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# The impact of organic and intensive farming on the tropical estuary

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## ABSTRACT

Two marine farm ponds, one practicing the organic method and the other practicing the intensive method of shrimp farming located near the Guaraíras estuary (Rio Grande do Norte, Brazil), have the potential of causing eutrophication of the estuary by disposal of excess organic matter and nutrients. Here we report nutrients, chlorophyll concentrations and stable carbon isotope ratios from the respective ponds to access differences in their potential impact on estuary water quality. Total phosphate and chlorophyll-a concentrations of pond water under the organic and intensive management method were different (i.e., 3.39 ± 0.63 μM and 17.87 ± 7.89 μM for total phosphate and 11.88 ± 9.91 μg/L and 64.46 μg/L for chlorophyll-a, respectively). With the exception of $pCO_2$, parameters related to carbonate system also showed greater values in the organic pond compared to the intensive pond. Sediment total phosphorus concentrations were: 1.48 ± 0.13 mg/g for the organic pond and 5.99 ± 1.30 mg/g for the intensive pond. The mean stable carbon isotopic composition of the shrimp muscle tissues from the organic pond ($\delta^{13}C$ = -17.1 ± 0.0‰) and intensive pond ($\delta^{13}C$ = -18.2 ± 0.1‰) were very similar, despite the fact that, compared to the $\delta^{13}C$ value shrimp tissue, the feed in the intensive pond had very different carbon isotope ratios ($\delta^{13}C$ = -25.3 ± 0.1‰). Pond water and sediments from the intensive shrimp farm, by having a higher phosphorus concentration, have a greater potential for causing estuary eutrophication compared to the organic shrimp farm. The small range in carbon isotope ratio between the shrimps from the two types of management indicates that the commercial shrimp feed had little contribution to the biomass of the cultured shrimp in the intensive shrimp pond.

## 1. Introduction

In traditional intensive shrimp cultures (IT), a substantial portion of waste pond water is discharged daily into estuarine streams, necessitating a similar replacement of clean source water. The production of 1.0 kg of shrimp using traditional intensive management, consumes approximately 20,000 L of waste water, which is ultimately released into estuarine system (Timmons and Losordo, 1994). In addition to the chemical and biological impacts of intensive farming, the destruction of mangroves associated with the construction of ponds to make way for shrimp ponds have left coastal areas exposed to erosion and flooding (Orchard et al., 2015; van Wesenbeeck et al., 2015). This in turn, has altered natural drainage patterns, increased salt intrusion, and removed a critical habitat for many aquatic species.

As a result of such negative environmental and social consequences from intensive farming, organically-managed shrimp farming (OG) techniques were developed. The organic shrimp farming technique is based on the absence of chemical products, restricted density of shrimps per pond and environmental monitoring and preservation around the farm (Rönnbäck, 2003).

Nutrients, total alkalinity (TA), aqueous partial pressure of $CO_2$ ($pCO_2$), saturation state of carbonate (Ω), pH and dissolved oxygen (DO) are critical indicators of water quality ranging from oceans to ponds. Parameters such as TA, $pCO_2$, Ω and pH are closely linked to the inorganic carbon cycle and are proxies of water quality (Howland et al., 2000; Ramos e Silva et al., 2002; Ovalle et al., 1990;

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Ramos e Silva et al., 2010a,b). Total alkalinity indicates a pond's buffering capacity, i.e. its ability to resist large pH changes. The most important components of alkalinity are bicarbonates, carbonates, phosphates and borate. Large daily changes in pH can cause stress, poor growth and even death of farmed shrimps or the natural biota. Shrimps can live in a broad range of alkalinity concentrations. The desired total alkalinity level for most shrimp species lies between 50 and 150 mg/L $CaCO_3$, but no less than 20 mg/L. High $pCO_2$ is caused by a high organic matter decomposition rate with a limited oxygen availability, which in turn, affects the pH and the saturation state of carbonate $\Omega$. The speciation of chemical elements is affected by pH (Millero, 2006) and the dissolved oxygen (DO) reflects the balance between biologic production and respiration in water bodies (Chester, 1990). Nutrient enrichment in coastal estuaries, brought about by traditional Intensive shrimp farming, might have long-range consequences in estuarine system, such as eutrophication and the ensuing consumption of DO (Oestreich et al., 2016).

Analyses of $\delta^{13}C$ values of food and shrimp have been regularly used to determine the importance of different feeding sources for the shrimp population (Shearer and Kohl, 1993). The use of stable isotopes to study marine food chains is useful as long as the isotopic signature of the potential food sources in question have sufficiently distinct $\delta^{13}C$ values (Burns et al., 1998). For example, Burfor et al. (2004) used stable carbon isotopes from various carbon sources to study the diet of shrimps on extensive shrimp farms. In addition, the isotopic identity of sediment organic matter and particulate carbon might be useful to identify effluent sources.

To better understand the impact of different shrimp farm management practices on the quality of water and on sediment, this study compared the chemical characteristics of sediments and water of an IT and an OG shrimp pond connected to an estuarine system in Brazil (Guaraíras estuary, Rio Grande do Norte, Brasil). In addition, we determined the carbon isotope ratios of muscle tissue from the shrimp populations (*Litopenaeus vannamei*), the soil organic matter and suspended particulate carbon on both ponds. We test the hypothesis that OG shrimp should have a different carbon isotopic composition than that IG shrimp, since their foods sources are likely to be different.

## 2. Materials and methods

### 2.1. Study site

The Guaraíras estuary is located nearly 90 km to the south of the city of Natal in the state of Rio Grande do Norte, Brazil (06°05′S and 06°15′S; 35°00′W and 35°15′W) (Fig. 1). This shallow estuary represents an area under the influence of shrimp farms, agriculture and domestic sewage. The mangrove forests which surround this estuary have been partially displaced by shrimp farms. Approximately 93,987 inhabitants live around this system, which consists of 2874 ha of shrimp breeding farms and 16,664 ha of sugar cane monoculture. The climate is dry from September to December and the rainy season occurs from February to August, however, since 2001, January shows the highest precipitation levels. The mean annual temperature and precipitation are 26.8 °C and 1600 mm, respectively. Average depth of the water column in the estuary is 2 m. The water quality varies between the rainy and dry season: salinity: 0.30–35.70 psμ; pH: 7.10–8.22; TA: 0.88–2.57 mM; dissolved oxygen saturation: 36.84–92.26%; $PO_4$: <0.1–4.0 μM; $N_{OX}$: 9.30–21.00 μM (Ramos e Silva et al., 2010a,b).

Nitrogen and phosphorus input into the Guaraíras estuary was estimated to be 1429 and 755 t/yr, respectively (Lacerda et al., 2006). The previously mentioned authors have quantified different sources of N and P, such as agriculture, husbandry, waste water and urban runoff.

Management practices are different for each IT and OG shrimp breeding system, with respect to stocking density of the shrimp *Litopenaeus vannamei,* breeding cycles, the feeding and water replacement regime (Fig. 1). The samples were collected from shrimp ponds which are between 2 and 6 ha, respectively for the IT and for the OG. All the samples were collected during one crop cycle which comprised pre-stocking (A), shrimp culture (B) and pre-harvest (C). Sampling was conducted after the rainy season between Aug and Oct 2005. Such a sampling design took into consideration the effects of different management practices (OG and IT) related to water chemistry of the Guaraíras estuary, which supplies water to the shrimp ponds (Ramos e Silva et al., 2010a,b). As for the shrimp pond sediments (OG and IT), the reference data were based on published data by Ramos e Silva et al. (2007) on shrimp ponds built on former mangrove forests.

### 2.2. Collection protocols and analyses

#### 2.2.1. Water

Samples were collected from each shrimp pond at the surface (0.5 m), using an oceanographic bottle type Go-Flo (General Oceanics, model 1080) between 08:00 a.m. and 10:30 a.m., totaling nine different sample collection spots from each pond at every stage of crop cycle. The rate of water exchange per rearing cycle ($\approx$120 days) varied between both the OG and IT ponds (Fig. 1).

Water samples were mixed with chloroform (1 mL:1000 mL) and filtered "in situ" through 0.45 μm cellulose acetate membrane filters using a clean Nalgene filtration system. Total ammoniacal nitrogen (TAN), dissolved oxidized nitrogen ($N_{OX} = NO_2^- + NO_3^-$), phosphate ($PO_4 = H_3PO_4 + H_2PO_4^- + HPO_4^{2-} + PO_4^{3-}$), total dissolved phosphate (TDP) and total phosphate (TP), were determined by spectrophotometry using a Varian Instrument, Cary 100 UV-VIS Spectrophotometer (Grasshoff et al., 1983).

Total dissolved phosphate and total phosphate were previously treated using the digestion solution of potassium persulfate ($K_2S_2O_8$) (Grasshoff et al., 1983). Un-ionised ammonia ($NH_3$) was calculated (Millero, 2006), from measurements of temperature, salinity, pH and TAN using the DAO software MS Excel version (Prime Solution). Standards for all analyses were made up in deionized water and the accuracy of repeated analyses ($n = 10$) showed satisfactory levels, with relative errors lower than 10% for nutrients determinations. All nutrient analyses were conducted within 48 h from collection.

Oxygen concentrations were determined according to modifications of the Winkler methodology (Grasshoff et al., 1983). As a result, it was possible to determinate the dissolved oxygen saturation (DOS), using temperature (T) and Salinity (S) data run by DAO software.

Samples for chlorophyll-a (Chl-a) determination were filtered through Whatman glass-fiber GF/C 1.2 μm porosity filter, and the filters were stored in the cool and dark for less than 24 h prior to analysis. In the laboratory Chl-a was determined by spectrophotometry (Strickland and Parsons, 1972).

Total alkalinity was determined in water collected in 300 mL BOD reagent bottles (Kimble), poisoned with mercuric chloride (DOE, 1994), $HgCl_2$, followed by the open cell titration system (van den Berg and Rogers, 1987), and the concentrations obtained by DAO software (Prime Solution). The technique accuracy reached ±0.2 mV, 36 μmolL/L. All TA determinations were made in less than 12 h from collection. The pH was determined in water collected as above according to the methodology (Millero et al., 1993; Millero, 1986) defined for estuarine waters where the "Tris" buffer were signed in the lab with m-cresol purple indicator (Patsavas et al., 2013; Dickson et al., 2007) through a Varian Instruments Cary