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# Habitat heterogeneity facilitates resilience of diurnal raptor communities to hurricane disturbance

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ABSTRACT

The response of avian communities to hurricane disturbance may differ according to their specific requirements or functional groups, but little is known regarding the response of top-predator birds of prey to these disturbances. We aimed to evaluate the influence of the major Hurricane Patricia on the diversity of diurnal raptors in tropical dry forest, along the coast of Jalisco, Mexico. We conducted raptor surveys at 13 sites located within the eyewall radius of maximum hurricane winds along the path of the hurricane, and 16 sites located outside the hurricane eyewall. We compared the density and species richness of raptors among four habitats of tropical deciduous and semi-deciduous forest, mangroves, and agricultural fields, within the hurricane eyewall and outside the radius of maximum winds. Our results demonstrated a reduction in raptor density in tropical forests within the radius of maximum hurricane winds, where raptor density was significantly lower in deciduous forests within the hurricane eyewall compared to deciduous forests outside the eyewall. Species richness of diurnal raptors was similar among habitats and conditions with the exception that mangroves within the hurricane eyewall had significant higher raptor species richness compared to mangroves outside the eyewall. There was also a significant increase in species evenness, and decrease in similarity, of raptor communities in mangroves and deciduous forest sites within the hurricane eyewall compared to sites outside the eyewall. The reduced density of diurnal raptors in tropical forest sites within the path of the hurricane probably reflects the impact of hurricane winds on forest structure, whereas the increase in species richness and evenness of raptor communities in mangroves within the hurricane eyewall suggests that these habitats could provide a refuge for diurnal raptors following hurricane disturbance. Our results highlight the importance of maintaining landscape heterogeneity of native vegetation to provide alternate habitats for wildlife communities following major disturbance, and facilitate their resilience to extreme climatic events such as hurricanes.

## 1. Introduction

Hurricane impacts have increased in frequency and intensity over the last decades (Webster et al., 2005; Elsner et al., 2008; Emanuel, 2013), provoking changes in the physical environment with impacts on animal communities (Emanuel, 2005). Strong winds associated with hurricanes can provoke structural damage of bird habitats, with more severe hurricane damage in large trees and mature forests, while open habitats may be less impacted (Gresham et al., 1991; Varty, 1991; Roth, 1992; Wauer and Wunderle, 1992). The response of avian species to hurricane disturbance may differ according to their specific requirements or functional groups, making it important to evaluate the vulnerability of organisms to such natural disturbances.

In avian communities, terrestrial species that rely on plants for food are likely to be more affected by hurricane impacts. Eight months after landfall by Hurricane Hugo in the Caribbean, Wauer and Wunderle (1992) found significant declines in abundance for 76% of primary consumer species that rely on plant resources of fruits, seeds, or flowers, compared to 46% of secondary consumers. Various studies have determined a decline in frugivorous and nectarivorous birds 4–8 months after hurricane disturbance, whereas insectivorous birds may increase in abundance as they are able to forage for insects in areas opened-up by hurricanes (Lynch, 1991; Wauer and Wunderle, 1992; Wunderle et al., 1992; Wiley and Wunderle, 1993; Wunderle, 1999; Wunderle and Arendt, 2011). This diet-related population response suggests that hurricanes have significant indirect effects on avian communities through loss of food resources, nest-sites, and habitat, rather than direct mortality (Wiley and Wunderle, 1993). However, few studies have evaluated the influence of hurricane disturbance on bird groups with distinct functional requirements, such as raptors that are primarily

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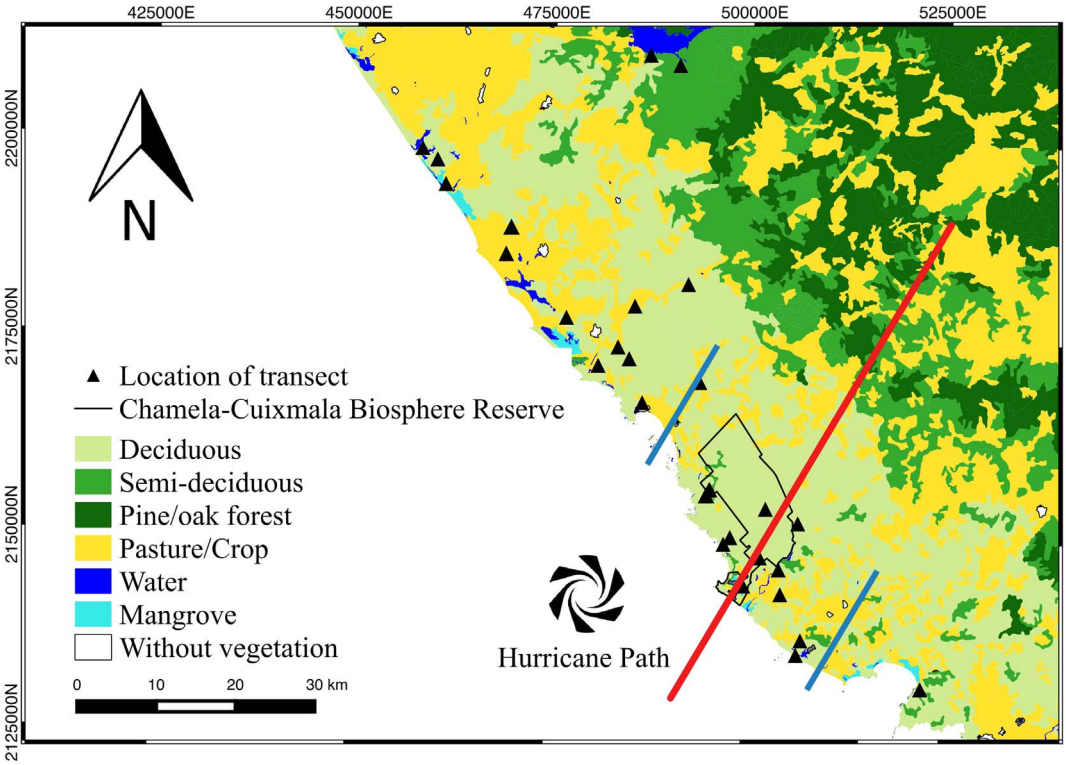


**Fig. 1.** Map of the study region along the coast of Jalisco, Mexico, showing the location of survey sites in each habitat type within the main path of Hurricane Patricia, and outside the boundaries of maximum hurricane winds. Red line indicates the track of Hurricane Patricia obtained from historical hurricane tracks of the National Oceanic and Atmospheric Administration (https://coast.noaa.gov/hurricanes/). Blue lines represent the boundaries of maximum hurricane winds estimated from data published by Kimberlain et al. (2016).

carnivorous and function as top-predators in avian communities (Newton, 1979).

Wauer and Wunderle (1992) found that whereas 70–92% of nectivore and fruit/seed eating bird populations declined in abundance, only 25% of raptor populations demonstrated a decline 8 months after hurricane landfall. In particular, most populations of the Red-tailed Hawk (*Buteo jamaicensis*) and American Kestrel (*Falco sparverius*) remained unchanged after landfall by Hurricane Hugo (Wauer and Wunderle, 1992), possibly due to an increase in detectability of their prey. Similarly, in the Yucatán Peninsula of Mexico, Lynch (1991) found no significant response of the Roadside Hawk (*Rupornis magnirostris*) to landfall by Hurricane Gilbert, although the Ferruginous Pygmy-Owl (*Glaucidium brasilianum*) showed a significant decline with no recovery up to a year-and-a-half after hurricane impact. However, no studies have specifically evaluated the response of a raptor community to hurricane disturbance, particularly on the Pacific coast of the continental Neotropics, even though a greater number and percent of hurricanes occur and make landfall along the Neotropical Pacific coast compared to the Atlantic (Jáuregui, 2003).

In the 2015 hurricane season (June-November), the largest and strongest hurricane ever recorded, category 5 Hurricane Patricia, made landfall as a category 4 major hurricane on the Pacific coast of Jalisco in Mexico (Kimberlain et al., 2016). Hurricane Patricia had estimated maximum winds of 241 km/h over an eyewall (wall of clouds that surround the eye of the hurricane and where the most damaging winds and intense rainfall is found) radius of 5 nautical miles (9.3 km), producing a narrow swath of severe damage to buildings and forest structure (Kimberlain et al., 2016). It is not yet known what impact this hurricane landfall may have had on the rich biodiversity of the tropical dry forest in the region. Therefore, in the present study we aimed to evaluate the potential influence of this hurricane disturbance on the diversity of diurnal raptors in the tropical dry forest along the Pacific coast of Mexico. We specifically aimed to determine whether there were differences in density, species richness, and community structure of diurnal raptors in habitats within the hurricane eyewall of severe damage compared to habitats outside the main path of hurricane impact. Evaluating the response of species or functional groups to hurricanes enables us to assess their potential vulnerability to disturbance produced by environmental change, with important implications for conservation.

## 2. Methods

### 2.1. Study area

The study was conducted in the tropical dry forest on the coast of Jalisco in western Mexico, specifically in the coastal municipalities of La Huerta and Tomatlán. The region has a warm, semi-humid climate with a mean annual temperature of 26 °C (García, 2004). Mean annual rainfall is 788 mm (range 453–1393), the majority of which occurs during the rainy season from June to October, with a prolonged dry season from November to May (Bullock, 1986; García-Oliva et al., 2002). The dominant vegetation is dry deciduous forest, located mainly on the hills (Lott and Atkinson, 2002), which has a canopy height of 12 m, a dense understory, and is characterized by a loss of leaf cover for 5–8 months in the dry season (Rzedowski, 2006). Common tree species in deciduous forest are *Croton pseudoniveus, Lonchocarpus constrictus*, *Trichilia trifolia*, and *Cordia alliodora*, (Lott et al., 1987). Semi-deciduous forest occurs in humid valleys from sea-level to 1000 m asl, and is characterized by larger trees of 25 m canopy height that maintain their foliage through most of the year (Rzedowski, 2006). This forest has a large proportion of trees ≥30 cm diameter at breast height (dbh), with common tree species of *Thouinidium decandrum, Capparis verrucosa* and *Astronium graveolens* (Lott et al., 1987). Wetlands with mangrove vegetation also occur along the coast, and are dominated by short, evergreen trees of *Laguncularia racemosa, Rhizophora mangle*, and *Avicennia germinans* (Durán et al., 2002). In some low-lying areas of community lands along the coast, tropical dry forest has been replaced by cattle