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SHORT COMMUNICATION

Biological invasion by *Thespesia populnea* in sites under fluviomarine influence

Invasão biológica por *Thespesia populnea* em sítios sob influência fluviomarinha

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Abstract

The present study aimed to report the biological invasion by *Thespesia populnea* of sites under fluviomarine influence and adjacent environments of the Sergipe River, in Aracaju, Sergipe, Northeastern Brazil, by *Thespesia populnea*, as well as to evaluate the susceptibility of the occurrence of the species in other Brazilian regions. The study site comprises a mangrove area and adjacent sites of the Sergipe river. The focuses of the invasion by *T. populnea* were obtained by means of walks throughout the extension of the site (active search). To evaluate the susceptibility of occurrence of the species in Brazil, an ecological niche modeling analysis was performed. The invasion of the species was registered at several points in the study area, with the highest concentrations in the most degraded sites. The results of the model analysis demonstrate high to extremely high susceptibility to the occurrence (biological invasion) of the species in several parts of the country. The attributes of the species, observations in situ and results of the modeling analysis suggest the need to control *T. populnea* in the study area and prohibition of its planting in the Brazilian territory.

Keywords: exotic invasive, modeling analysis, mangrove.

Resumo

O presente estudo objetivou relatar a invasão biológica por *Thespesia populnea* de sítios sob influência fluviomarinha e ambientes adjacentes do rio Sergipe, Aracaju, Sergipe, no Nordeste do Brasil, bem como avaliar a suscetibilidade de ocorrência da espécie em outras regiões do país. O local do estudo compreende uma área de mangue e locais adjacentes do rio Sergipe. Os focos de invasão de *T. populnea* foram obtidos por meio de caminhadas ao longo da extensão do sítio (busca ativa). Para avaliar a suscetibilidade de ocorrência da espécie no Brasil, foi realizada uma análise de modelagem de nicho ecológico. A invasão da espécie foi registrada em vários pontos da área de estudo, com as maiores concentrações nos locais mais degradados. Os resultados da análise de modelagem demonstram alta a extremamente alta suscetibilidade à ocorrência (invasão biológica) da espécie em várias partes do país. Os atributos da espécie, as observações *in situ* e os resultados da análise de modelagem sugerem a necessidade de controlar *T. populnea* na área de estudo e a proibição de seu plantio no território brasileiro.

Palavras-chave: exótica invasora, análise de modelagem, manguezal.

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The Atlantic Forest is a biome formed by several ecosystems, including Mangrove (Schaeffer-Novelli, 1995). As a priority area for biodiversity conservation (International Conservation Organization, 2011), it has been constantly suffering from environmental degradation (Almeida, 2000; Galindo-Leal and Câmara, 2005; Tabarelli *et al*., 2005). Thus, this situation of continuous degradation promotes cases of biological invasion (BI) establishment.

According to Williamson (1999), disturbed environments tend to be more susceptible to invasion by exotic species. BIs are capable of causing disorder in the food chain, as well as of nutrients cycling and plant productivity (Ziller and Galvão, 2002). In addition, they are considered to be the second largest cause of biodiversity loss worldwide (Iucn, 2000). Moreover, their secondary impacts are usually underestimated, reducing the real size of damages (Rogers *et al*., 2017). In Brazil, studies on the subject are still quite a few (Ziller, 2001; Petenon and Pivello, 2008; Andrade *et al*., 2009; Sousa *et al*., 2017), mainly in the Mangrove, and none of them with *Thespesia populnea*.

Being undemanding (Morton, 1966), *T. populnea* develops very well in a wide variety of soil and climatic conditions. The species can be found vegetating on saline, limestone, loamy and semi-compacted soils, with different levels of waterlogging and conservation of tropical and subtropical regions (Iqbal *et al.,* 2002; Francis, 2002; Francis, 2004; Warrier, 2010; Areces-Berazain and Ackerman, 2016). The species has very rapid growth and propagation, being still quite wind resistant. It is considered an exotic invasive species in several parts of the globe (Little and Frank*,* 1964; Friday and Okano, 2005; Orwa *et al.,* 2009; Ammondt *et al.,* 2013; Cabi, 2016). It competes for space and resources with native species, reducing native biodiversity (Cabi, 2016).

The discovery of early-stage invasion cases is a crucial step in effectively resolving the problem. The ecological niche modeling is based on the identification of sites that carry essential conditions and resources for establishment of certain species, allowing to predict their geographic distribution from known occurrence data and environmental data (Guisan and Zimmermann, 2000; Guisan and Thuiller, 2005). This type of analysis allows us to perform several studies, such as stipulate priority areas for conservation, analyzing invasion potential, as well as predicting the past and future distribution of species (Peterson and Vieglais, 2001; Hugall *et al*., 2002; Siqueira and Peterson, 2003, Garcia, 2006, Nyari *et al*., 2006, Giovanelli *et al*., 2008).

In Brazil, there is little information about *T. populnea*. No studies about biological invasion involving the species were found in the databases consulted. In this context, the objective of the present study was to report the biological invasion by *T. populnea* in sites under fluviomarine influence and adjacent environments of the Sergipe river, as well as to evaluate the susceptibility of occurrence (biological invasion) of the species in other Brazilian regions through modeling of ecological niche.

The study area (10°57’47,14”S; 37°2’57,56”W) comprises a mangrove area and adjacent sites of the Sergipe river, between the neighborhoods of Coroa do Meio and Atalaia Velha, municipality of Aracaju, Sergipe, northeastern Brazil. The area has approximately 40 ha and shows signs of anthropic disturbance, such as compacted soils, sewage and garbage from different sources (França and Rezende, 2010).

According to the Köppen-Geiger classification system, the climate of the region is As’ – tropical type with dry summer season (Peel *et al.,* 2007). The predominant soils are Eutrophic Flubic Neosols and Salic Gleysols (Embrapa Solos, 2006).

Native from Asia (Camara *et al.,* 2009), *Thespesia populnea* (L.) Sol. ex Corrêa (Malvaceae) is popularly known as algodão-da-praia, in Brazil, and as *indian tulipe tree, false rosewood, milo, pacific rosewood, motel debou* and *alamo blanco* in other parts of the world. Its height varies from 5 to 12 m., has tortuous trunks, alternate, simple and palmate leaves, deltoids, arranged in spiral form, lanceolate stipules, axial flowers, solitary, paleaceous coloration, with pedicel and five petals, sometimes with two bracts near to the base, globular capsule-type fruits, usually indeiscent, with valves where black seeds with ovoid shape are confined (Little and Skolmen, 1989; Friday and Okano, 2005; Oudhia, 2007).

For confirmation and registration of the species, parts of the plant were collected, herborized and deposited in the ASE Herbarium of the Federal University of Sergipe, São Cristóvão, Sergipe. Focuses of *T. populnea* invasion were obtained by means of walks throughout the site (active search). Each grouping of individuals of the species was georeferenced and this data was later used for making maps in Google Fusion Tables.

In order to evaluate the susceptibility of the biological invasion of Brazilian states and biomes by *T. populnea*, an ecological niche modeling analysis was performed. For this purpose, species occurrence data were obtained from GBIF (2016) and *Species*Link (2016). For modeling analysis, the Bioclim algorithm was used as well as the climate envelope (Elith *et al.,* 2006). The analysis and the map were performed in DIVA-GIS 7.5 software (Hijmans *et al.,* 2012).

To validate the generated modeling, the occurrence points were divided into two datasets: training and test, 70% and 30%, respectively. Thus, the characteristic operating curve (ROC) was analyzed, which evaluates the model performance through the area under the curve (AUC). The AUC is widely used to balance the efficiency of generated models. This analysis allows to recognize if the model is capable of discriminating the presence or absence of the species (Elith *et al*., 2006), generating in this way, more reliable models.

Focuses of invasion of the species were recorded at various points in the study area (Figure 1). The highest concentrations of these focuses occurred in the most degraded sites, with the presence of compacted soils, sewage and garbage. In such points there were large amounts of regenerating and juvenile individuals (Figure 2A-F), indicating that the species is well-adapted to the locality. This fact corroborates the idea that disorders are facilitators of biological invasions (Williamson, 1999).

Figure 1. Area invaded by *Thespesia populnea* in sites under fluviomarine influence of the Sergipe river, Aracaju, Sergipe, Northeastern Brazil.

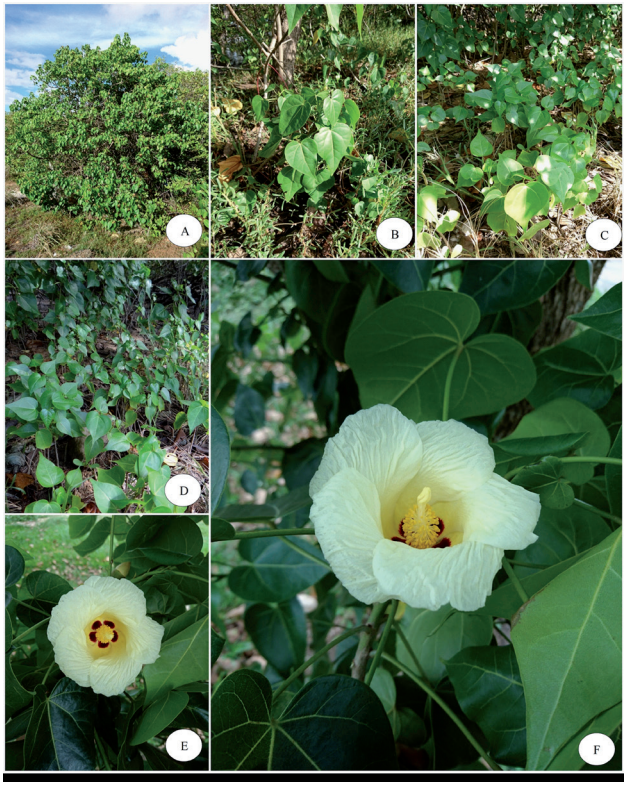

Figure 2. *Thespesia populnea* in sites under fluviomarine influence of the Sergipe river, Aracaju, Sergipe, Northeastern Brazil. (A) adult individual; (B-D) regenerating individuals; (E-F) flower detail.

In relation to the modeling analysis of ecological niche (Figure 3), it was evidenced that almost all the Brazilian coast presents extremely high susceptibility of biological invasion by the species. The results also pointed to a susceptibility varying from high to extremely high throughout the Seasonal and Ombrophylous Forests (Atlantic Forest and Amazonian Forest), as well as in the Pampa biome. Except for some regions, the susceptibility of invasion by the species in the Cerrado was low or there was no susceptibility. For the Caatinga, the susceptibility varied widely, from not susceptible to extremely high susceptibility. The resultant value for AUC was 0.97, being therefore above the random amount, indicating a high-reliability degree of the results.

The susceptibility to occurrence of the species in Brazil observed through the modeling analysis, corroborates with its capacity of tolerance to diverse edaphoclimatic conditions. This fact is of particular concern because of the great biological importance of some sites with high or extremely high susceptibility to occurrence. The Atlantic Forest, for example, is considered a priority area for biodiversity conservation by Conservation International (Myers *et al.*, 2000). Only 8% of its original area remains (MMA, 2002) and part of this remnant is under strong anthropogenic pressure, which favors biological invasions. It is known that allochthonous species promote numerous impacts on

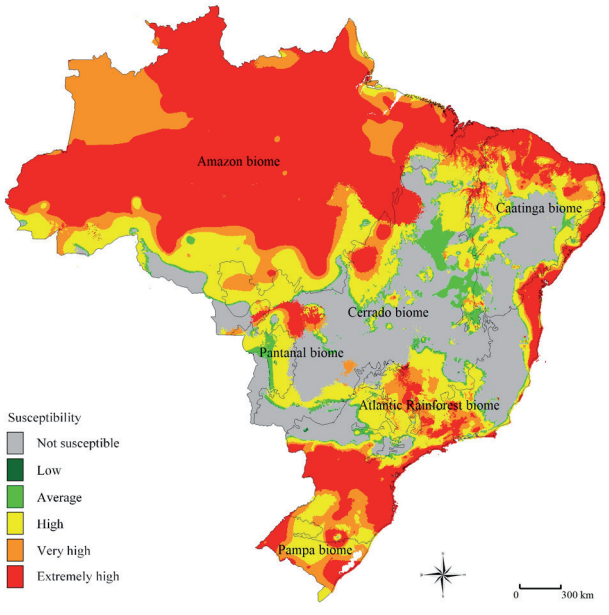

Figure 3. Susceptibility of Brazilian biomes to biological invasion by *Thespesia populnea*.

the environment and on native species (Pimentel *et al.,* 2001). In this sense, a contingent of more than 15 thousand species (of which 8 thousand are endemic) can be affected (Tabarelli *et al.,* 2005; Forzza *et al.,* 2016).

The problem is even more relevant for coastal areas, especially for mangroves, since they are the preferred areas of occupation of the species in Brazil. This ecosystem has a great ecological and economic importance, as it acts as a barrier against the erosive action of tides, biological filter, nursery and nutrient concentration area, serving food for numerous species of crustaceans and fish of commercial interest (Alves, 2001). In addition to the attributes already listed, other factors act together for the success of *T. populnea* in these environments: the species reproduces during most of the year and has propagules adapted to float in the water, which favors its dispersion at long distances by sea currents (Nakanishi, 1988).

Other biomes also showed a high degree of susceptibility of occurrence of *T. populnea*, as in the case of the Amazon Forest and some Caatinga regions, however, the result should be taken with caution. Until now, no cases of biological invasion by the species have been observed or reported in continental environments anywhere in the world. In these places, the species seems to behave only as naturalized (personal observation), perhaps because it does not have dispersers. In any case, special care must be taken to introduce the species in these biomes, especially in riparian forests.

It is important to emphasize that the modeling relates occurrence data with environmental data. Hence, attention must be paid to result limitations. For example, in the case of environmental variables, we must remember that climatic cover in an area is not homogeneous, affecting the individual's distribution (Pereira and Peterson, 2004; Anacleto and Oliveira, 2014). Moreover, habitat fragmentation can change the distribution of a species by transforming previously available niches, as well as the effects on interactions that regulate the species in which may limit the species to a particular location (Pereira and Peterson, 2004; Iménez-Valverde *et al*., 2008).

Facing the results, it is noted that *T. populnea* has high potential to invade much of the Brazilian territory. Also, it should be remembered that most of these areas comprise phytogeographical domains that host huge biodiversity, such as the Atlantic Forest and Amazon Rainforest. Thus, the attributes of the species, observations *in situ* and the results of the modeling analysis suggest the need of control *T. populnea* in the study area and the prohibition of its planting in the Brazilian territory.

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