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Isolated Point Discharges into Coastal Swashes as Nutrient Sources to Coastal Waters

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By

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Abstract

Coastal water quality in the Grand Strand of South Carolina is directly influenced by human activities. Nutrient-rich runoff, stemming from numerous anthropogenic sources, finds its way into coastal waters through freshwater inputs often through tidal creeks, termed swashes. In order to better describe the amount of nutrient inputs into Singleton Swash and White Point Swash, we examine anthropogenic runoff from isolated identifiable point discharges and their nutrient concentrations. We report concentrations of dissolved inorganic nitrogen (DIN, as the sum of nitrate, nitrite and ammonium) and phosphate in discharge and creek water. We hypothesize that nutrient concentrations of isolated, minor point discharges are not significant enough to alter primary channel chemistry due to rapid flow rates, and suggest that non-point sources may play a larger role in nutrient loading in the coastal zone.

Introduction

Background

One of the largest pressures to the health of coastal ecosystems is pollution due to nutrient loading in coastal systems (Killberg-Thoreson et al. 2013). Freshwater nutrient runoff has increased due to a rise in anthropogenic activities (Schutte et al. 2013, Paerl 1999, Pastore et al. 2019, Hale et al. 2015). A surge in population of the coastal regions has caused an increase in both agriculture and developed lands, which have substantially impacted the amount of nutrients entering coastal water bodies (Killberg-Thoreson et al. 2013, Paerl 1999, Hale et al. 2015).

Freshwater runoff in South Carolina's coastal region has increased due to widespread development. Runoff can be categorized into two different groups, point-source and nonpoint-source (Libes 2009). A point-source pollutant is a chemical that can be traced directly back to its origin through a discrete and distinct input such as a pipe. A nonpoint-source pollutant refers to a chemical deposited on land and, following precipitation, enters waterways from various diffuse locations as surface and groundwater runoff (Chen et al. 2019).

Surface freshwater runoff in the coastal zone of the Grand Strand of South Carolina is often channeled to the ocean through swashes (Smith and Sanger 2015). Swashes are wide sandy fields at the location where tidal creeks reach the beach and whose geomorphology and hydrology are continuously altered due to longshore currents, extensive coastal development and discharged creek water (Legut et al. 2020, Smith and Sanger 2015). Discrete point-sources of nutrient-rich freshwater emptying into the main channel of one such swash, Singleton Swash, have also been documented (Legut et al. 2020). There is a dearth of information and data on the sources and forms of nutrient inputs into swashes, as well as, the specific role they play in the hypoxic conditions of nearshore waters. Therefore, nutrient concentrations of discrete freshwater inputs should be analyzed, located, quantified and contrasted to primary swash channels in order to better describe these nutrient inputs (Smith and Sanger 2015, Legut et al. 2020).

Dissolved Inorganic Nitrogen (DIN)

Dissolved inorganic nitrogen (DIN) is currently one of the largest sources of pollution problems in coastal systems (Kennish and Jonge 2011). Worldwide, river transport of DIN to the coastal ocean has nearly doubled within the past four decades. The greatest sources of nitrogen inputs are the use of inorganic nitrogen fertilizers, NO_x emissions from the combustion of fossil fuel and nitrogen fixation in agriculture.

In estuarine and coastal waters, dissolved inorganic nitrogen (DIN) has three main forms; nitrate (NO_3^-), nitrite (NO_2^-) and ammonium (NH_4^+). Nitrate is normally found to have highest concentrations of the three forms (Kennish and Jonge 2011). Dissolved inorganic nitrogen (DIN) is used as a reference to denote the effects of terrestrial-based nitrogen nutrients on water quality (Chen et al. 2019). In temperate waters, the seasonal flux of DIN typically has its smallest amounts in the spring and summer due to high autotrophic uptake and production and its largest amounts in the winter due to low autotrophic uptake and production (Kennish and Jonge 2011).

Phosphate

Anthropogenic inputs of phosphorus into waterways have increasingly grown from historic levels. Rapidly increasing concentrations of phosphorus within water systems has contributed to; the rise in nutrient levels, amplified productivity and helped in the degradation of water quality. A large source of anthropogenic phosphorus inputs is agriculture. A high quantity of phosphorus comes from phosphorus-containing fertilizers as well as animal manure (Kennish and Jonge 2011).

Phosphate (PO_4^{3-}) is the primary inorganic phosphorus indicator of the presence of land-based phosphorus nutrients. In estuarine waters, phosphate concentrations are normally lower than nitrate concentrations due to phosphate attaching to particulate matter or forming insoluble precipitates and therefore accumulating on the seafloor (Kennish and Jonge 2011).

Hypotheses

This study aims to address the following hypotheses:

- Freshwater inputs have higher nutrient concentrations than the tidal creek.
- Point discharges supply excess nutrients to the primary channel.
- Concentrations of nutrients from isolated, minor point discharges are not significant enough to alter primary channel chemistry due to rapid flow rates.

Methods

Study Sites

For this project two sites were studied, Singleton Swash and White Point Swash (Figure 1), both located in Horry County, South Carolina. Singleton Swash and White Point Swash are both influenced by urban development and anthropogenic activities. Freshwater point discharges have been repeatedly seen at both locations by the Sand Biogeochemistry research program at Coastal Carolina University.

Figure 1. Map of study area and the two study sites, Singleton Swash and White Point Swash

Sampling

Samples were collected from isolated freshwater point discharges and adjacent creek water at both swashes. The prescence of point discharges was determined by visual confirmation. A handheld YSI ProDSS meter with a ODO/CT (YSI Inc., Yellow Springs, OH, USA) probe assemblage was used to record water temerpature, oxygen, and salinity. The point discharge and creek water samples were collected using 10-mL polypropylene-polyethylene syringes and filtered on site through 0.2-µm, nylon-membrane in-line filters into 20-mL HDPE bottles for the nutrient analyses. All samples were stored on ice in a cooler for transportation back to the laboratory where they were then frozen until analysis (Legut et al. 2020). Flow rates of point discharges were collected from Singleton Swash point discharges using a 250-mL graduated cylinder and a stopwatch.

Analytical methods

A microvolume column was set up for the reduction of nitrate (NO_3^-) to nitrite (NO_2^-), according to the principles in Strickland and Parsons (1972), and nitrite was analyzed spectrophotometrically (Bendschneider and Robinson, 1952). Ammonium (NH_4^+) was analyzed by fluorescence according to Holmes et al. (1999), and phosphate (PO_4^{3-}) was analyzed spectrophotometrically by the molybdenum blue complexation method (Murphy and Riley, 1962; Hansen and Koroleff, 1999).

Statistical Methods

Data was explored graphically and statistically using MS Excel, as described in Hannides et al. (2014). Statistically, concentrations were compared using a two-factor ANOVA with replication for the samples from White Point Swash. For the Singleton Swash samples, concentrations were compared using a single-factor ANOVA.

Comparison of nutrient sources

The relative contribution of nutrients from point discharges as compared to nutrients from the primary channel was quantified as Percent Contribution, *PC* (%), as follows:

$$PC = \frac{F_{pd} \times C_{pd}}{F_{pc} \times C_{pc}} \times 100 \qquad 1$$

where *F* is flow rate (L/min) and *C* is nutrient concentration (µmol/L) for point discharges (*pd*) and the primary channel (*pc*). The calculation was only performed for Singleton Swash where measurements of flow rates of point discharges were conducted. The flow rate for the primary channel at Singleton Swash was collected from Pastore et al. (2019) based on the ebb-flow measurements.

Results

Salinity and Oxygen

The primary channel at both Whitepoint Swash and Singleton Swash had higher salinites (PSU) than their corresponding point discharges (Figures 2-3). Oxygen saturation (%) was higher in the primary channel compared to the point discharges for Whitepoint Swash on 2/26/21 and for Singleton Swash on 3/30/21 (Figure 4-5). Oxygen saturation (%) was lower in the primary channel compared to the point discharge for Whitepoint Swash on 1/26/21 (Figure 4).

Dissolved Inorganic Nitrogen (DIN)

DIN concentration of the point discharges was larger compared to the primary channel concentrations for Whitepoint Swash on 1/26/21 as well as Singelton Swash (Figure 6-7). For Whitepoint Swash on 2/26/21, DIN point discharge concentrations were lower compared to the primary channel concentrations (Figure 6). Point discharge concentrations were statistically significantly different compared to the primary channel ($p < 0.05$).

Phosphate

Phosphate concentrations for point discharges were higher compared to the primary channel concentrations at both Whitepoint Swash and Singelton Swash for all sampling events (Figure 8-9). Concentrations of point discharges compared to the primary channel were found to be statistically significantly different ($p < 0.05$).

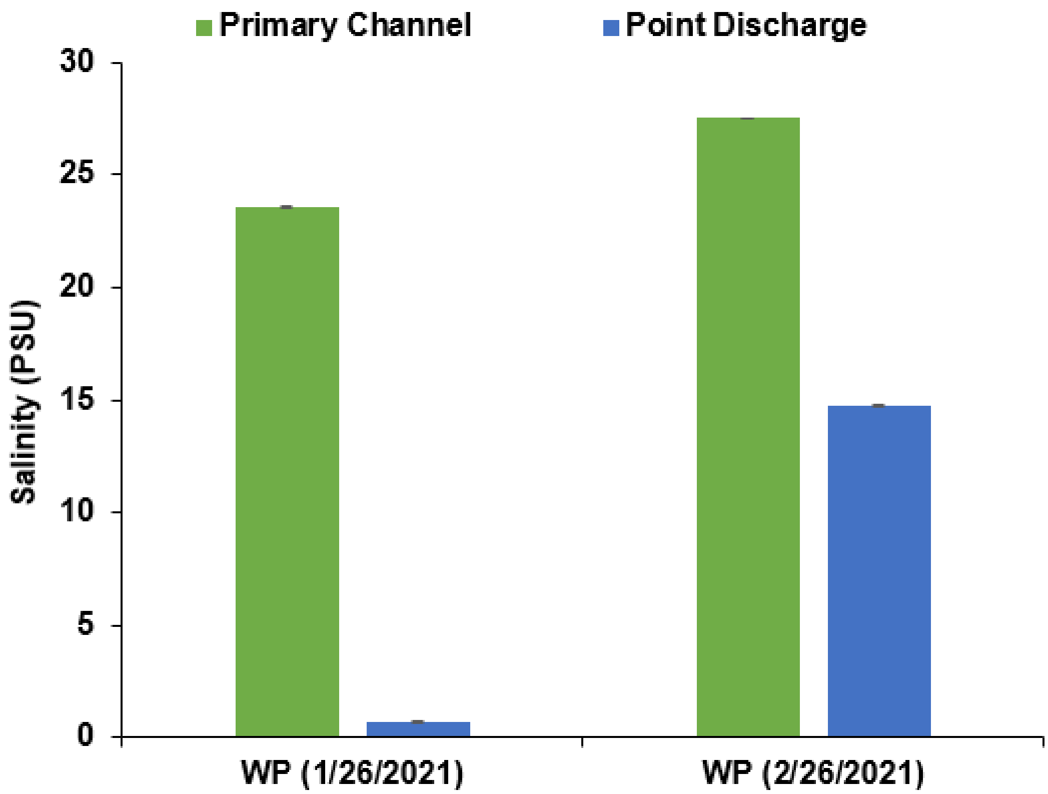

Figure 2. Average Salinty (PSU) collected at Whitepoint Swash (WP) on 1/26/21 and 2/26/21 for the primary channel and the point discharges. Error bars represent one standard deviation.

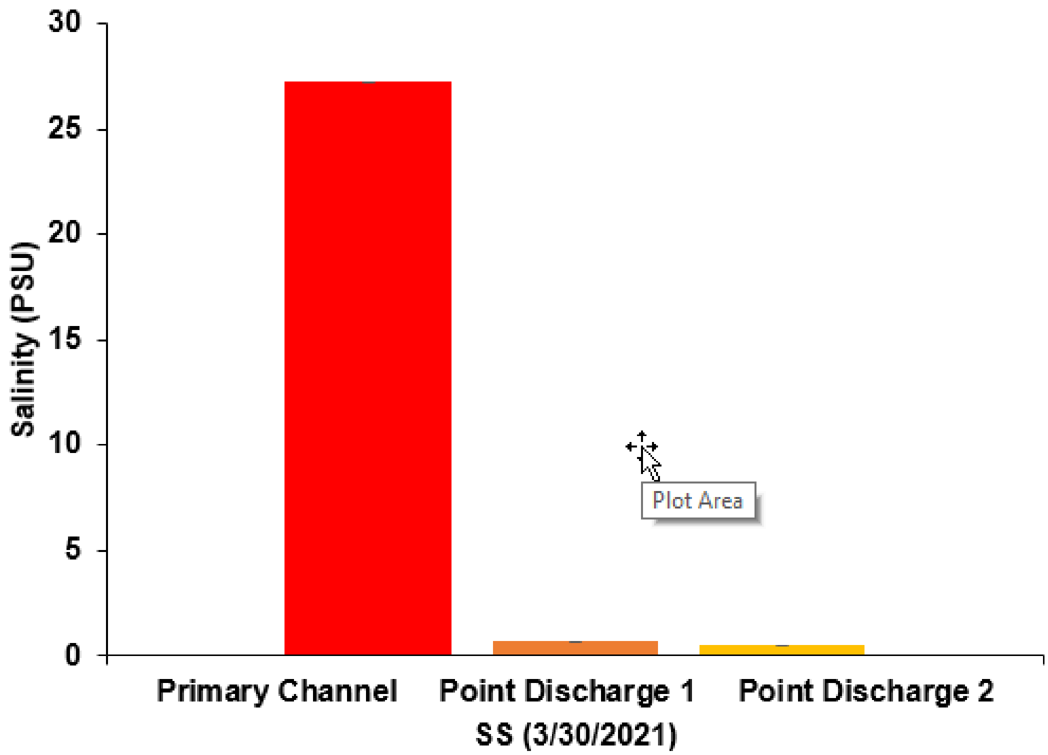

Figure 3. Average Salinty (PSU) collected at Singelton Swash (SS) on 3/30/21 for both the primary channel and the point discharges. Error bars represent one standard deviation.

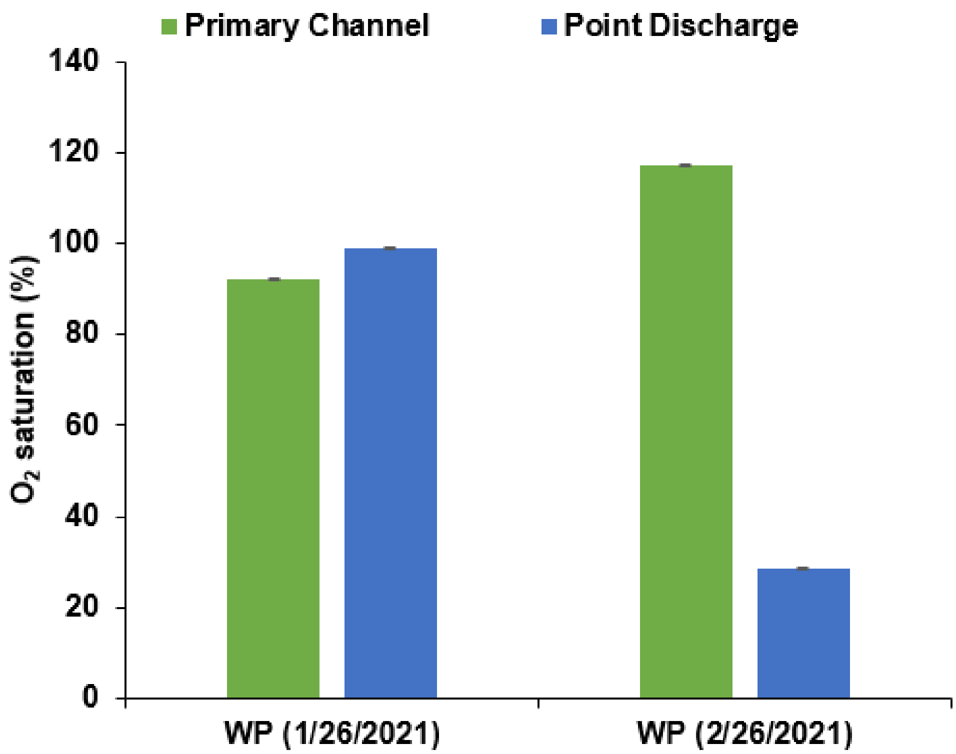

Figure 4. Average oxygen saturation (%) collected at Whitepoint Swash (WP) on 1/26/21 and 2/26/21 for the primary channel and the point discharges. Error bars represent one standard deviation.

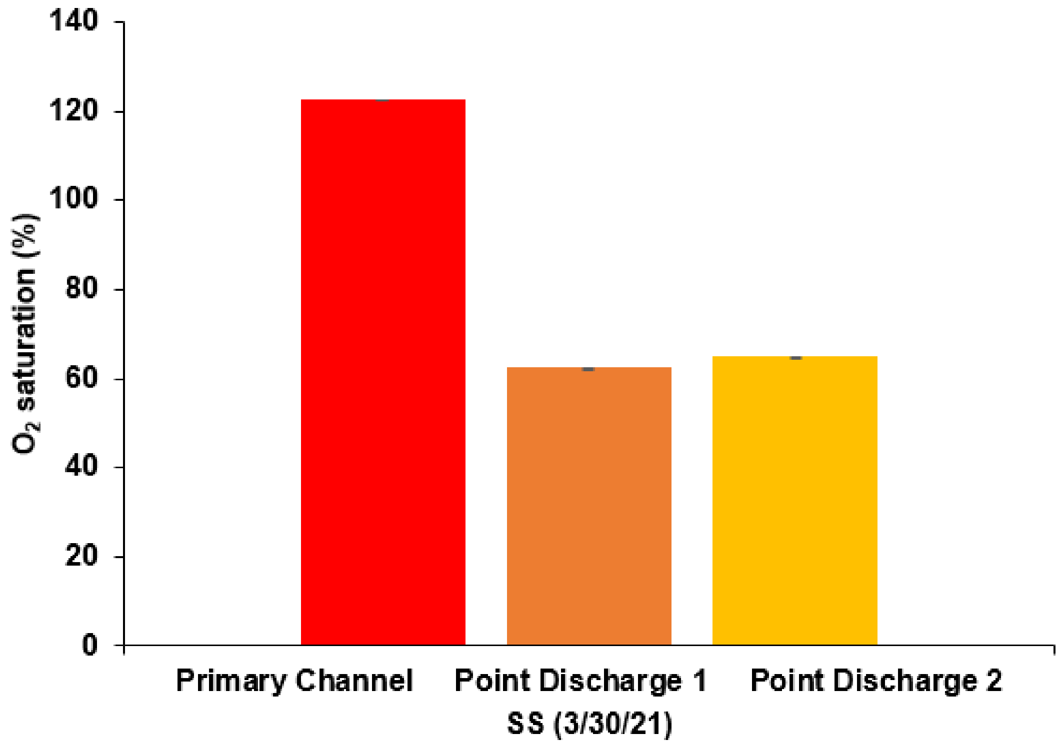

Figure 5. Average Oxygen saturation (%) collected at Singelton Swash (SS) on 3/30/21 for the primary channel and the point discharges. Error bars represent one standard deviation.

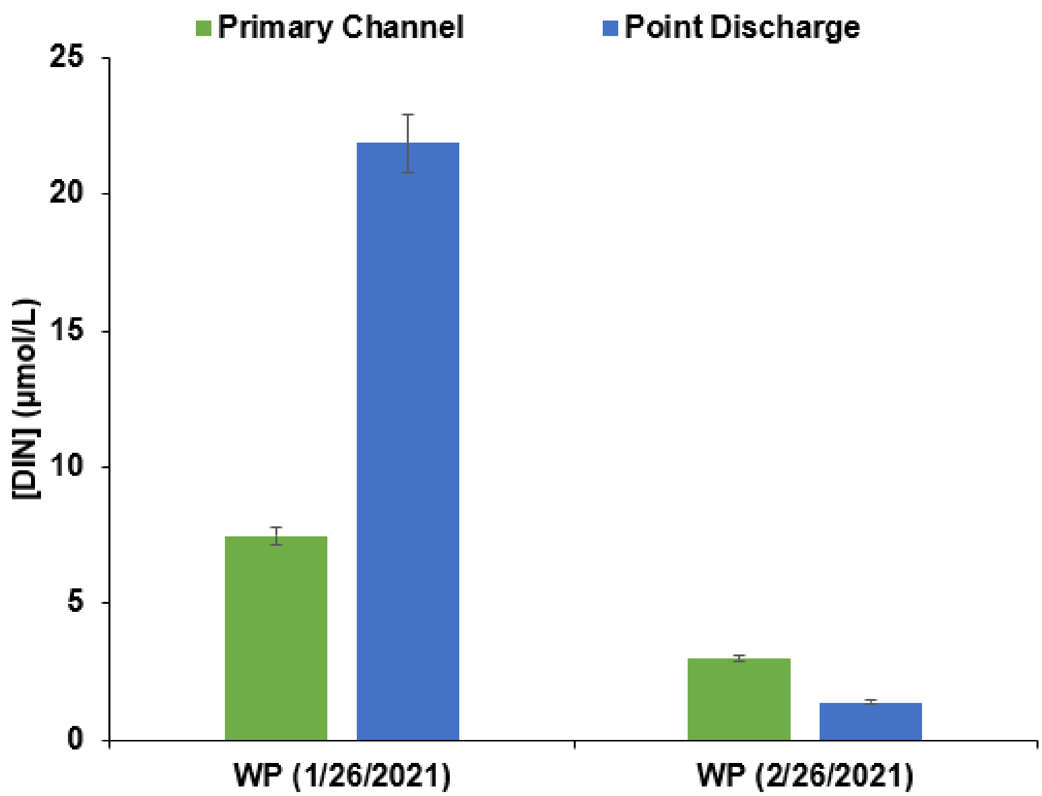

Figure 6. Average [DIN] (µmol/L) collected at Whitepoint Swash (WP) on 1/26/21 and 2/26/21 for the primary channel and the point discharges. Error bars represent one standard deviation.

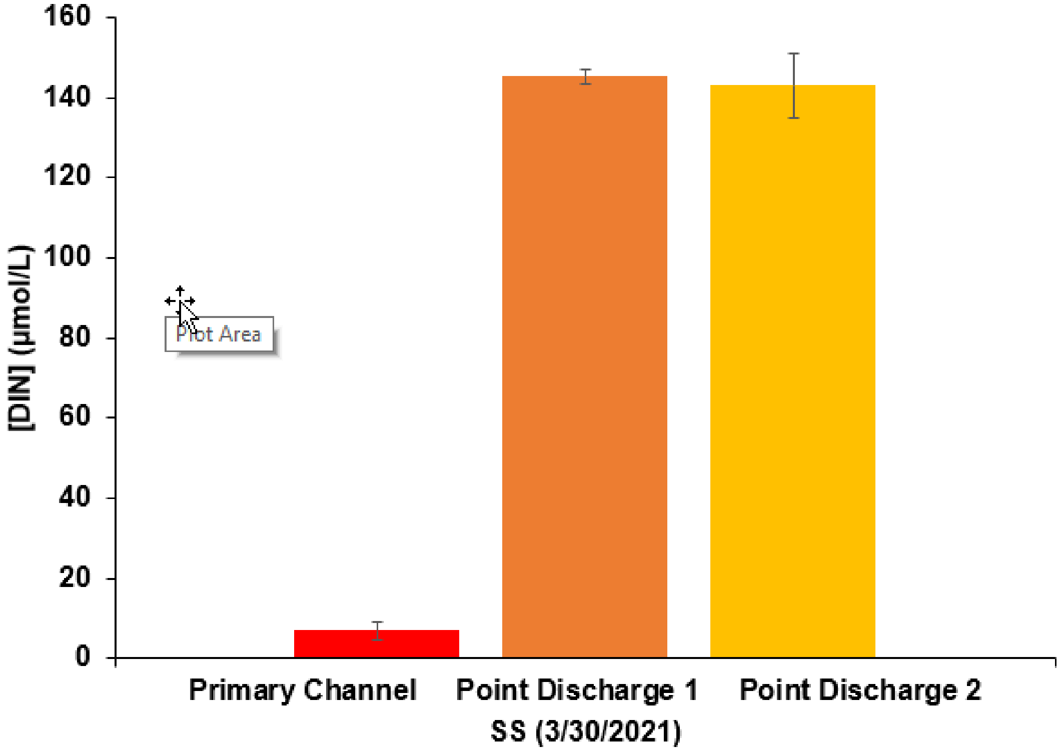

Figure 7. Average [DIN] (µmol/L) collected at Singelton Swash (SS) on 3/30/21 for the primary channel and the point discharges. Error bars represent one standard deviation.

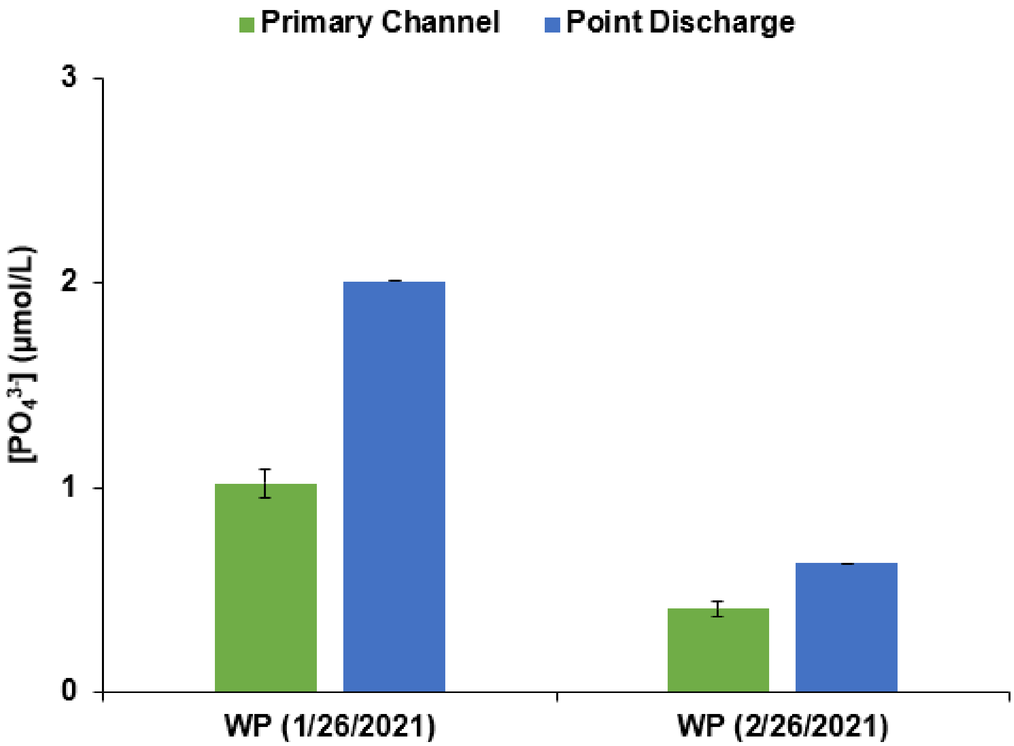

Figure 8. Average [PO_4^{3-}] (µmol/L) collected at Whitepoint Swash (WP) on 1/26/21 and 2/26/21 for the primary channel and the point discharges. Error bars represent one standard deviation.

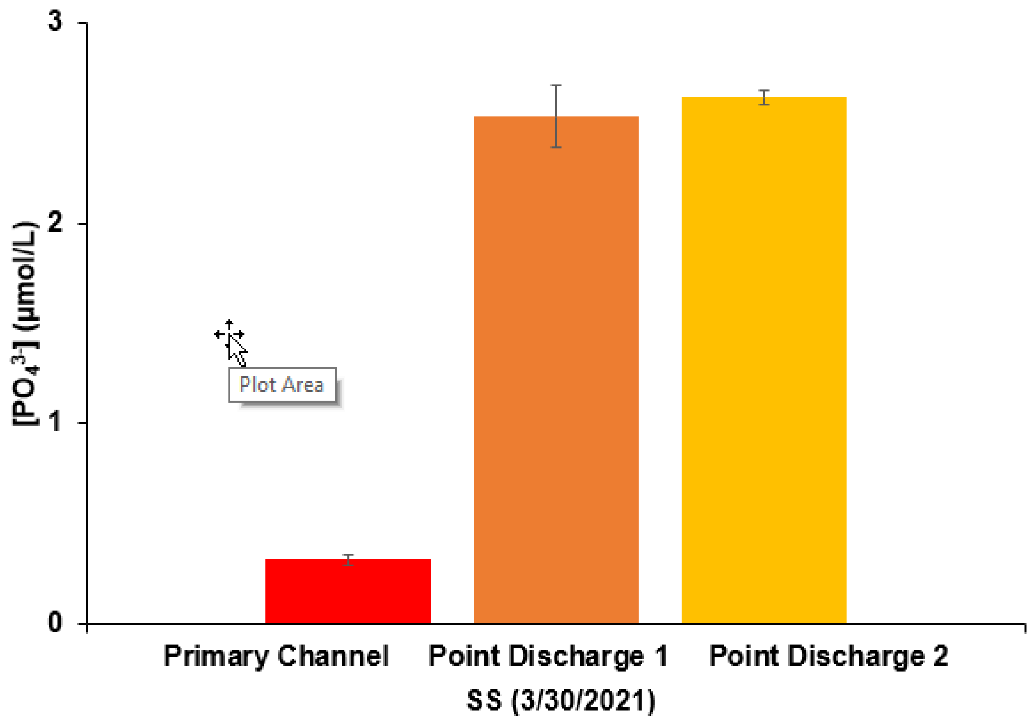

Figure 9. Average [PO_4^{3-}] (µmol/L) collected at Singelton Swash (SS) on 3/30/21 for the primary channel and the point discharges. Error bars represent one standard deviation.

Comparison of nutrient sources

Table 1 indicates flow rates calculated for Singelton Swash point discharges and the primary channel, nutrient concentrations and percent contribution of the nutrients from the point dischargs to the primary channel.

Table 1. Singleton Swash water flow, nutrient concentrations and percent contribution of nutrients from the point discharges compared to the primary channel. Primary channel water flow is based on ebb-flow measurements in the primary channel from Pastore et al. (2019).

Location	Water Flow (L/min)	[DIN] (μmol/L)	$[PO_4^{3-}]$ (μmol/L)	% Contribution [DIN]	% Contribution $[PO_4^{3-}]$
Primary Channel	1.26×10^6	6.8	0.3		
Point Discharge 1	30.0	145.3	2.5	0.05%	0.02%
Point Discharge 2	25.9	143.1	2.6	0.04%	0.02%

Discussion

Salinity and oxygen

The salinity of the primary channel for both Whitepoint Swash and Singleton Swash were higher than their corresponding point discharges supporting that these point discharges are freshwater (Figures 2-3).

Oxygen percent saturation was higher in the primary channel compared to the point discharges for Whitepoint Swash on 2/26/21 and for Singleton Swash on 3/30/21 (Figure 4-5). The higher percent saturation could be from a large quanity of submerged aquactic macroalgae seen in the primary channel at Singelton Swash. On 1/26/21, oxygen percenet saturation was smaller in the primary channel compared to the point discharge for Whitepoint Swash (Figure 4). This pattern difference could be due to the point discharge having a lower temperature. Dissolved oxygen in surface water is influenced by temperature and has both a daily and seasonal cycle. Colder water can contain more dissolved oxygen than warm water. During the winter and spring seasons, dissolved oxygen is expected to be high while the water temperatures are low (Libes 2009).

Dissolved Inorganic Nitrogen (DIN)

Nitrogen inputs into coastal waters have increased due to a rise in agriculture runoff, industrial activities and sewage effluent (Schutte et al. 2013). DIN concentration of the point discharges was greater than the primary channel concentrations for Whitepoint Swash on 1/26/21 as well as Singelton Swash (Figure 6-7) supporting that point discharges supply excess nutrients to the primary channel. On 2/26/21, the concentration of DIN for the point discharge was lower than the primary channel (Figure 6). The point discharge could be lower than the primary channel due to less rainfall to support runoff or a lack of fertilization in the resdiental areas. The nitrogen could also have been taken up by the shore plants lining the point discharge.

Phosphate

Human activities have lead to a mobilization of phosphorus into the environment that has increased substaintially since the industrial revolution (Hale et al. 2015). Concentrations of phosphate for the point discharges were higher than the primary channel concentrations at both Whitepoint Swash and Singelton Swash for all sampling events (Figure 8-9). This pattern supports that primary discharges transport excess nutrients into the primary channel.

Comparison of nutrient sources

The percent contribution of DIN and phosphate for point discharges compared to that of the primary channel at Singleton Swash was found to be less than 2%. Due to the high flow rate of the primary channel, the excess nutrients being added into the primary channel are not significant enough to alter the chemistry of the primary channel itself. In the future, flow rates of the primary channel and point sources should be obtained from both swashes.

Because the flow rates from point sources were too low to alter the primary channel chemistry, we do suggest that non-point sources such as tidal creeks may play a larger role in nutrient loading in the coastal zone. Data should be obtained from the coastal ocean as well as the primary channel and point discharges to look at the potential effects of the rapid flushing of the nutrients out of the swash and into the coastal ocean. A longer data set of point discharge samples should be obtained to compare the point discharges to a seasonal time-series of the primary channel. This will allow correlations to be made between seasonality and nutrient concentrations. Submereged aquatic macroalgae data could also be looked at due to nutrient uptake in the primary channels.

Conclusion

Long Bay, South Carolina is a rapidly growing area. With this growth comes urbanization and increased anthropogenic activities which generate nutrient rich runoff. Isolated freshwater point discharges are inputing excess nutrients into the primary channel at both Whitepoint Swash and Singleton Swash. While excess nutrients are being added into the primary channel, the flow rates are too low for these nutrients to alter the chemistry of the primary channel. Since alteration of the tidal creek chemistry by point discharges is unlikely, non-point sources may play a bigger role in nutrient loading into the coastal zone. It is important to monitor the health and chemistry of these tidal creeks in order to understand the role they play in delivering nutrients to the coastal ocean.

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