tidal creek in Kenya were shown to have a sediment trapping efficiency of 64% (Kitheka et al., 2002). Mangrove mesocosm experiments showed promising results in Hong Kong, where the mesocosms retained 70% dissolved organic carbon, 75% TN and 86% TP (Wu et al., 2008). Other studies have found mangroves to be a source rather than a sink of nutrients (Rivera-Monroy et al., 1995; Sutula et al., 2003). A meta-analysis of mangrove nutrients, taking into account latitude, precipitation, experimental design, etc., found mangroves to generally act as a source of nutrients for the surrounding marine environments (Adame and Lovelock, 2011). Mangrove systems in coastal areas with high nutrient levels and *Avicennia* forests tended to export nutrients. Latitude may also play a role, as mangroves at lower latitudes have higher productivity, possibly resulting in higher levels of organic material export (Odum, 2000). Adame and Lovelock (2011) admitted that the range of different methods and environments in their meta-analysis "limited our understanding of the role of mangroves in the coastal zone," and therefore mangroves as related to nutrient sequestration.

### 1.2. Goals and objectives

This study estimates the water quality role of mangroves in southwest Florida by quantifying and comparing nutrient concentrations in several mangrove tidal creeks in Naples/Dollar Bay in southwestern Florida, USA. Specifically, this project has three objectives:

- To quantify and compare seasonal nutrient TN and TP concentrations in five tidal creeks of different size and in different states of urbanization in Southwest Florida as indicators of the role of mangroves in water quality maintenance.
- To interpret the effects of tides, urbanization, and seasons on nutrients and other water quality factors in these tidal creeks.
- To demonstrate the effects of upstream urban development on nutrients in tidal mangrove watersheds and the significance of mangroves in removing anthropogenic inputs from the watershed.

### 1.3. Hypotheses

The following hypotheses were tested in this study:

- Nutrient concentrations measured at the low tide will be lower than the concentrations at the high tide.
- Nutrient concentrations of downstream locations in tidal creeks will be lower than the concentrations at upstream sites.
- Mean nutrient levels will be higher in tidal creeks with higher upstream anthropogenic disturbances.
- Nutrients will be lower during the dry season, a period characterized by low precipitation and freshwater inflows.

## 2. Materials and methods

### 2.1. Study sites

Study sites were chosen in mangrove tidal creeks along the Greater Naples Bay area, consisting of Naples Bay (26°5′ N, 81°47′ W) and Dollar Bay (26°8′ N, 81°78′ W) on the southwestern Florida coastline