



Relationship between anthropogenic sewage discharge, marsh structure and bird assemblages in an SW Atlantic saltmarsh

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ARTICLE INFO

Article history:

Received 10 June 2010
Received in revised form
6 December 2010
Accepted 7 December 2010

Keywords:

Saltmarsh bird
Spartina alterniflora
Eutrophication
Coast
Bahía Blanca estuary
Argentina

ABSTRACT

One of the main effects of urbanization on coastal areas is through the discharge of sewage, which increases nutrient concentrations in the receiving environment. Salt marshes, like other coastal marine environments, are limited by nutrients, mainly nitrogen, and thus increasing nutrient loadings to a marsh may have consequences on marsh characteristics. We evaluated how the effects of nutrient enrichment in the form of sewage input, affected the vegetation structure and bird assemblages in a *Spartina alterniflora* salt marsh system near Bahía Blanca, Argentina (39° 01' S – 56° 25' W). Surveys of nutrient concentration, vegetation and birds were made at three different distances from the sewage discharge source. The concentration of ammonium, phosphate, and nitrate and the percent organic matter was higher in marshes nearest to the sewage discharge source. Bird composition and abundance, and vegetation physiognomy changed along a gradient of nutrient concentration. The increased habitat complexity found near the areas of higher nutrient concentration was exploited by birds that use neighboring interior and coastal habitats, including *Spartina densiflora* marshes, freshwater marshes and upland shrubby habitats. Our results show that local increases of nutrient inputs directly changed the vegetation physiognomy, and indirectly the composition and abundance of bird assemblages.

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1. Introduction

The human population tends to live near the coastline (Wolanski, 2007), and thus, human activities can have greater impacts on the coastal ecosystems than on inland habitats (UNEP, 2006; Valiela, 2006). One of the main results of coastal populations is the discharge of sewage, which involves increased nutrient concentrations in the coastal environment (GESAMP, 1990). Salt marshes, like other coastal ecosystems, have relatively low-nutrient supplies (Valiela and Teal, 1974), and so nutrient increases can have large consequences i.e., changing the (1) structural complexity of marsh plants by enhancing biomass and stem density, (2) species composition, and (3) zonation patterns (Levine et al., 1998; Daleo et al., 2008). Also, nutrient increases may lead to marsh subsidence and habitat fragmentation, depending on the balance between sediment depositions, increased plant production, and increased decomposition (Valiela and Teal, 1974; Harper, 1995; Deegan, 2002). Specifically, in salt marshes characterized by large monospecific plant stands, nutrient enrichment may modify the plant physical structure by changing the plant growth form (Deegan, 2002). Nitrogen is usually

the limiting nutrient controlling aboveground salt marsh vegetation production (Mendelssohn, 1979) and its availability increases the plant canopy and standing stocks, which is followed by higher rates of vegetation decay (Mitsch and Gosselink, 2000), and changes in species composition (Craft et al., 1995; Vaithianathan and Richardson, 1997). A case largely studied in the northern hemisphere is the change of the dwarf form of *Spartina alterniflora* into the tall form as a result of an increase in nutrients loading to a marsh (Valiela and Teal, 1974; Valiela et al., 1978). This increased nitrogen loading, however may or may not lead to a net gain of the marsh depending on the balance between the change in marsh plant production and decomposition. Increases in the primary production or vegetation biomass may produce more detritus (Harper, 1995; Deegan, 2002) which is important in food webs (Deegan et al., 2000) and in creating peat that forms the physical structure of the marsh platform (Friedrichs and Perry, 2001). Dead vegetation deposition ('wracks') on coastal marshes is a natural disturbance that can increase habitat heterogeneity (Valiela and Rietsma, 1995; Minchinton, 2002). Thus when nutrients loadings to a salt marshes increase we expect greater vegetation heterogeneity because of the increased canopy structure and more frequent occurrence of wracks.

Vegetation structure, composition, and floristic characteristics are substantial factors influencing bird habitat selection, because

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these factors provide food, nesting sites, and cover from predators (Macnally, 1990; Vickery et al., 2001; Buchanan et al., 2006). Individuals select habitats that are an optimal combination of resources that allows them to perform multiple activities (e.g., foraging, breeding, roosting; Hilden, 1965; Fretwell and Lucas, 1970; Block and Brennan, 1993; Steele, 1993). Thus habitat structural heterogeneity is often a good predictor of bird diversity (Mac Arthur and Mac Arthur, 1961; Wiens, 1973; Roth, 1976). This result is probably due to the role of habitat complexity in promoting niche diversification (Wilson, 1974; Roth, 1976). There are many examples of the effect of nutrient enrichment on the aquatic environment (i.e., lakes estuaries; Robledano et al., 2008), such as those generated by algal blooms on waterbirds (Rosa et al., 2003), waterbird breeding (Rönkä et al., 2005) and shorebirds (Raffaelli, 1999; Lopes et al., 2006). Bird abundance is positively correlated with lake nutrient levels (Nilsson and Nilsson, 1978; Hoyer and Canfield, 1990, 1994; McCarty, 1997). However, although the effects of eutrophication are a well studied phenomena worldwide (Vitousek et al., 1997; Valiela, 2006), we are not aware of studies on the effects of nutrient enrichment on bird assemblages associated with salt marsh habitats.

The salt marshes of the SW Atlantic are being modified at an increasing rate (Costa et al., 2009), primarily by cattle grazing, fire (Isacch et al., 2004), and sewage discharges (Nebbia and Zalba, 2007; Martinetto et al., 2010). As happens elsewhere, in this region there are sewage discharges into the salt marshes. Specifically, there is an important sewage discharge on a *Spartina alterniflora* salt marsh in Bahía Blanca (Argentina) where salt marshes develop characteristics of those of the SW Atlantic (Isacch et al., 2006). Because increased nutrients on a salt marsh are expected to increase vegetation structure from the direct consequences of eutrophication (Daleo et al., 2008), we predicted that bird assemblage will also change from the indirect influences. Thus, we studied how nutrients change along a gradient from the sewage discharge source, and how this gradient is related with the vegetation structure and bird composition and abundance.

2. Materials and methods

2.1. Study area

The study was performed at the Bahía Blanca estuary (39°01'S–56°25'W; Argentina), which includes one of the largest SW Atlantic salt marshes (Isacch et al., 2006; Fig. 1). The bay has a total area of 2300 km² (Montesarchio and Lizasoain, 1981), with 10% of that surface covered by salt marshes and 20% by mudflats (Isacch et al., 2006). The salt marsh vegetation is dominated by two species; *Spartina alterniflora* grows in the lower marsh, and *Sarcocornia perennis* grows in the upper marsh. The industrial and port city of Bahía Blanca (300,000 inhabitants) is located on this coast. This city discharges its sewage into the bay relatively far from the city (Fig. 1). As in most of the bay, a large salt marsh dominated by *S. alterniflora* develops around the discharge point. Our observations suggested that there are strong variations in the salt marsh vegetation characteristics linked with the sewage discharge, and that they are not typical of a natural gradient. The latter conclusion is supported by a study about biomass variation of *S. alterniflora* marshes developed in that region (Isacch et al., 2007), in which it was found that *S. alterniflora* plants reached larger sizes near the sewage discharge.

Three sites were selected at different distances from the sewage to study the relationship between anthropogenic nutrient concentration, the vegetation and birds, (Fig. 1). The salt marsh growing around the sewage discharge pipe and the proximal part of the discharge focus, was considered as the area of maximum nutrient effect (Naposta marsh, 10 ha; Fig. 1). A second site located approximately 200 m from that source was considered as an area of

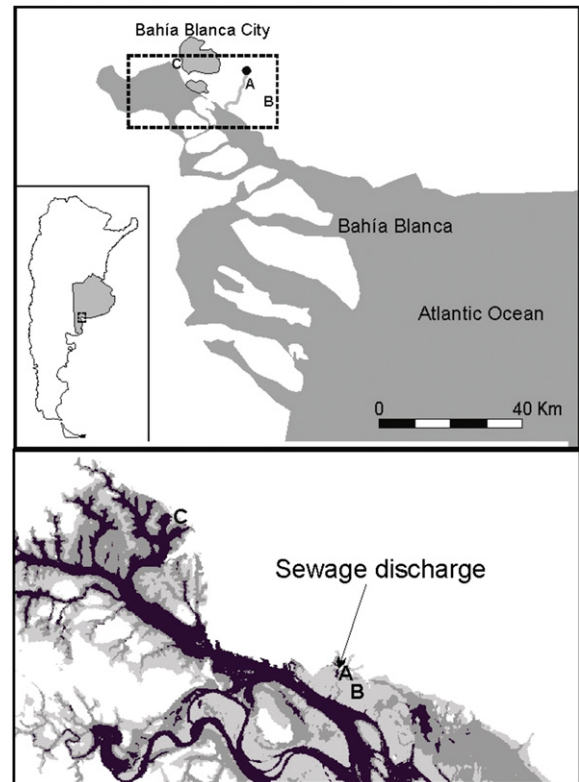


Fig. 1. Top: Bahía Blanca (Argentina) during a low tide. White dotted lines enclose the amplified area included in the bottom image. The black dot represents the location of the sewage discharge source. The inset in the lower left shows the location of the study area in Argentina. Bottom: a detail of the sewage discharge source and the three sites sampled (A, B and C) in *Spartina alterniflora* salt marshes from Bahía Blanca estuary. The four main habitats identified here are uplands (white), salt marshes (light grey), mudflat (dark grey) and sea (black). Letters indicate the location of the three sites studied: (A) the Naposta marsh located near the discharge site; (B) the Midway marsh, located 200 m from the discharge source; and (C) the Maldonado marsh 10 Km from the discharge source.

medium effect (Midway marsh, 11.5 ha; Fig. 1). A third site located at 10,000 m from the main discharge source was considered as an area of low effect (Maldonado marsh, 14.5 ha; Fig. 1). All marshes have similar tidal conditions, given that they are positioned to the SW, and were located at the same distance (~1500 m) from the main tidal channel. We assumed, therefore, that the three marshes are similar except for their exposure to the sewage outfall.

2.2. Nutrient levels

To evaluate if the sewage discharge caused nutrient enrichment of the soil, we collected sediment samples to determine the total organic matter content (OM), concentration of dissolved inorganic nitrogen (nitrate and ammonium), and concentration of inorganic phosphorous (i.e., phosphate) in porewater. Twenty sediment samples were obtained using a stratified random sampling design at different distances from the sewage channel: 20 m and 80 m (Naposta marsh), 150 and 220 m (Midway marsh), and 10,000 m (Maldonado marsh). Sediment samples were collected by pushing a PVC core (3 cm diameter, 8 cm length) into the sediment. Cores were immediately transported to the laboratory, where porewater was obtained by centrifugation (9000 × g, 10 min), filtered, and stored at –20 °C until the analysis of dissolved nutrients. The nitrate concentration in porewater was determined calorimetrically as nitrite after reduction by cadmium followed by diazotization (Strickland and Parsons, 1968). The concentration of ammonium was measured using the

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