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Loading nutrients from oases to sea on arid watersheds NW Mexico

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ABSTRACT

In arid climates, inputs of nitrogen and phosphorus in coastal waters are mainly driven by groundwater discharge, and runoff from oases near the coast. Each nutrient may increase from human activity and be a source of environmental pollution of coastal zones. We report on nutrient variability and content at five oases in Baja California Sur, their watercourses, and discharge sites to the sea during a 4 year period (2004–2007). Measurements were carried out of temperature, salinity, dissolved oxygen, nitrates, nitrites, ammonium, orthophosphates, and silicates along the oasis watercourses and adjacent coasts. Higher content of nitrogen and phosphorus was found at sites where agriculture and high populations were present. Differences on geographic localization, and rainfall rates were not an important factor on nutrient variability. Lagoons and estuaries as part of the end of the watercourses were important because these zones reduce nitrogen and phosphorus by biological activity and sediment retention, so that water quality of adjacent coast is not disturbed. The Oasis San José is affected by sewage input from a population (77 000 inhabitants) and this water body seems to be near its limit of assimilative capacity to these nutrients.

1. Introduction

In arid climates, including northwestern Mexico, discharge of freshwater to coastal areas is mainly driven by runoff (Lechuga et al., 1999; Mendoza-Salgado et al., 2006, 2005a), groundwater discharge (Michael et al., 2005; Santos et al., 2011), and runoff emerging from oases (Faurea et al., 2002). These inputs are the main paths that introduce nitrogen and phosphorus as eutrophicating pollutants to coastal zones (Michael et al., 2005).

In the Mexican State of Baja California Sur, there are approximately 81 oases which are formed from underground aquifers (Maya et al., 2011) the majority of studies are ecologically oriented (Bernardi et al., 2007; Funes-Rodríguez et al., 2007; Llinas-Gutiérrez and Jiménez, 2004; Maya et al., 1997; Morgan et al., 2005).

Some oases have a watercourse that discharges into the Gulf of California or Pacific Ocean. The water source can diffuse and create a watercourse that discharges into an inland or coastal pond surrounded by typical freshwater vegetation (León-De La Luz and Domínguez-Cadena, 2006; León-de la Luz et al., 2008). Some inland ponds temporarily nourish larger waterways until the water is lost by evaporation, infiltration, or discharge into the sea.

The chemical composition of the spring source, its surface watercourse, and fate may vary, depending on type of soil, density of vegetation, solar radiation, rainfall, agricultural use, and waste water discharge. Nitrogen and phosphorus enrichment of groundwater is largely derived from agriculture (Beman et al., 2005; De Jonge et al., 2003; Smith et al., 2005) or urban development (Pickett et al., 2011). Along the waterway, salinity is modified by the type of soil, rate of evaporation, or proximity to the sea (Al-Khashman, 2007). Runoff is a source of nitrogen, phosphorus, and silicates as it discharges into the sea, where it may affect marine biota (Melwani and Kim, 2008). By the extent of chemical variability of discharge, the source of the chemicals may increase marine primary productivity or cause ecological disturbances (Estradas-Romero et al., 2009; Lechuga-Deveze et al., 2001; Morquecho and Lechuga-Deveze, 2004).

Those scenarios can be important for the arid Baja California Peninsula, where smaller and larger towns are dependent and associated with oases. The goals of this study were to examine the inputs of inorganic dissolved nutrients from oases to sea. Our approach was to measure concentrations of DIN, DIP, and ratio N:P in specific sites of watercourse: upstream, town, downstream, lagoon and coast. We then assessed the influence of discharge to the water quality at the coast of five large and well-known oases of the State of Baja California Sur.

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2. Methods

The oases studied are localized on a latitudinal gradient (Fig. 1) on different watershed, have different rainfall rates, and support human activities. Along the waterway of each oasis, there is a town associated which having different number of inhabitants and human activities (Table 1).

In November 2004, February, May, August, and October 2005, October 2006, and October 2007, water samples were taken in the oases of San Ignacio, La Purísima, Mulegé, Todos Santos, and San José (Fig. 1). Each oasis was sampled at sites as close to the water source as possible, along the outflowing watercourse, near the site of inflow into the pond, and at the mouth of the watercourse, usually at the discharge site into the sea.

In case of San Ignacio the Oasis and the downstream watercourse were sampled at five sites along a distance of 12 km (Fig. 2a). Water emerges (Spring) at two ponds where the town of San Ignacio is located (Ponds 1and 2), and two sites (Downstream 1, Downstream 2) that have low anthropogenic influence. Further downstream, surface water is lost by infiltration. During times of heavy rain, the watercourse can reach and discharge into Laguna San Ignacio on the Pacific coast (Fig. 2a).

Oasis La Purísima was sampled at five sites along a distance of 47 km (Fig. 2b): The first site is close to the spring, where there is a small dam and labeled Upstream. The second site is labeled Pond, located between the small towns of San Isidro and La Purísima; the third site is labeled Downstream. This site is without measurable human influence. Site 4 is at the inlet to the estuary; this site is settled by fishermen. The fifth site is on the coast.

Table 1
Oases and its influences factors.

Oases	Population	Watershed (km^2)	Rainfall (mm y^{-1})	Human activities
San Ignacio	800	11 236	100–110	Tourism and agriculture
Mulegé	3800	4693	113–154	Tourism and fishing
La Purísima	400	4988	100–300	Agriculture and ranching
Todos Santos	5100	8003	161–682	Tourism and agriculture
San José	77 000	6922	174–682	Tourism

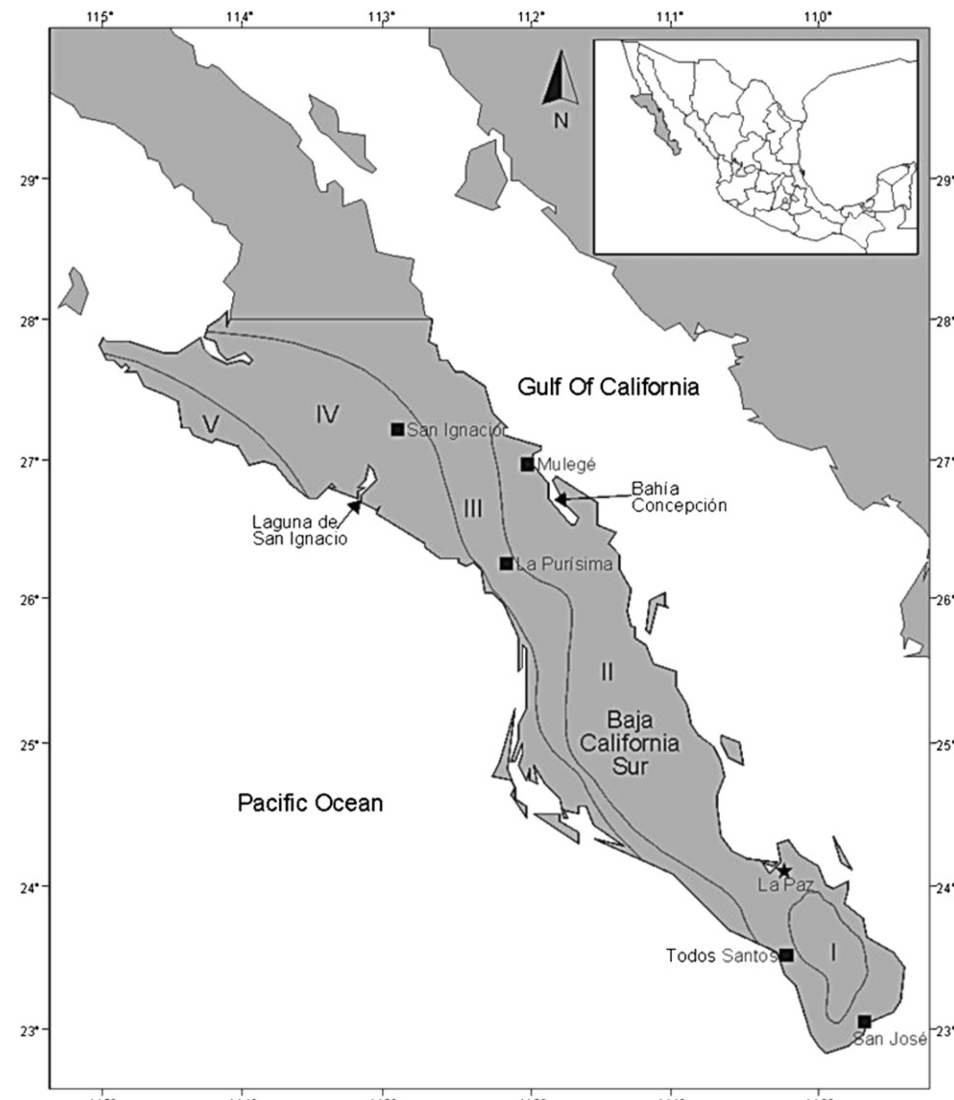

Fig. 1. Study area showing the oases localization and regionalization of rainy regime. Zone I rainfall on summer-fall; Zones II, III, and IV rainfall on both summer-fall and winter-spring; Zone V rainfall on winter-spring (Regionalization taken of Salinas-Zavala et al., 1990).