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Original article

Integrating life-history traits and amphibian upland habitat use in a Neotropical hotspot

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ABSTRACT

Effective management of semi-aquatic animals requires detailed information on upland habitat use around aquatic habitats. Quantifying the amount of habitats needed to sustain local animals' populations is a crucial criterion when setting protective buffers to water bodies, especially for amphibians, which depend on these upland habitats for breeding and development. Differences in upland habitat use can emerge among amphibian species with distinct life-history traits, including reproductive-strategy (pond-breeding vs. non-pond breeding anurans), life-stage (adults vs. juveniles), and sex (males vs. females). To date there has been no quantitative study of upland habitat use in the Neotropics, which can provide a baseline for quantifying the amount of upland forested habitats needed to sustain local amphibian populations. We monitored three ponds for over two sampling year using drift fences with pitfall traps to investigate how reproductive-strategy, life-stage, and sex affect anuran upland habitat use in a forest remnant in the Atlantic Forest hotspot. We found no differences in upland habitat use between adult and juvenile anurans. However, we found that although the species richness of pond-breeding and non-pond breeding anurans was similar near wetlands, there was greater abundance of pond-breeding compared to non-pond breeding anurans. We also found a strong difference between the sexes in pond-breeding anurans, with males remaining closer to wetlands than females. Thus, the sex ratio of amphibian populations can be strongly skewed toward males if only small protective terrestrial buffers (50-m) are enforced during land development. Our findings also point to the inadequacy of current Brazilian policies to protect small wetlands and the fauna that depend on them. We recommend that policymakers adjust regulatory criteria to set hierarchical protective buffers around wetlands allowing different levels of land-use intervention.

1. Introduction

Effective management and conservation of semi-aquatic animal populations requires detailed information on their use of the upland forest habitat surrounding aquatic environments (Semlitsch, 2002). Despite their biological importance in maintaining biodiversity, upland habitats have ambiguous or non-existent criteria in their regulatory policies, also varying from one country to another (Semlitsch and Jensen, 2001). Consequently, a serious gap exits in biodiversity protection when regulations or ordinances, especially those of local or state governments, are established based on criteria to protect water resources only, without considering critical habitats to wildlife species (Semlitsch and Bodie, 2003). It is especially worrying for amphibians with biphasic life cycles, which depend on these environments for breeding and development. Upland habitats also play an essential role in population dynamics by ensuring the survivorship of amphibians in earlier stages of development (Trenham and Shaffer, 2005). Considering that 82% of amphibian species in the world are forest-dependent (Stuart et al., 2004), improved understanding of amphibian upland habitat use along forested sites is critical to conservation planning.

While nearly half of the world's amphibian species are found in

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the Neotropics (IUCN, 2015), most studies on habitat use are concentrated in the Northern Hemisphere (e.g. Herrmann et al., 2005; Lamoureux et al., 2002; Schabetsberger et al., 2004; Trenham and Shaffer, 2005). Nearctic amphibians are known use forest habitats up to 159–290 m from the edge of aquatic habitats (Semlitsch and Bodie, 2003). Although Nearctic and Neotropical amphibians may present similar habitat use, differences in the climate conditions between these biogeographical realms or in the physiological requirements between tropical and temperate species (Wiens and Donoghue, 2004) may influence amphibian movement patterns and consequently affect their use of upland habitats.

Upland forest habitat use, often measured as species abundance and richness, is known to decrease with increasing distance from the edge of aquatic habitats (Rittenhouse and Semlitsch, 2007; Semlitsch and Bodie, 2003). However, this relationship may be expected to vary among species and individuals since amphibians with distinct life-history traits respond differently to habitat changes (Becker et al., 2007; Dixo and Martins, 2008). Amphibians with aquatic larvae are more affected by habitat loss, habitat fragmentation, and habitat split, than species with direct development (Becker et al., 2010). Moreover, differences in reproductive strategy have been shown to affect the way in which amphibians species are driven to extinction (Fonseca et al., 2013). In addition, juveniles of most amphibian species are small and more prone to water loss than adults, and thereby they have more limited mobility (Peterman et al., 2013). Even juveniles of generalist amphibian species can be more sensitive to habitat changes (Patrick et al., 2006) and respond differently from adults to variation in microhabitat or microclimate conditions (Halpern et al., 2005; Todd and Winne, 2006). Differences in upland habitat use can also arise between sexes in amphibians. Female amphibians tend to move farther than males (Bartelt et al., 2004; Muths, 2003; Schabetsberger et al., 2004), suggesting lower competition for food resources at greater distances from the breeding sites (Lamoureux et al., 2002; Rittenhouse and Semlitsch, 2007). On the other hand, by remaining closer to breeding sites males may arrive earlier than females and improve the choice of calling sites, increasing mating opportunities (Douglas, 1979; Semlitsch, 1985). Therefore, uncovering the life-history effects on upland habitat use may be critical for adjusting forest management planning to incorporate sufficient areas to maintain amphibian population viability.

Several studies have demonstrated the inadequacy of state and federal policies to protect wetlands for amphibian communities (Comer et al., 2006; Trenham and Shaffer, 2005). Although current knowledge indicates the need to increase buffer protection around aquatic habitats, the new Brazilian Forest Act, the main Brazilian environmental legislation [Brazilian Law #12,651; May 25, 2012], removed the regulation that defined protected areas surrounding water bodies with less than 1-ha surface, previously established as 50-m protective buffer area. The recent approval of this Forest Act has been considered the worst environmental setback in the past half-century (Metzger et al., 2010), jeopardizing Brazilian biodiversity in several ways, particularly through habitat loss and fragmentation (Ab'Sáber, 2010). To date, most studies on upland habitat use for Brazilian amphibians have focused on isolation between aquatic and terrestrial habitats within agricultural landscapes (e.g. Silva and Rossa-Feres, 2011; Silva et al., 2012, 2011). Notwithstanding the appropriateness of this approach for such studies, the use of distance between breeding pools and near forest fragments hinders the amount of forested habitats effectively used by amphibians.

We report here the first quantitative study of amphibian upland habitat use in a forest remnant within the Atlantic Forest hotspot. This ecoregion is home of nearly 8% of global amphibian species, from which almost 90% are endemic (Haddad et al., 2013) and is highly threatened by human economic activities (Mittermeier et al., 2005). Our objective was to investigate how species richness and abundance of amphibians around breeding ponds can differ when accounting for different life-history traits, such as reproductive-strategy, life-stage, and sex.

2. Material and methods

2.1. Study area

Our study was conducted in Serra do Brigadeiro State Park (SBSP) (20°43′S, 42°29′W), an Atlantic Forest remnant with approximately 15,000-ha in Minas Gerais state, southeastern Brazil. Serra do Brigadeiro mountain, where SBSP is located, has primarily submontane and montane ombrophilous dense forest formations (Tai, 2012) and elevational range of 1000–1985 m. Serra do Brigadeiro mountain acts as a watershed between the basins of Doce and Paraíba do Sul Rivers. Precipitation is primarily concentrated from November to February, with average rainfall exceeding 230 mm/month, accounting for approximately sixty percent of total average annual rainfall (1558 mm/year). The dry season begins in May and lasts until August and average rainfall in this period is less than 36 mm/month. Average temperatures are 14.3 °C during winter and 17 °C in summer (Sá-Júnior et al., 2012).

2.2. Experimental design

Pitfall traps with drift fences (Gibbons et al., 1974) were used to investigate the spatial distribution of anurans around ponds. At the SBSP, we selected ponds with similar features regarding the area of water surface, elevation, slope, and vegetation structures in their adjacent forests, resulting in three ponds (Fig. 1). Selected ponds had 0.270–0.307-ha surface and between 1320 and 1380-m elevation. The distance between ponds varied from 660 to 1100-m. All three ponds are filled by adjoining temporary streams during the rainy season. Two of the three ponds are permanent and one is temporary, remaining filled from October to May of each year. Previous studies showed that species richness and abundance of anurans in this temporary pond has not been driven by hydroperiod (Assis, 2009), leading us to consider all three ponds equally appropriate to the investigation of amphibian upland habitat use.

Adult amphibians generally migrate in a straight line between their terrestrial homes and reproductive wetlands (Semlitsch, 2008). Because amphibians follow perpendicular routes to the wetland shore, we installed our experimental arrays along a perpendicular axis from each pond edge toward adjacent forest's interior. Each experimental array (block) was composed of five sampling units parallel to the pond edge at distances of 0, 10, 20, 40, and 80-m (Fig. 1). The pond with greatest forest extent along its edge was selected for the installation of two experimental arrays arranged on the opposite sides of the pond, totaling four experimental arrays.

The hemispherical perimeter associated to each arc distance (sampling unit) encircling the pond increases with distance from the pond edge. At this point, one can standardize sampling effort using the relative or absolute approach. The relative sampling approach involves the installation of additional traps or traps with greater fence coverage at longer distances from the pond, in order to allow proportional sampling of uplands habitats encircling the pond. The absolute sampling approach applies equal sampling effort to all distances, controlling for area effects (Quinn and Keough, 2002). As we were interested in providing an estimate of the number of individuals at each distance, we applied the absolute