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Original article

Predicting impacts of climate change on habitat connectivity of *Kalopanax septemlobus* in South Korea

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A B S T R A C T

Understanding the drivers of habitat distribution patterns and assessing habitat connectivity are crucial for conservation in the face of climate change. In this study, we examined a sparsely distributed tree species, *Kalopanax septemlobus* (Araliaceae), which has been heavily disturbed by human use in temperate forests of South Korea. We used maximum entropy distribution modeling (MaxEnt) to identify the climatic and topographic factors driving the distribution of the species. Then, we constructed habitat models under current and projected climate conditions for the year 2050 and evaluated changes in the extent and connectivity of the *K. septemlobus* habitat. Annual mean temperature and terrain slope were the two most important predictors of species distribution. Our models predicted the range shift of *K. septemlobus* toward higher elevations under medium-low and high emissions scenarios for 2050, with dramatic reductions in suitable habitat (51% and 85%, respectively). In addition, connectivity analysis indicated that climate change is expected to reduce future levels of habitat connectivity. Even under the Representative Construction Pathway (RCP) 4.5 medium-low warming scenario, the projected climate conditions will decrease habitat connectivity by 78%. Overall, suitable habitats for *K. septemlobus* populations will likely become more isolated depending on the severity of global warming. The approach presented here can be used to efficiently assess species and habitat vulnerability to climate change.

1. Introduction

Climate change is regarded as one of the major drivers of changes in biodiversity and ecosystems, and its possible effects are receiving worldwide attention (Duraiappah et al., 2005; Sala et al., 2000). Indications for impacts of climate change have already been found in many species over a wide taxonomic range (Nussey et al., 2005; Parmesan, 2006; Parmesan and Yohe, 2003). In addition, such impacts may be reinforced by habitat loss and fragmentation, which can lead to species range shifts and a reduction in habitat connectivity (Honnay et al., 2002; Opdam and Wascher, 2004).

Although species may have the capacity to shift their range, long distances between habitats or other barriers may restrict their movement. Moreover, the ability to move across the landscape depends on species-specific behavior and landscape structure (Bélisle, 2005; Goodwin and Fahrig, 2002). Thus, understanding the range-shifting capacities of species in response to climate change has important conservation implications for the predictions of future extinction risk and distribution changes (Angert et al., 2011). More importantly, because climate change appears to be inevitable, an effective adaptation strategy may involve preserving and restoring landscape connectivity for long-term persistence of ecological processes, such as dispersal and gene flow (Crooks and Sanjayan, 2006; Rosenberg et al., 1997; Templeton et al., 2001).

Landscape connectivity, or the degree to which the landscape facilitates or disturbs movement among resource patches (Taylor et al., 1993), affects dispersal success and colonization rates (With and King, 1999a, 1999b). Such patterns in turn influence the biodiversity, ecosystem function, and resilience of species to climate change (Fahrig, 2003; Gonzalez et al., 2009; Lawler, 2009). Specifically, well-connected landscapes may enable tracking of species' suitable climate and habitat conditions through time and

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thereby may allow ecological and evolutionary processes to be sustained. Increasingly, ecologists have reported that improving connectivity is necessary for biodiversity conservation and is thus one of the most commonly recommended strategies for helping species adapt quickly and survive rapid climate change (Heller and Zavaleta, 2009; Theobald et al., 2012).

Even though global warming has begun to affect the regional climate system (Boo et al., 2004; Jung et al., 2002) and cause range shifts of terrestrial flora in many countries (Allen et al., 2010), it is unknown whether existing biosphere reserves and semi-natural forests may ensure species' long-term persistence. In this study, we use a species distribution modeling tool to model the current and future potential geographic distribution of *Kalopanax septemlobus* (Araliaceae) in South Korea. We then applied a graph-theoretical method to predict the likely impacts of climate change on habitat connectivity. Natural populations of *K. septemlobus* are threatened by climate change and from illegal logging for timber, medicine, and edible products (Chang et al., 2001; Kang, 2003). The objectives of this study are: (1) to identify climatic and topographic factors associated with *K. septemlobus* distribution by using ecological niche modeling (ENM), (2) to predict the current distribution of suitable habitats and project them under future climate scenarios for 2050, and (3) to evaluate changes in habitat distribution patterns and connectivity.

2. Materials and methods

2.1. Study area and focal species

The study area is in the southern half of the Korean Peninsula and the islands of South Korea (Fig. 1), which lie between latitudes 33° and 39°N, and longitudes 124° and 131°E. Its total area is 100,148 km^2, approximately 64% of which is covered by forests mostly in the north and east regions (KFS, 2012). The area is in a temperate zone with four distinct seasons and is affected by East Asian monsoons. However, global warming has increased the temperature and precipitation levels and widened seasonal and regional weather differences on the Korean Peninsula, changing its climate gradually closer to a subtropical climate (Philander, 2012).

K. septemlobus, commonly known as the prickly castor oil tree, is a hermaphroditic, deciduous tree species in the family Araliaceae. Widely but sparsely distributed through Northeast Asia (Lee and Kang, 2002; Ohashi, 1994), this species blooms in July–August, and various insects act as agents of pollination (Fujimori et al., 2006). Fruits are available in September and October, and seeds are dispersed by birds and squirrels (Iida and Nakashizuka, 1998). It is a multi-purpose tree, important for high quality timber and as a source of food and medicine. However, illegal cutting and over-exploitation due to the increasing demand have led to damage and destruction of its natural habitat (Kang, 2003).

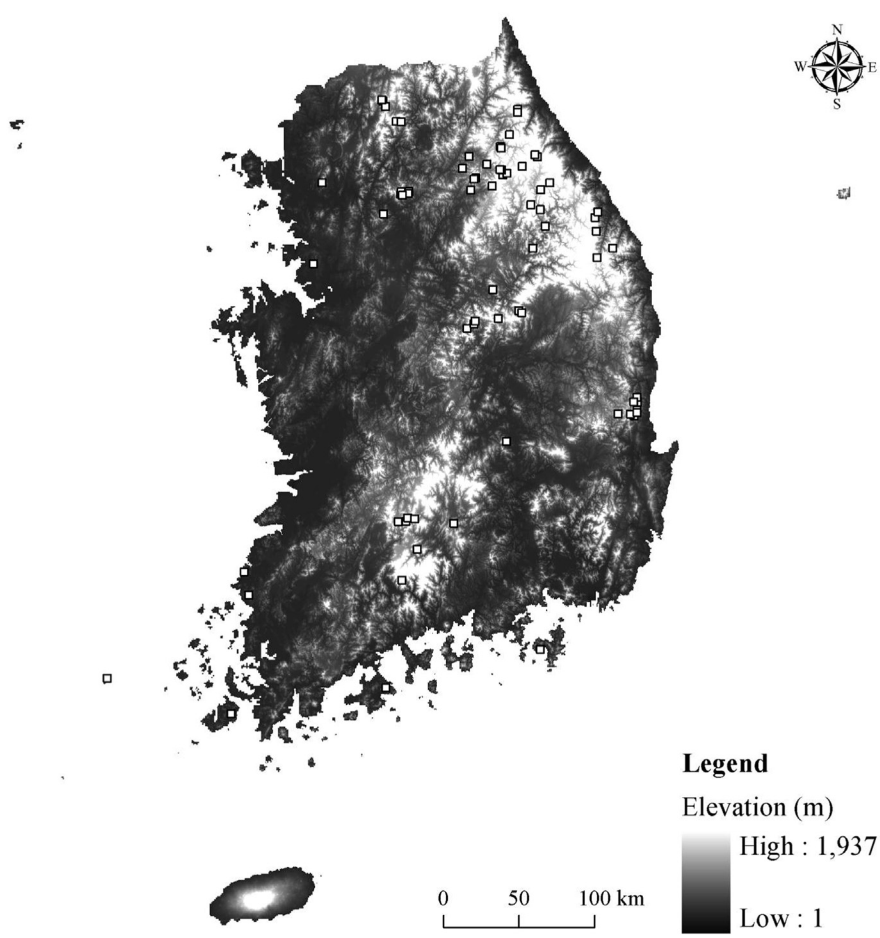

Fig. 1. Digital elevation model of the study area, with the presence locations of *Kalopanax septemlobus* (n = 72) indicated as squares.