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Predicting the Spatial Spread of Invasive *Prosopis juliflora* (SW.) D.C along Environmental Gradients in Gabel Elba National Park, Egypt

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Abstract— The predicting and spatial distribution of most invasive plants is poorly documented and studied. This study examined the spatial distribution of a successful invasive plant, Mesquite (*Prosopis juliflora*), in Wadi Merikwan in Gabel Elba National Park. The occurrence data of *P. juliflora* and five environmental variables; distance from the main road, elevation, soil moisture, soil pH, and light intensity were collected and measured from 107 random plots at the Wadi Merikwan. A spatial logistic regression analysis was developed to identify the factors that contribute most to the spread of this invasive plant. The spatial regression analysis indicated that elevation and distance from road were the only significant factors correlated with the spatial distribution and potential spread of *P. juliflora* ($p < 0.05$) at the Wadi Merikwan. In contrast, soil moisture, soil pH and light, intensity of each plot were all not significant factors in relation to the spatial distribution of invasive species at the Wadi Merikwan.

Index Terms— Distance from road, Elevation, Light intensity, Protected area, Regression analysis, Soil moisture, Soil pH.

1 Introduction

Prosopis juliflora (SW.) DC, is an evergreen tree native to South America, Central America and the Caribbean. In the United States of America, it is well known as mesquite. It is fast growing, nitrogen fixing, and tolerant to arid conditions and saline soils. *P.juliflora* has invaded, and continues to invade, millions of hectares of rangeland in South Africa, East Africa, Australia and coastal Asia [1]. In 2004 it was rated one of the world's top 100 least wanted species (Invasive Species Specialist Group of the IUCN, 2004).

P. juliflora will form an evergreen forest even in the driest zones of the Northeastern Semi-Arid Region, in years of little rainfall, as well as in years of periodic drought [2]. According to [3], *P. juliflora* is a tree with a twisted stem, flexible branches with long, strong thorns, bipinnate leaves; pale-yellow flowers arranged in spikes; flattened fruit, non-dehiscent with hardened epicarp, pulpy sweet mesocarp, multi-seeded and curved. [4], gives a more detailed description of *P. juliflora*, stating that it is a tree typical of arid and semi-arid regions.

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The root system includes a tap root that grows deeply downward in search of water tables; the stem is green-brown, sinuous and twisted, up to 6–9 m in height and 45 cm in diameter, with strong axial thorns situated on both sides of the nodes and branches, from 63 mm to 2.5 cm; bark somewhat rough and dull-red; leaves compound, bipinnate with one or sometimes two pairs of rachis, each having 12 to 25 pairs of green folioles, almost pendulous; flowers lateral to the axis, with a tubular light greenish-yellow 1.5-mm-wide calyx with 5 hooded teeth, a light greenish-yellow corolla composed of 5 petals, 3 mm wide, pubescent along its edges; 10 orange-colored stamens spread lengthwise and 4-mm-wide brown anthers at their end with a thin, white curved style, superior 4-mm-thick ovary, slightly pubescent, light green; the fruit is a nondehiscent pod, curved, approximately 4 mm thick, 1 cm wide, up to 15 cm in length, made up by a light yellow hardened epicarp, fleshy mesocarp, rich in saccharose, whose contents oscillates between 20–25% and 10–20% of reduced sugar and a woody endocarp which contains the seeds.

P. juliflora introduced intentionally into Gabel Elba National Park (GEPA), after 1985 for agro-forestry uses by local people of Old-Halaby village, Eight years after the species introduction, local people in GEPA alike viewed *Prosopis* as a noxious and problematic tree because of its aggressive invasive ability, which a domestic camels grazing has been represented the main vector for accelerating its spread from the initial area of invasion into new area of invasion, includes satellite populations in Wadi Shalal, W. Mericowan, W. Sarara, W. Abib,W. Shaab and new Halaib village. The range of expansion was expanded to 116 km northward from the introduction foci (Old Haliab village) at latitude 22° 13' 64" E and longitude 36° 38' 51" N. to the latest satellite invasion population (Wadi Aibib) at 22°47'56.25"N and 35°43'49.26" E. The camel trade between Egypt and Sudan has been represented a

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critical agent in re-introduction of *prosopis* in the northern part of GEPA which may lead to repeat a similar scenario for invasion the northern area in near future.

Understanding and predicting the distribution of invasive species is central to controlling their spread and mitigating the impact of biological invasions. Inevitably, recent studies have concentrated on predicting the potential distribution of invasive species [5] [6] [7].

Studies that emphasize specific sites or habitat types have provided a general model of the distribution of invasive plants and have measured their impacts on natural communities. Additional studies have shown that forested regions have been impacted to a lesser extent than other communities [8]. Management and control of biological invasion have been a great challenge for researchers and the general public. The geography of native habitat, including the availability of water sources, elevation, slope and aspect, and human disturbances are important factors in the process of plant invasion [9]. The spatial distribution of invasive plants, however, is poorly documented [10]. We know the general regions where an invasive plant may be found, but detailed maps are usually unavailable. The study aimed to provide the first geographic characterization of the invasive plant *P. juliflora* (SW.) DC, in Gabel Elba National Park; and to develop test models to identify factors contributing most to the spread of this invader. We hypothesized that the spatial distribution of *P. juliflora* is site specific and that intensive anthropogenic disturbance causes greater invasion

2 Material and Methods

2.1 Study Area

The Gabel Elba Protected area is located in the southeastern corner of the Eastern Desert of Egypt (Fig. 1).

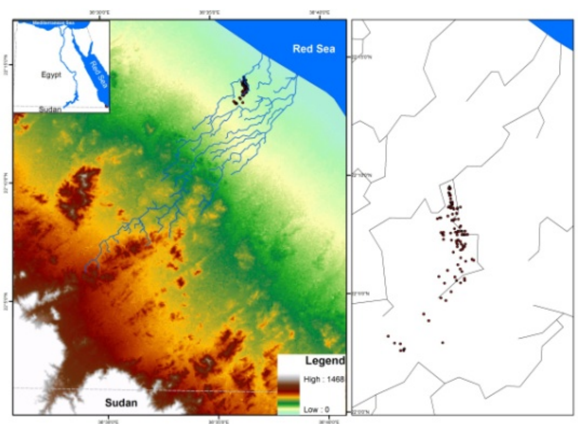

Fig. 1. The study area, showing the location of plot samples.

It coversabout 35,600 sq km.It extends between latitude 22°0' and 23°2' N, and longitude 36°0' and 36°55' E. The present study represents a part of the Great Sahara of North Africa that is an arid to hyper-arid region with very limited rainfall.The boundaries extends more than 50 km north of Shalatein south to the border with Sudan, east covering the coral reefs and islands of the Red Sea west into the Eastern Desert. We selected WadiMerikwan as principal study area survey becauseof its proximity to areas affected by P.juliflora invasion in Gabel Elba National Barksee (Fig. 1; [11], for site description).

2.2 Field Data Collection

Field data collection was conducted between June 2013 and December 2014. We established 21 sampling points; each sampling point contained 5 to 10 plots, each 10-m x 10-m in size. The plots were distributed approximately 150 m apart along the transect lines. Each transect length was determined by measuring the distance from the sampling point to the main road. We collected data from 107 plots within the Wadi Merikwan.We measured the following six variables, which are most likely to constrain the geographic distribution of the species: species richness per plot, distance from the main road, elevation, soil moisture, soil pH, and light intensity. Light intensity was recorded with a portable photometer (LI-COR Instruments, Inc., Lincoln, Nebraska, USA). Distance from the main road was measured digitally using ArcGIS software packages. Elevation data were obtained with a Garmin Global Positioning System (GPS) map (Garmin, 60 CSx, USA). Soil moisture and soil pH measurements were determined by a Kelway Soil Meter (Kel Instruments Co., Inc., Wyckoff, NJ, USA). Last, *P. juliflora* occurrence data (1-presence, 0-absence) were recorded at each plot. Occurrence data were used to detect the distribution of *P. juliflora* within the wadi.

2.3 Statistical Analysis

Logistic regression analysi were developed at plot level to identify contributing factors in the region using IBM SPSS Statistics 20 (SYSTAT Software, Inc., Chicago, IL). We used logistic regression analysis because of the robustnature of the models with binary data [12], and their good performance in predicting the distribution of invasive at different spatial scales [6] [13]. We extracted two explanatory variables from a GIS database, Kentucky Lake Geographic Information System (MARC Associates 1998) using ArcMap (ESRI, Redlands, CA). These variables were distance from the main road, and elevation. The occurrence data (1, 0) of *P. juliflora* at the landscape level were determined based on the plot-level occurrence data. We recorded "1" if *P. juliflora* covered more than 50 percent of the plot and "0" if it covered less than 50 percent of the plot.

3 Results

The occurrence of mesquite was found on 45.7 percent of the Wadi Merikwan (n = 49, based on a total of 107 plots).The results of logistic regression models indicated that elevation and distance from road were the only significant factors to the potential spread of *P. juliflora* ($p < 0.05$) (Table 1). Analysis showed that probability of occurrence declines with increasing elevation ($P < 0.05$; Z =-0.491), but increase the closer the distance from the road ($P < 0.05$; Z =0.251) (Table 1).

Light intensity, soil pH and soil moisture were correlated with invasive plant richness and its occurrence. Light intensity was positively correlated with plant richness but soil pH and soil moistur variables were negatively correlated with invasive plant richness and its occurrence (Table 1).

TABLE 1

RESULTS OF LOGISTIC REGRESSION ANALYSIS FOR DISTANCE FROM ROAD, ELEVATION, LIGHT INTENSITY, SOIL PH AND SOIL MOISTURE AT WADI MERICOWAN IN GEBEL ELBA NATIONAL PARK.

Parameter	*Estimate*	*SE*	*Z*	*p-value*
Constant	6.767	2.715		0.014
Distance to road	0.001	0.000	0.251	0.039
Elevation	-0.103	0.027	-0.491	0.000
Light intensity	0.000	0.000	0.135	0.211
Soil pH	-0.107	0.273	-0.038	0.697
Soil moisture	-0.003	0.004	-0.066	0.493

4 DISCUSSION

We predicted that the geographic conditions of habitats could cause a greater occurrence of *P. Juliflora* because these factors have been found to play a significant role in plant invasion [9] [14]. The results of our study showed that the occurrence of *P. Juliflora* is heavily associated with environmental factors in general. However, it provided little evidence that the distribution of *P. Juliflora* is determined by habitat conditions. Environmental variables and functional groupings influenced community structure of non-native plant species and invasion patterns of globally common invaders. Previous analyses documented non-native species richness declines with increasing elevation and distance from the road and related to progressive filtering of the lowland species pool along the elevational gradient [15] [16] [17].

Our results indicated that the probability of ocuuerance of invasive *P. juliflora* increase close to the road. Distance from road can influence the non-native plant community [18] [17]. Roads can act as conduits for invasion by providing high propagule loads, high light availability, disturbance and low competition from native vegetation [19] [20] [21]. Furthermore, roads can offer novel habitats compared to interior vegetation [22] that might enhance colonization by non-native species [20]. This may be especially true at higher elevations or in more protected areas, where there is a sharper contrast between roadside and interior habitat conditions [18] [17]. In our study, the large amount of tree of *P. juliflora* was found in roadside subplots. This suggests that few species are roadside specialists and the remaining species have already invaded at least 100 m near to the road line. Our findings results showing *P. juliflora* non-native species enter the plant community at lower elevations near the roadside and spread up slope and into the native vegetation matrix [15] [16] [17]. Soil conditions represent an environmental barrier that can constrain species distributions and filter community membership at multiple spatial scales [20]. Soil moisture and texture are key environmental conditions related to differences in naturalized and invasive species distribution patterns in this semi-arid system. Our results indicated that soil pH and soil moisture were correlated negatively with plant richness and its occurrence Using trait-based approaches and identifying key environmental barriers such as soil pH and soil moisture can be used in management strategies focusing on habitats of importance along the invasion continuum [23] [24] [25].

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