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Vegetation community and factors that affect the woody species composition of riparian forests growing in an urbanizing landscape along the Chao Phraya River, central Thailand

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ABSTRACT

Improved knowledge of the environmental factors that affect woody composition is urgently required for species conservation in riparian zones of urbanizing landscapes. We investigated the environmental factors influencing tree abundance and regeneration in diverse forest types growing in the riparian area of an urbanizing landscape along the Chao Phraya River. We established 252 0.1-ha circular plots in remnant forest patches along 372 km of the river. Cluster analysis was applied to classify the forest types. The relationships between environmental variables and tree abundance were assessed with ordination analysis, and generalized linear models were used to assess seedling/sapling abundance. The cluster analysis revealed five forest types, including floodplain forest with three sub-forest types, swamp forest, and mangrove forest. The ordination indicated that tree abundance in the floodplain forest was positively affected by distance to the ocean and the proportion of forested area. Swamp forest was positively influenced by the proportion of urbanized area and mean rainfall. Mangrove forest was negatively related to distance to the river. Seedling/sapling abundance of the dominant species in the floodplain forests was positively affected by lowland plain topography and negatively affected by the proportion of urbanized area, whereas swamp and mangrove forest species were positively influenced by the proportion of urbanized area and estuarine topography. Mature tree density influenced seedling/sapling abundance of all forest types. Tree abundance and regeneration of the riparian landscape was prevented by the urbanized area, floodplain, estuarine topography, and mature tree densities in remnant forests. These results suggest that remnant forest patches of conserved riparian forests along the urbanized landscape of the Chao Phraya River must be protected and the factors determining their colonization must be considered to enhance restoration practices.

1. Introduction

Riparian systems are aquatic-terrestrial ecotones shaped by fluvial and upland geomorphic processes with unique biotic, biophysical, and landscape characteristics (Gregory et al., 1991; Wiens, 2002; Osterkamp and Hupp, 2010). Riparian areas are spatially and temporally dynamic, often characterized by multiple gradients of structural and functional changes from the water's edge to the upland area (Charles Goebel et al., 2012). Riparian plant communities perform an array of important ecosystem functions, including stream bank stabilization, thermal regulation of streams, nutrient filtration and retention, reduction of erosion potential, and provision of forage and habitat for wildlife (McJannet et al., 2012; DeVore et al., 2016; Muller et al., 2016). Given their unique attributes, characterizing the composition and structure of riparian vegetation is integral to riparian protection and conservation efforts (McCloskey et al., 2016). Vegetation in riparian areas commonly inhabits a diverse mosaic of landforms, communities, and environments within the larger landscape (Wiens, 2002;

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Fernandes et al., 2016). Vegetation composition within the riparian zone is highly variable due to the influence of extreme environmental factors (e.g., wet soils, floodplain topography, and flooding regime), which restrict where species can grow (Lyon and Gross, 2005). Riparian zones are often the most sensitive ecosystems to change within the surrounding environment but are among the ecosystems most disturbed by man, worldwide (Salinas and Casas, 2007). Many riparian forests are critically endangered due to a variety of anthropogenic pressures, such as urbanization and natural hazards, from complex interactions between natural and anthropogenic factors (Urban et al., 2006; Michez et al., 2016).

Urbanization and associated changes in land use continue to increase as the proportion of inhabitants in urban centers grows, driving profound changes to the structure and function of natural ecosystems that remain within urbanized landscapes (Zipperer et al., 2012; Han et al., 2016). Rapid worldwide urbanization is expected to cause extensive losses in biodiversity in the coming decades (Urban et al., 2006). The attendant effects of these changes alter biotic and abiotic processes in natural ecosystems within and adjacent to urban centers, and urbanization can reduce species diversity, richness, and native plant abundance (Pickett et al., 2011; Cameron et al., 2015). Riparian landscapes generally promote urbanization and mechanized agriculture (Oneal and Rotenberry, 2008). Expansion of cities leads to reduced and fragmented primary riparian forests within a matrix of massive and extensive infrastructure (Zipperer et al., 2012; Santos et al., 2016). Consequently, small vegetated patches, including remnant natural areas and novel urban environments, such as parks and gardens, replace large agricultural and semi-natural areas. These patches are often isolated and under the influence of a set of selective pressures, limiting the growth and performance of perennial species (Williams et al., 2009; Santos et al., 2016; Schwoertzig et al., 2016). Riparian zones are often preserved for their aesthetic and recreational value within urban settings and may attract disproportionate visitation by humans compared to similar zones farther from developed areas. Human trampling in urban forests associated with recreational use may cause severe disturbance (Long and Nair, 1999; Oneal and Rotenberry, 2008), driving changes in tree canopy cover and overall tree species diversity (Nowak et al., 2013). In addition, riparian zones are commonly used for farming along riverbanks, which affects the forest and agricultural ecosystems. These disturbances caused by intense use of riparian zones for agricultural activities greatly reduce the composition, diversity, and native species richness of riparian forests (Sunil et al., 2016).

Disturbances associated with urbanization and agriculture that reduce riparian forests have been attributed to localized and regional changes in land use (Cameron et al., 2015; Santos et al., 2016; Sunil et al., 2016). Furthermore, urbanization may shape stream communities by restricting species dispersal within and among stream reaches (Urban et al., 2006). The Chao Phraya River, located in an urbanized region of central Thailand, passes through 11 regions along its 372-km path, including the largest cities in the country, Bangkok (current capital) and Ayutthaya (former capital). It is the center of economic and social development in Thailand. Economic growth is presently expanding from Bangkok to surrounding areas and especially into cities located along the Chao Phraya River. Consequently, environmental problems and deterioration of natural resources and natural vegetation are occurring throughout the Bangkok metropolitan region. The cities along the Chao Phraya River are almost devoid of natural vegetation, having long been converted into urban and agricultural areas (Royal Forest Department, 2014). Tejajati et al. (1999) reported on the vegetation in suburban areas of Bangkok and showed that the tree communities fell into three categories: quasi-natural forest communities, secondary forest and mantle communities, and abandoned fruit orchard communities. This finding suggests that urbanization of the Bangkok metropolitan region has disturbed the riparian forests, reducing them to small vegetation patches, with loss of the primary forests. Riparian vegetation structure, composition, and dynamics have received growing attention in the past decade (e.g., Lyon and Gross, 2005; Teodoro et al., 2014; Muller et al., 2016; Whigham et al., 2017). To obtain a comprehensive understanding of the vegetation patterns in these riparian vegetation communities, the interactions between riparian vegetation and environmental factors must be ascertained. There has been great scientific interest in determining the driving factors for impact assessments and riparian forest monitoring, including identifying the correlations between variables, such as ecological strategies, species lifespan, species richness, and species cover (Santos et al., 2016). However, the ecology of riparian forests along the Chao Phraya River in Thailand remains poorly understood. Therefore, we investigated the environmental factors and woody species characteristics important for colonization in various riparian forest types along the Chao Phraya River, central Thailand. Our objective was to improve urbanized riparian ecosystem management, with a focus on determining: 1) the most important factors affecting the tree distribution in different forest types of the riparian area and 2) the factor(s) that prevent regeneration of riparian forest species.

2. Methods

2.1. Study area

The study site was located in the riparian zone of the Chao Phraya River, starting from the Pak Nam Pho sector of Nakhon Sawan Province and ending in the Pak Num sector of Samut Prakan Province. The Chao Phraya River is the main river in central Thailand (Fig. 1). It is 372 km long and passes through 11 cities and provinces. The upper part of the river flows through the cities of Nakhon Sawan, Uthai Thani, Chai Nat, Sing Buri, Lopburi, and Ang Thong and continues in the lower part through the cities of Ayutthaya (former capital), Pathum Thani, Nonthaburi, Bangkok (capital), and Samut Prakan. The upper and lower reaches are rural and urbanized zones (Hydro and Agro Informatics Institute, 2012). The upper part of the river has a high elevation, which decreases toward the lower part, resulting in a wider lowland plain area (Fig. 1). The origin of the river (Nakhon Sawan) is a long distance from the ocean, whereas the mouth (Samut Prakan Province) is an estuary of the Chao Phraya River (Gulf of Thailand). We defined the riparian area and focused only on the floodplain by following the Chao Phraya River's highest flood level in 2011, which falls within an elevation of 0–30 m above mean sea level (Hydro and Agro Informatics Institute, 2012; Gale and Saunders, 2011). Thus, the study area had a flat topography encompassing 14,252 km^2 (Fig. 1); this area is called the lowland plain of central Thailand (Hydro and Agro Informatics Institute, 2012). Mean annual temperature and rainfall are 28.5 °C and 1338 mm, respectively. Rainfall is lowest in Nakhon Sawan (774.5 mm), increases gradually across the study area, and is highest in Bangkok and Samut Prakan (1500 mm) (Thai Meteorological Department, 2015). The area has a wet season (May–October) and a dry season (November–April). The dry season is subdivided into cool-dry (November–January) and hot-dry sub-seasons (February–April).

2.2. Sampling plot selection and species composition

The field study period was from January 2016 to December 2016. Old growth riverine forests along the Chao Phraya River were selected for study. This forest has been disturbed by urbanization and is fragmented into small remnant forest patches. Several of the remnant forest patches were sampled to determine species composition.

We established circular plots with a radius of 17.84 m (area = 0.1 ha) in each remnant forest patch. At the center of each 0.1-ha circular plot, we established a sub-circular plot with a radius of 4 m (area = 0.005 ha) for collecting sapling/seedling data, generating a total of 252 plots (total area = 25.2 ha) along the length of the Chao Phraya River (Table 1). The Universal Transverse Mercator coordinates were obtained for each plot using a global positioning system device