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Drivers of wetland disturbance and biodiversity impacts on a tropical oceanic island

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ABSTRACT

Wetlands are biologically important elements of landscapes and among the most threatened ecosystems on Earth. On the island of Mauritius, many remaining wetlands are being rapidly converted and fragmented by intense land-use demands. We surveyed 209 coastal wetlands on Mauritius to assess their biophysical attributes, land-use activities, and patterns of disturbance, to help identify factors that threaten wetland biodiversity. Most wetlands exhibited severe edge-related disturbances and more than half were fragmented. Plant species richness was highest in larger, unfragmented wetlands and lower in wetlands with degraded margins. Urban wetlands were smaller and more likely to be fragmented than those adjoining other land uses such as grazing and agriculture. Flooding of urban homes and infrastructure was more likely to occur near fragmented than natural wetlands. Ongoing wetland decline in Mauritius not only contributes to the loss of local biodiversity but reduces the larger ecosystem role these habitats play in regulating surface water and protecting adjacent marine habitats.

1. Introduction

Despite international recognition that wetlands are enormously important for biodiversity, ecosystem health and human well-being, they continue to be degraded and destroyed faster than any other terrestrial ecosystem. About half of the wetlands worldwide have been lost, converted or degraded in the twentieth century (World Resources Institute, 2005). Many causal factors have been associated with wetland loss and degradation including vegetation clearing and drainage for agriculture, infrastructure expansion, invasive species, pollution and global climate change (Daniels and Cumming, 2008; Foote et al., 1996; Zelder and Kercher, 2004).

Biologically, wetlands are unique ecosystems where aquatic and terrestrial life-forms intermix (Mitsch and Gosselink, 1986). When permanently inundated, wetlands require specialized plant-forms (hydrophytic species) that can survive both inundation and low-oxygen soils and aquatic fauna that can tolerate varying oxygen levels (Keddy, 2000). The wet to dry transition along wetland ecotones frequently supports a distinctive, productive and diverse biological community that is not well-represented elsewhere in the landscape (Carter et al., 1994; Chapman et al., 1996). Further, wetlands provide crucial habitats for terrestrial species that have aquatic life-stages or require water for survival (Keddy, 2000).

In addition to their biological values, wetlands have key hydrological functions. They capture surface flows, slowing water movement, and may promote aquifer replenishment (Gosselink and Turner, 1978). Reducing water velocity allows large particulate matter to settle, reducing sedimentation and nutrient pollution of coastal waters (Keddy, 2000). In Mauritius, as in many other tropical regions, coastal waters support sensitive lagoon environments that include inshore coral reefs and seagrass beds. In many parts of the tropics, such environments are being degraded by nutrient pollution and sedimentation arising from expanding land-uses in coastal regions (Laws, 1992; Rogers, 1990).

Wetlands provide further environmental services. On average, Mauritius has one cyclone approach annually within 100 km of its coasts (Jury, 1993), producing heavy rains that can overwhelm the landscape, impacting mountain slopes, rivers, floodplains and

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human communities. Wetlands and low-lying areas provide a repository for excess water from overrun rivers and surface flows. When wetlands are lost or people colonize floodplains, severe rainfall events can cause a major loss of property and loss of life (Keddy, 2000). In many parts of Asia, for example, annual flooding from high rainfall affect millions of people each year (United Nations, 2009).

It is only in the last decade that wetlands in Mauritius have received much societal recognition and even partial legal protection. The country signed the Ramsar Convention in 1997 and designated its first protected marine wetland in 2001. Despite some level of institutional recognition, wetlands are still being rapidly converted in Mauritius, with a ~60% loss of wetlands in the northern region of the country since 1980 (Government of Mauritius, 2002). The unrelenting pressure on the wetlands in Mauritius highlights a general lack of understanding of their biological importance as well as poor government policy for their protection.

Here we examine the causal factors associated with wetland disturbance and loss in coastal regions of Mauritius, an island that has already suffered a severe loss of its native vegetation (Safford, 1997) and biodiversity (Cheke, 1987). We assess the distribution of coastal wetlands and describe their biophysical attributes, and then identify land-use activities that are their key threats.

2. Methods

2.1. Wetland location

Wetlands can develop under various landscape conditions depending on topography and dominant water sources, such as from riverine flooding, landscape depressions, non-permeable edaphic features, and estuarine or lake fringes (Gosselink and Turner, 1978). For the purposes of this study we defined wetlands as areas of brackish water not actively attached to the marine environment via surface flows and characterized by soils, plants and animals whose distributions are affected by permanent or frequent inundation.

We located wetlands based on 1:25,000 topographic maps (circa 1990), local government planning maps at 1:5000 scale (circa 2006), and expert opinion. The data presented here include only smaller coastal wetlands (<30 ha in size) and not larger protected wetlands. Wetland delineation was based on the identification of hydric soils, hydrophytic plants and the presence of permanent standing water or frequent inundation. Hydric soils are saturated during the plant-growing season and develop anaerobic conditions that favour the growth and regeneration of hydrophytic vegetation (Sprecher, 2001). Hydric soil features can include sulfidic odor, gleying, redoximorphic features (such as a reduced matrix and zones of Fe–Mn oxides), and oxidized root zones (Sprecher, 2001).

2.2. Wetland biophysical attributes

We surveyed up to 209 coastal wetlands using rapid assessment techniques, recording floristic, structural and physical attributes for each wetland. The area, shape and circumference of each wetland were determined by delineating the wetland edge with a GPS unit. Vegetation structure and composition were recorded by walking the circumference of each wetland and traversing its centre with 3–5 parallel transects, depending on wetland size. The presence of terrestrial and aquatic vertebrate (mammals, birds, reptiles, amphibians, and fish) and selected invertebrate (butterflies and mollusks) species was determined by visual sightings, acoustical cues, and other signs (burrows, herbivory patterns, footprints, droppings, and bones) during our daytime surveys.

Soil and hydrological characteristics were assessed by digging 3–5 pits to a depth of 25–50 cm. Soil chroma and value were defined using Munsell Soil Colour Charts (Munsell, 1992). Salinity of standing water (when it occurred) was measured using a salinity refractometer with values ranging from 0 to 33. We estimated algal cover of the wetland surface area and water clarity, and noted the water source and periodicity.

2.3. Anthropogenic disturbances

We assessed five features of anthropogenic disturbance to most wetlands: (1) *Edge disturbance*: The proportion of the wetland margin disturbed by human activities such as agriculture, wetland filling and infrastructure. (2) *Fragmentation:* Three fragmentation conditions were recorded: natural state, fragmented by road, fragmented by land-use activities. (3) *Filling*: The presence and composition of fill and the extent of the edge that was filled. (4) *Surrounding land uses*: Categorized as no active land use, rural grazing, rural farming (sugarcane or small farmer), urban without houses or urban with houses (or golf courses). (5) *Flooding risk:* Determined by examining obvious floodwater marks (not seasonally defined) on nearby houses and infrastructure (with the census also occurring during the wet season) with the following ranking: none, infrastructure, houses.

2.4. Data analysis

We examined wetland distribution across the island of Mauritius at different spatial scales. First, we investigated the relationship between topography and wetland distribution within watersheds using a regression analysis of wetland area and river density. Second, we evaluated the spatial relationships between wetlands with nearest-neighbor comparisons of pairwise linear distances among sites.

From >600 wetland transects, we identified major gradients in the vegetation composition of wetlands using Nonmetric Multidimensional Scaling (McCune and Mefford, 1999). Monte Carlo randomization tests (100 runs) were used to determine whether ordination axes explained significantly more variation than expected by chance. To improve ordination performance, singleton species (those recorded at only one wetland) were excluded from analyses. We used Spearman rank correlations to determine whether species richness of floral and faunal species were

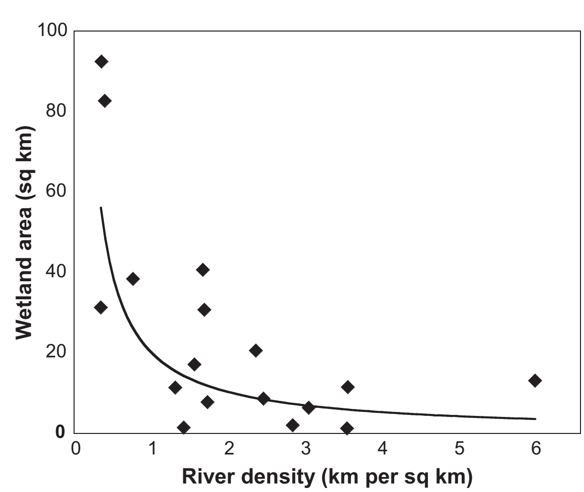

Fig. 1. The relationship between river density and wetland area in Mauritius. A power curve is fitted to the data for 17 river catchments (river density = 20.243 ∗ [wetland area$^{-0.971}$]). A linear regression comparing observed and fitted values was highly significant ($F_{1,17}$ = 27.38, R^2 = 64.61%, P = 0.0001).