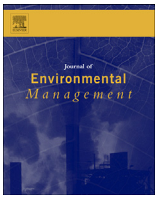
Journal of Environmental Management xxx (2017) 1–11

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman



Research article

Assessing distributions of two invasive species of contrasting habits in future climate

Rajendra Mohan Panda [a], [*], Mukunda Dev Behera [b], Partha Sarathi Roy [c]

[a] School of Water Resources, Indian Institute of Technology Kharagpur, West Bengal, India
[b] Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology Kharagpur, West Bengal, India
[c] Centre for Earth and Space Sciences, University of Hyderabad, Hyderabad, India

ARTICLE INFO

Article history:
Received 19 May 2017
Received in revised form
4 December 2017
Accepted 20 December 2017
Available online xxx

Keywords:
Invasion
Climate change
Range size
Niche
Species distribution modelling

ABSTRACT

Understanding the impact of climate change on species invasion is crucial for sustainable biodiversity conservation. Through this study, we try to answer how species differing in phenological cycles, specifically *Cassia tora* and *Lantana camara*, differ in the manner in which they invade new regions in India in the future climate. Since both species occupy identical niches, exploring their invasive potential in different climate change scenarios will offer critical insights into invasion and inform ecosystem management. We use three modelling protocols (i.e., maximum entropy, generalised linear model and generalised additive model) to predict the current distribution. Projections are made for both moderate (A1B) and extreme (A2) IPCC (Intergovernmental Panel on Climate Change) scenarios for the year 2050 and 2100. The study reveals that the distributions of *C. tora* (annual) and *L. camara* (perennial) would depend on the precipitation of the warmest quarter and moisture availability. *C. tora* may demonstrate physiological tolerance to the mean diurnal temperature range and *L. camara* to the solar radiation. *C. tora* may invade central India, while *L. camara* may invade the Western Himalaya, parts of the Eastern Himalaya and the Western Ghats. The distribution ranges of both species could shift in the northern and north-eastern directions in India, owing to changes in moisture availability. The possible alterations in precipitation regimes could lead to water stress, which might have cascading effects on species invasion. *L. camara* might adapt to climate change better compared with *C. tora*. This comparative analysis of the future distributions of two invasive plants with contrasting habits demonstrates that temporal complementarity would prevail over the competition.

1. Introduction

1.1. Climate change and invasive species

Invasive species may have unique responses to climate changes, with invasive potential being highly species-specific (Pearson et al., 2002). Invasive species increase the vulnerability of ecosystems to other climate-related stressors (Burgiel and Muir, 2010). Reductions in the ranges of species are likely to occur with the global rise in temperature, when physiological activities of plants decelerate after a thermal optimum. The plant phenology and capacity of individual species to resist adverse changes in climate are crucial for their invasion success in the future climate. According to Broennimann et al. (2006), by 2050, annuals are less likely to be affected by climate change than are perennials. The availability of global climate data offers an opportunity to predict the future distribution of species under moderate to extreme climate change scenarios. According to the Intergovernmental Panel on Climate Change (IPCC) Protocol, the A1B scenario is moderate with high economic growth. It assumes balanced use of energy resources and efficient technology. In contrast, the A2 scenario is seen as extreme with a rapid population growth and low per capita income, wherein technology is assumed to change at the regional level with poor economic development (Solomon et al., 2007).

1.2. Habits and invasion capabilities of species

Complementarity is a property of reciprocating in which some aspects of a set of objects (e.g., species) differ from those of the

---

[*] Corresponding author.
E-mail addresses: rmp.iit.kgp@gmail.com (R.M. Panda), mukundbehera@gmail.com (M.D. Behera), psroy13@gmail.com (P.S. Roy).

https://doi.org/10.1016/j.jenvman.2017.12.053
0301-4797/© 2017 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Panda, R.M., et al., Assessing distributions of two invasive species of contrasting habits in future climate, Journal of Environmental Management (2017), https://doi.org/10.1016/j.jenvman.2017.12.053

objects of another set (Williams, 2001). It encompasses interactions among two or more species in space and time (Ewel, 1986; Fargione and Tilman, 2006). Exotic invaders with superior resource use capabilities dominate. Such invaders are introduced mostly in places where there are anthropogenic disturbances. These species use the available resources efficiently and change the properties of native ecosystems (Vitousek, 1986). They alter the species composition and reduce the abundance of native species (Hejda et al., 2009). With their superior growth potential and efficient dispersal mechanism, these invaders establish themselves in native ecosystems rapidly (Sharma et al., 2005). Species with different phenological cycles (e.g., annual or perennial) uses resources asynchronously, by space partitioning and different growth periods (Gulmon et al., 1983; Qin et al., 2003). Annuals senesce after each growing season by exhausting their growth pool and perennials need resources throughout their life cycles (Leffler and Ryel, 2012). The limited availability of soil nitrogen and moisture inhibits the growth of perennials much more significantly than it does that of annuals as-the latter remain active for a short span of time (Blank, 2010; Leffler and Ryel, 2012).

1.3. *Habits of target species*

Cassia tora (Fabaceae) and *Lantana camara* (Verbenaceae), two widespread species, were selected for the present study. They have similar life forms and common origins, but they differ in life cycle patterns, *C. tora* is an annual and *L. camara* is a perennial. *C. tora* is native to the Old World, eastwards to Polynesia, and it is found in open lands and crop fields in South-East Asia and in the south—west Pacific (Singh, 1968). It has anti-oxidant, anti-microbial, anti-proliferative, anti-genotoxic, hepato-protective, hypolipidemic, anti-inflammatory, anti-diabetic and immune-stimulative properties (Shukla et al., 2013). Its seeds are used as a coffee substitute. Each *C. tora* plant produces an average of 643 seeds. The species exhibits effective seed dormancy. Seed germination sets in with pre-monsoon rainfall in June and reduces during the dry—months (October–November) of winter (Gupta and Yadav, 2007). The seed germination can be delayed due to low temperatures, which reduces the permeability of the seed coat; warm climatic conditions favour its distribution (Singh, 1968). Seeds of *C. tora* are dispersed over short distances by water and animals.

L. camara is a species native to Central and South America. It has become naturalised in more than 60 countries between latitudes 35°N to 35°S (Day et al., 2003). It has anti-bacterial, anti-microbial, anti-inflammatory, anti-tumour, and anti-AIDs properties (Sharma et al., 2007). The species was imported to India as an ornamental plant in 1809, and now, it is a common weed of dry forests, *jhum* (slash-and-burn) fallows, and pastures (Sharma et al., 2005). *L. camara* plant produces an average of 10,000–12,000 seeds per year, and these seeds germinate throughout the year when the soil moisture, light, and temperature are sufficient (Kohli et al., 2006; Gentle and Duggin, 1997). Often, water logging and soil salinity impede the growth of this species (Swarbrick et al., 1998). Birds facilitate the long-distance dispersal of *L. camara* (Cronk and Fuller, 1998).

1.4. *Species distribution modelling*

Several species distribution models (SDMs) can be used to describe individual species' responses to the changing climate, and to describe the suitability of habitats for invasive species over a geographic space (Richardson et al., 2000; Kriticos et al., 2003; Jiménez-Valverde et al., 2011). SDMs use presence or presence—absence data. In case true absence data are not available, pseudo-absence data or randomly simulated background data are often used by different models. The generalised linear model (GLM) is a widely-used, simple, parametric linear regression technique used for predicting the distributions of invasive species (Nelder and Baker, 1972; Fitzpatrick et al., 2007). Generalised additive model (GAM) is an extension of this model, but it fits a non-parametric and nonlinear relation between species and the environment (Yee and Mitchell, 1991). The Maximum Entropy (Maxent) model is a non-parametric and nonlinear machine learning technique, used for mapping habitat suitability in the future climate (Phillips et al., 2006; Hijmans and Graham, 2006). Like GAM, Maxent can quantify complex species—environment relationships. Both the regression models calculate occurrence probabilities, whereas Maxent estimates the relative probabilities of the species distribution.

In the present study, we assessed the invasive potential of species with different phenological cycles to understand the impacts of climate change on their distributions. We took advantage of the fact an extensive floral database is available to quantify the invasion potentials of *C. tora* and *L. camara* in moderate and extreme climate change scenarios. The spatiotemporal changes in the range sizes were mapped to compare the occupation of the native niches by the two species. Our hypothesis was that *C. tora*, with its short life span, would be more sensitive to diurnal variations, while *L. camara* would be sensitive to seasonal variations. The two species are likely to compete for resources as their peak growing seasons overlap. We also tried to answer the question; do differences in phenological cycles define the invasion success of species under climate change scenarios?

2. Materials and methods

2.1. *Data preparation*

We pooled the species location points, collected through stratified random sampling, by the project ‘Biodiversity Characterization at Landscape Level' (http://bis.iirs.gov.in) project, a national level assessment (Roy et al., 2012). The sample design involved a nested quadrat of dimensions 20 m × 20 m laid for trees or lianas, which accommodated two 5 m × 5 m quadrats at the opposite corners for sampling shrubs. The sample plots were selected to accumulate species composition data across vegetation strata, with a minimum sampling intensity of 0.001–0.002% (Roy et al., 2012). We considered a total of 1684 and 2526 location points for *C. tora* and *L. camara*, respectively (Fig. 1). We gathered 35 climate data layers from CliMond data at a resolution of 10` (Kriticos et al., 2012), and masked these layers to India's boundary with WGS84 projections using ArcGIS 10. The multicollinearity of the predictor variables was tested using the package ‘usdm’ in R (Naimi, 2015). We selected variables with VIF (variance inflation factor) < 5 and a correlation < 0.75 for modelling.

2.2. *Modelling*

The regression models (GLM and GAM) were fitted with the binomial distribution (link = ‘probit') using the present point locations, and absences selected randomly from within the area of interest. We used simulated pseudo-absences data after 10,000 randomisations, giving equal weights to presences and absences (Barbet-Massin et al., 2012). The importances of the variables were examined using the package ‘caret' in R (Kuhn, 2016). Similarly, we selected 10,000 background points for the Maxent model that did not include actual occurrences. The extrapolation of the simulations of the model was restricted to India's boundary to maintain a similar correlation structure across the geographical space (Jiménez-Valverde et al., 2009). We prepared a bias file by selecting background points from the areas of present locations. Using Arc

Please cite this article in press as: Panda, R.M., et al., Assessing distributions of two invasive species of contrasting habits in future climate, Journal of Environmental Management (2017), https://doi.org/10.1016/j.jenvman.2017.12.053