POSTER 15

# Phenological Changes of *Monochamus alternatus* and *M. saltuarius* in Response to Climate Change

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## I. Introduction

Climate change a global phenomenon observed a warming of 0.85°C over the period 1880 to 2012 (IPCC, 2013), and the recent 30 year period (1983-2012) was likely the warmest period of the last 1400 years. Insects, poikilothermic organisms, are mainly affected by ambient temperature on most aspects of their biology, such as developmental rate, oviposition, and longevity. The developmental rate is a species-specific characteristic, hence, a change in the developmental rate of one species could be different from another species, which affects both species emergence time.

In South Korea, *Monochamus alternatus* Hope and *M. saltuarius* Gebler are the major vectors of the pine wood nematode (PWN), *Bursaphelenchus xylophilus* Nickle, the agent of pine wilt disease (PWD). *Monochamus alternatus* and *M. saltuarius* are native species in South Korea, which are mainly abundant in the southern and in the central to northern areas in South Korea, respectively. Although native to North America, the PWN, invaded South Korea in 1988 (Choi and Park, 2012). Pine trees, such as *Pinus densiflora* Sieb. et Zucc., *Pinus koraiensis* Sieb. et Zucc., and *Pinus thunbergii* Parl. are the widespread hosts of both *Monochamus* beetles in South Korea. The number of areas damaged by the PWN has dramatically increased with the distributions of *M. alternatus* and *M. saltuarius* spreading northwards and southwards, respectively, combined with a rapid spread of PWD. Both *Monochamus* beetles share their hosts, hence, they may compete with each other under the habitat expansion and the climate change conditions in the future.

Under the current climate conditions, *M. saltuarius* generally emerges earlier than *M. alternatus*. The early-emerging species has a survival advantage over the late-emerging species that shares its habitat. A species-specific change in their emergence time can affect their fitness in areas where both *Monochamus* beetles are distributed. Thus, this study quantitatively evaluated and compared the changes in the emergence times of two *Monochamus* beetles under climate change conditions in South Korea.

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## II. Materials and Methods

### 2.1. Climate data

The current and future climate data of South Korea cover a grid size of 1 × 1 $km^2$. The current climate conditions, including daily maximum, minimum and mean temperatures were averaged from 2011 to 2020 (the 2010s). The decadal averages of the representative concentration pathways (RCP) 8.5 scenario of the 2050s (2051-2060) and the 2090s (2091-2100) were used to describe the future climate conditions.

### 2.2. Spring emergence models and projection

Spring emergence models of both *Monochamus* beetles were developed (Park *et al.*, 2013; Jung *et al.*, 2015). The degree-day used in both models was calculated using a sine wave function. Both models were coded using R 3.2.4 (R Core Team, 2016). The 50% emergence times of overwintered *M. alternatus* larvae were grouped into three fractional modes (advance, regular, and delay) and *M. saltuarius* larvae were calculated for each grid over South Korea. The differences between *M. alternatus* and *M. saltuarius* in the 50% emergence times were calculated for each grid over South Korea and then projected using ESRI ArcGIS 10.1.

## III. Results

### 3.1. Spring emergence pattern of *M. alternatus*

The average of the 50% emergence times was predicted under the current and future climate conditions by using three fractional models (i.e., advance, regular, and delay) over South Korea. The average emergence times of *M. alternatus* over South Korea were 170.3–186.5 days of the year (DOY) in the 2010s (Fig. 1 a-c). Based on the future climate conditions, the average emergence times in the 2050s and the 2090s were 158.2–172.6 DOY and 146.8–160.3 DOY, respectively (Fig. 1 d-i). Thus, the average emergence times were advanced under the climate change condition.

### 3.2. Spring emergence pattern of *M. saltuarius*

Under the current and future climate conditions, the average of the 50% emergence times of *M. saltuarius* was also predicted by using the spring emergence model over South Korea.

The average of the 50% emergence times of *M. saltuarius* was 151.5 DOY in the 2010s (Fig. 2a). In the future, the average 50% emergence times in the 2050s and the 2090s were 140.5 DOY and 128.4 DOY, respectively (Fig. 2 b-c). Like *M. alternatus*, the average emergence times were also advanced under the climate change condition.

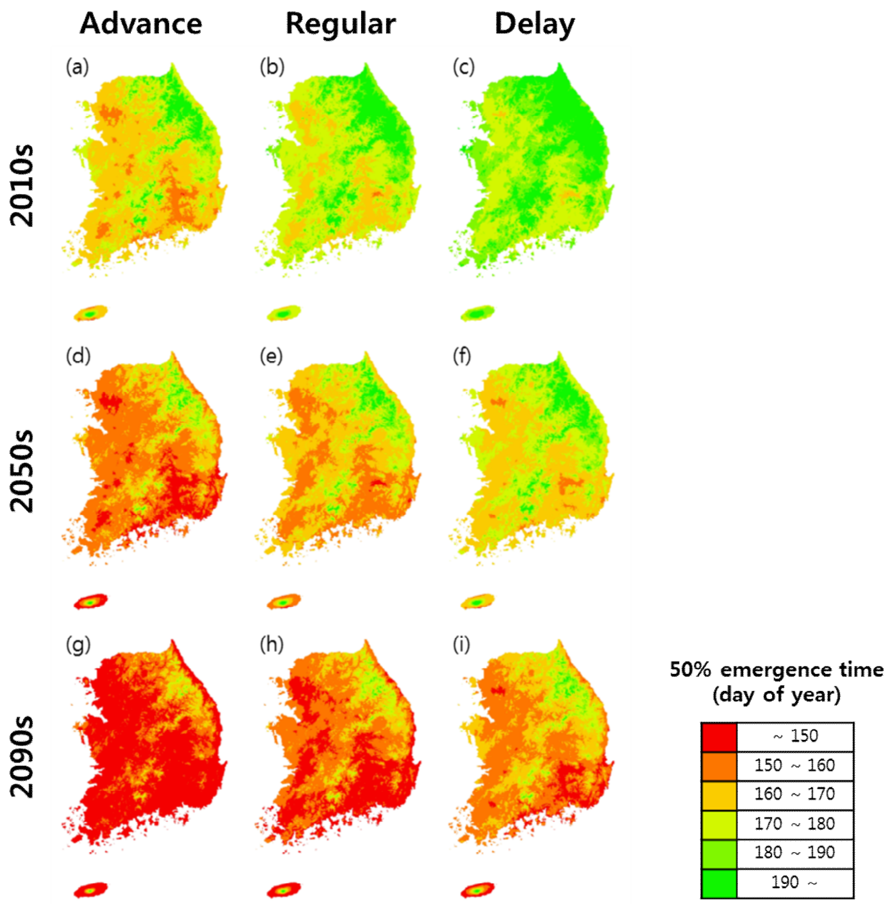


Fig. 1. The 50% emergence time of *M. alternatus* over South Korea under the 2010s (a-c), the 2050s (d-f), and the 2090s (g-i) climate conditions using three fractional models.

### 3.3. The difference between *M. alternatus* and *M. saltuarius* emergence times

The change in the emergence times of the two Monochamus beetles was compared between three time periods. In the future, the differences were decreased in all fractional modes (Fig. 3). Although the differences were decreased under the future climate conditions compared to the current conditions, the differences in the 2050s (Fig. 3 d-f) were similar to those in the 2090s (Fig. 3 g-i).

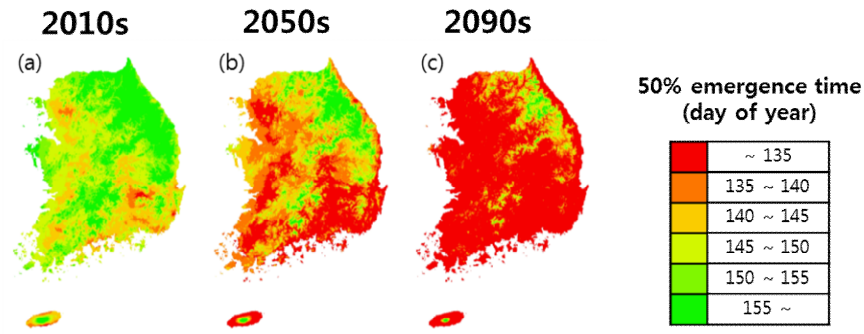


Fig. 2. The 50% emergence time of *M. saltuarius* over South Korea under the 2010s (a), the 2050s (b), and the 2090s (c) climate conditions.

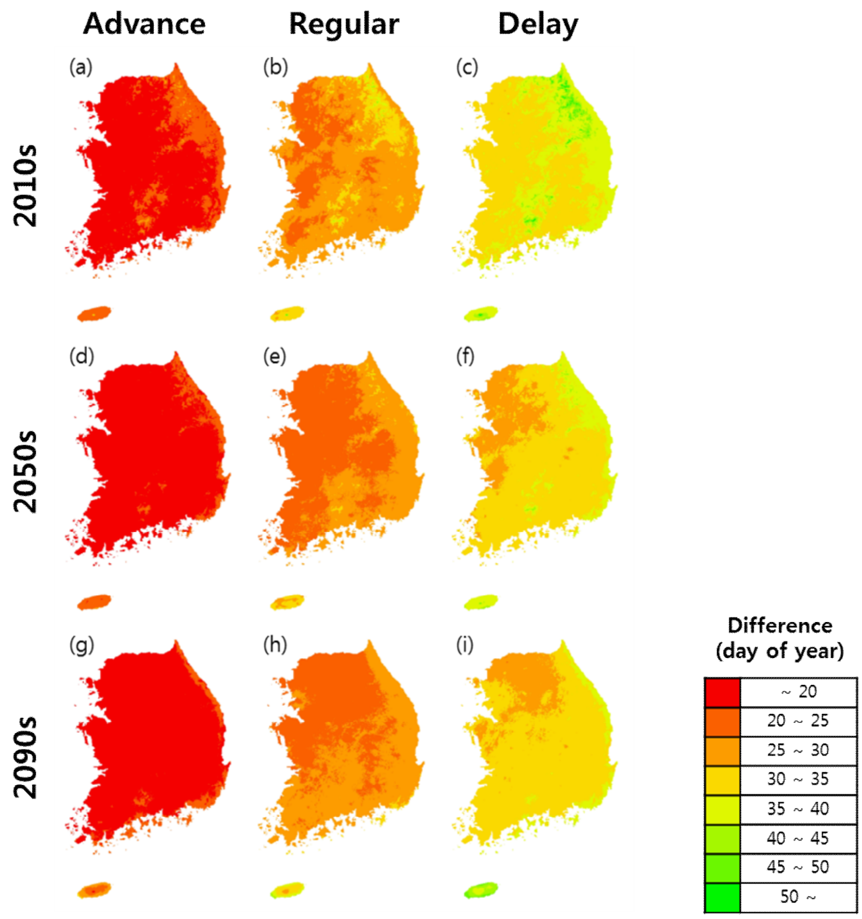


Fig. 3. The difference between the 50% emergence time of *M. alternatus* and *M. saltuarius* over South Korea under the 2010s (a-c), the 2050s (d-f), and the 2090s (g-i) climate conditions.

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