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Pond area and distance from continuous forests affect amphibian egg distributions in urban green spaces: A case study in Sapporo, Japan

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ABSTRACT

We examined factors that affect egg distributions of amphibians, which are currently declining globally, in urban areas. We counted the number of egg masses of two amphibian species (*Hynobius retardatus* and *Rana pirica*) in ponds in urban green spaces during two years (2011 and 2012) and investigated the effects of local and landscape factors on them. Forest area in green spaces and pond area had positive effects, and distance from continuous forests in the suburbs and the rate of pond shore protection had negative effects on the number of eggs. Among these factors, distance from continuous forests and pond area had strong effects on egg distributions. These results suggest the importance of water habitat size and the need for colonization by amphibians from surrounding continuous forests. To conserve urban amphibian assemblages, the preservation of ponds with sufficient area and continuous forests close to urban habitats would be important.

Introduction

Amphibians are currently declining globally (Alford and Richards, 1999; Stuart et al., 2004; Hof et al., 2011). Up to 33% of amphibian species (1856 species) have been threatened, and this number is higher than the proportions of birds and mammals (Stuart et al., 2004). Therefore, conservation actions to halt these declines are needed (Cushman, 2006; Becker et al., 2007). A variety of factors, including overexploitation, the spread of diseases, and climate change, have been suggested as the main drivers of amphibian declines (Alford and Richards, 1999; Stuart et al., 2004; Hof et al., 2011). Because suitable habitats for amphibians are limited and their dispersal abilities are low, habitat modification, such as habitat loss, degradation, and fragmentation (Alford and Richards, 1999; Stuart et al., 2004; Cushman, 2006; Hof et al., 2011), represent the greatest causes of amphibian declines.

Cities are the most intensive land use areas (Foley et al., 2005), and habitat loss and fragmentation, which are primary threats to amphibians (Hamer and McDonnell, 2008), are caused by city expansion (Miller and Hobbs, 2002). More than half of the global human population currently lives in cities, and continued expansion of cities is projected (United Nations Population Fund, 2006; Grimm et al., 2008). Furthermore, the increase in human population density is high in areas that have many endemic species and high conservation priorities (Cincotta et al., 2000). Considering these facts, the conservation of amphibians in urban areas will continue to be a great challenge.

Amphibian abundance has been shown to increase with the availability of forest and water areas (Guerry and Hunter, 2002; Trenham et al., 2003; Rubbo and Kiesecker, 2005), and the number of the immigrants decreases with increasing distance from source habitats (Rothermel, 2004; Smith and Green, 2005). Therefore, ponds in surrounding forests may sustain urban populations of amphibians, while populations may decrease as the distance from continuous forests increases. Although several studies have demonstrated the importance of surrounding forest cover for urban amphibian populations (Rubbo and Kiesecker, 2005; Hamer and Parris, 2011), to the best of our knowledge, effects of distance from source habitats have not been tested.

Most pond-breeding amphibians lay eggs in ponds and spend the nonbreeding season on the land (e.g., Semlitsch, 2008). Not only the existence of aquatic and terrestrial habitats, but also their spatial proximity, is important for population maintenance (Pope et al., 2000; Becker et al., 2007). Urban green spaces (e.g., city parks) contain both aquatic and terrestrial habitats, and these two habitat types are located close to each other. In urban areas, such green spaces would be important habitats for amphibians and would play important roles for amphibian conservation. In this study, we modeled the effects of habitat size and distance from continuous forests on the egg distributions of pond-breeding amphibians in urban green spaces. We also examined the effects of local habitat

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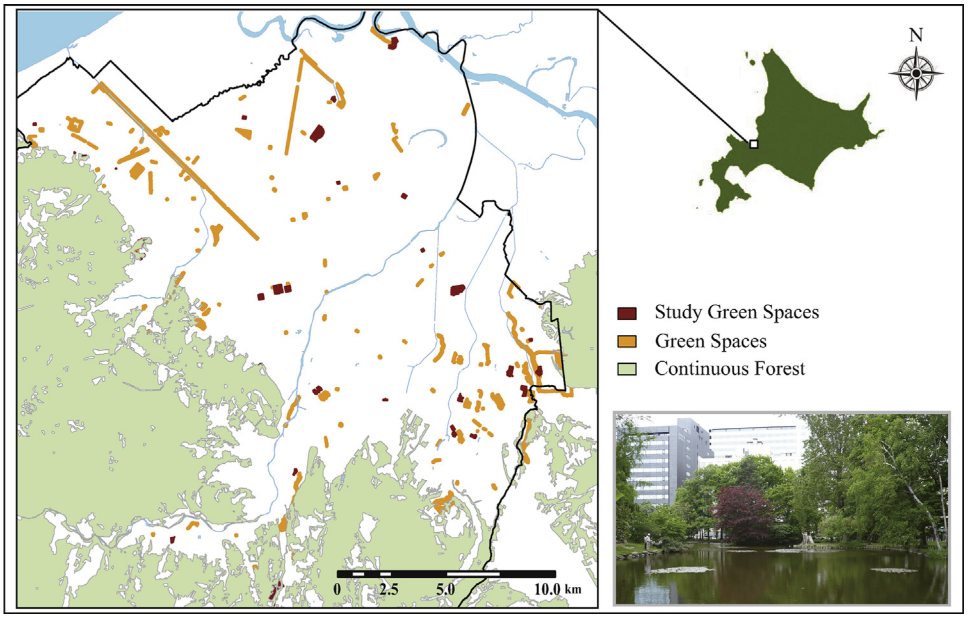

Fig. 1. Study area in Sapporo, Hokkaido. Forest patches classified as "continuous forests" were aggregated into a single continuous patch. Green spaces include forests, ponds and others (e.g., parkings; see also Table 1). White area is mainly composed of buildings and houses, and agricultural fields also exist in the marginal area. Solid black line indicates the borderline of Sapporo city. A picture of studied green space (Hokkaido prefectural office) is also shown. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

factors because habitat degradation (e.g., reductions in vegetation and shading by buildings) can cause reductions in amphibian populations (Hamer and Parris, 2011).

Methods

Study area and site selection

We conducted this study in Sapporo, Hokkaido, northern Japan. Sapporo contains more than 1,900,000 people and is located in the southwest on the Hokkaido Ishikari Plain (Fig. 1). Six amphibian species are known in Sapporo (Tokuda, 2011): three native species (*Hyla japonica*, *Hynobius retardatus*, and *Rana pirica*) and three exotic species (*Bufo japonicus*, *Rana nigromaculata*, and *Rana rugosa*). Annual mean air temperature is about 8.5 °C and total annual precipitation is approximately 1100 mm. Based on the City Planning Act, a 20,517-ha area designated for urbanization has been set up (present urban areas plus areas under urbanization during the next 10 years) (Greenery Promotion Department, Environmental Bureau, Sapporo, 2011), which represents about 22% of the city regions. Although Sapporo city have revised the city plan every five years, the area designated for urbanization increased by no more than 1% at each of recent three changes. The area was expanded at the urban fringe. A continuous forest (about 70,603 ha) is spread in the southwest regions and occupies 63% of Sapporo (Greenery Promotion Department, Environmental Bureau, Sapporo 2011). In this study, 29 urban green spaces (city parks and other public facility green spaces; Fig. 1) associated with aquatic areas (ponds) were used as study sites. We selected these green spaces in the entire urban area to vary four environmental variables (forest area, distance from the continuous forest, shore protection rate, and pond area: Table 1) while preventing them from highly correlating each other. We used green spaces with lentic water (i.e., pond) as the sampling sites, and sampled ponds that had various environmental conditions (e.g., vegetation cover, degree of shore protection). For example, some green spaces were larger than 20 ha and had well developed forests (e.g., Sapporo Art Park), while others were in the central urban area and had well-managed grassland (e.g., Hokkaido prefectural office). Most green spaces had shallow ponds (<50 cm depth), but some green spaces (Sapporo Art Park and Ainosato Park) had deep ponds (>1 m depth). There were no previous records and publications on the species studied in these sites.

Survey methods

We studied two native amphibian species: *H. retardatus* and *R. pirica*. Both species are pond-breeding amphibians that use forests as summer habitats (Tokuda, 2011). Because they lay eggs during early spring (after the snow melt), we can count and use the number of egg masses as the proxy of population sizes for the two species. Japanese tree frog *H. japonica* was the only other common amphibian species, and lay eggs in mid-summer. Therefore, we did not observe any eggs of other amphibian species in our study area throughout the sampling period. We surveyed the number of egg masses during 2 years (2011 and 2012) and used the results as an index of population size (e.g., Stevens and Paszkowski, 2004; Petranka et al., 2007). The breeding seasons of *H. retardatus* and *R. pirica* in the study area span from April to May (Tokuda, 2011). We visited each of the 29 green spaces two times per year and a total of four times during the periods 13 April–29 May 2011 and 23 April–20 June 2012. We walked along pond edges, searched for any egg sacs and masses in shallow lentic water (<1 m water depth), and recorded the number of egg sacs or egg masses (hereafter egg masses). During the two visits, we distinguished new egg masses from previously recorded ones by checking the location of the egg mass on a map; we excluded those that overlapped among surveys from our analysis. We took the total number of egg masses recorded during the two visits per site per year and calculated mean values for the 2 years. We rounded off the mean values for the number of egg masses and used them as a response variable in our analysis.

Measurements of environmental parameters

We used forest area in green spaces, distance from continuous forests, shore protection rate, and pond area as explanatory