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Evaluation of Some Ecological Parameters of Some Selected Eco Systems Invaded by *Prosopis juliflora* in Bundala National Park of Sri Lanka

T.D.P.C. GUNARATHNA[1], B. RANAWEERA[1], P.A.C.N.B. SURAWEERA[2] and K.H.M.I. KARUNARATHNA[3]

[1]*Department of Horticulture and Landscape Gardening, Faculty of Agriculture and Plantation Management,* [3]*Information and Communication Technology Centre, Wayamba University of Sri Lanka, Makandura, Gonawila (NWP), 60170, Sri Lanka*

[2]*Department of Wild Life Conservation, No.811/A, Jayanthipura Road, Battaramulla, 10120, Sri Lanka*

ABSTRACT

***Prosopis juliflora* (*Kalapu Andara*) is considered as one of the problematic invasive plant species in Bundala National Park of Sri Lanka. It is threatening the very existence of the park and its wild life by restricting growth of feeding plants for wild animals. Chemical and conventional methods of control cannot be applied in the national parks due to their threats to biodiversity and the restrictions imposed by wild life protection acts. Lack of ecological studies on *P. juliflora* is a major constrain when controlling its population. This study was carried out to evaluate some ecological parameters of some selected eco systems invaded by *P. juliflora*. Data were collected from four ecosystems; ecosystem without invasion by *P. juliflora*, ecosystem with invasion by *P. juliflora*, ecosystem where *P. juliflora* has been removed by uprooting two years ago and ecosystem where *P. juliflora* has been removed by uprooting four years ago. Data were statistically analyzed. Results reveled that *P. juliflora* can be suppressed by introducing a suitable dominant plant species to the eco system soon after the removal of *P. juliflora*.**

KEYWORDS: Bundala national park, Ecological indices, *Prosopis juliflora*

INTRODUCTION

Plant invasions are posing a great threat to biodiversity (Crowling *et al.*, 1997), which is already threatened by habitat destruction due to human population growth. Invasive species are broadly defined as those species that are not native to an area and that may displace or otherwise adversely affect native plant species (Drake *et al.*, 2003). These species, according to Drake *et al.* (2003), often produce prolific seeds that may disperse widely and remain viable in the soil for long periods of time. Invasion is defined as the whole process from the arrival of a new species into a community, to, its further spread into neighbouring communities (Prieur-Richard and Lavorel, 2000).

According to Crawley (1997), alien plants are the biggest single threat to plant conservation in nature reserves in many parts of the tropics and subtropics. However, Meffe *et al.* (1997), emphasized that maintenance of biological diversity is now recognized in many circles as the single highest conservation priority of our time because biological diversity is our living natural resources base, our biological capital in the global bank.

Prosopis juliflora is an evergreen tree native to South America, Central America and the Caribbean. In the United States, it is well known as mesquite. It is fast growing, nitrogen-fixing and tolerant to arid conditions and saline soils. Under the right conditions, it can be used to produce a variety of valuable goods and services i.e. construction materials, charcoal, soil conservation and rehabilitation of degraded and saline soils. In the late 1970s and early 1980s *P. juliflora* has been introduced to new environments across the world. It has invaded, and continues to invade, millions of hectares of rangeland in South Africa, East Africa, Australia and coastal Asia. In 2004 it was rated one of the world's top 100 least wanted species (Invasive Species Specialist Group of the IUCN, 2004) (Anon, 2008a).

Prosopis juliflora belongs to family Fabaceae and xerophytic adapted to many soil types under a wide range of moisture conditions. The value of the tree lies in its exceptional tolerance of drought and marginal soils. It can tolerate strongly saline soils and seasonal water logging. *Prosopis juliflora* has been planted successfully on soils with acid to alkaline reaction. It has a large crown and an open canopy, growing to a height of 5-10 m. Stem is green-brown, sinuous and twisted, with axial thorns situated on both sides of the nodes and branches. Bark is rough and dull red. The root system includes a deep taproot. Leaves are compound and leaflets in 13-25 pairs, oblong (3 × 1.7 mm) and dark green, bipinnate with one or sometimes two pairs of rachis, almost pendulous. Flowers are latteral to the axis with a tubular, light greenish-yellow, 1.5 mm wide calyx with hooded teeth and corolla light greenish-yellow, composed of five petals with 3 mm wide pubescent along its edges. The bisexual, pea like flowers are cross-pollinated by wind and insects. Fruit is a non-dehiscent pod, straight, linear, falcate to annular, with a coraceous mesocarp in one segment or divided into several segments. Seeds compressed, ovoid, hard, dark brown, with mucilaginous endosperm surrounding the embryo. Flowering begins at the age of 3-4 years. As well as it produces water soluble allelopathic chemicals in its leaves, roots, pods and flowers such as L-tryptophan, syringgin, laricriesinol (Anon, 2009a).

This species was introduced to Hambanthota district in the Southern province of Sri Lanka in early 1950s to improve saline soils in the area. However, it has spread in to natural ecosystems in Bundala National Park (BNP) and other areas having similar climatic conditions (Anon, 2012). The ecological significance of Bundala National Park as a habitat for water birds and in particular migratory shorebirds was recognized when it was named a RAMSAR site in 1991. However, now a days banks of its water bodies have been contaminated by *P. juliflora* threatening the very existence of the park and its wild life. In addition to that a dense population of cactus covers the ground and the *P. juliflora* grows with higher canopy, cutting off the sunlight for other plants. They have restricted the growth of feeding plants for animals like deer and elephants. Above conditions have put Bundala National Park on Sri Lanka's South Eastern coast, known for its water birds and picturesque landscapes of lagoons, water reeds, forest and wildlife in to a crisis (Anon, 2009b).

Uprooting is the major method that can be applied to control their threat because the other common weed plant management methods i.e. cover crops, mulching, weedicide application *etc.* cannot be applied in the national parks due to their threats to biodiversity and the restrictions imposed by the wild life protection acts. Uprooting is also minimized in National parks by its practical difficulties. Therefore, *P. juliflora* management is necessary to be carried out in national parks with the application of ecological methods that does not cause any threat to the flora and fauna. In the development of controlling methods, information on ecological parameters and the invasive behavior of plants are very important. Therefore, a study was conducted to study the ecological parameters and invasive behavior of *P. juliflora* in some selected eco systems of BNP.

MATERIALS AND METHODS

Field Study

From the areas where *P. juliflora* has being identified as a threat for flora and fauna, BNP was selected for the study due to the most devastative spread recorded there. The study was carried out from January to May 2016. In BNP four eco systems (ES) types were selected for the study, i.e. ecosystem without invasion by *P. juliflora* (ES 01), ecosystem with invasion by *P. juliflora* (ES 02), ecosystem where *P. juliflora* has been removed by uprooting two years ago (ES 03) and ecosystem where *P. juliflora* has been removed by uprooting four years ago (ES 04).

Four random transects were taken from each ecosystems and four random samples were taken from each transect by laying 1×1 m quadrate. After counting the total number of plant species in each quadrate, total number of *P. juliflora* plants and the number of plants from other plant species were counted. Two random soil samples were taken from each transect. Accordingly from each ecosystem eight soil samples were taken. And average pH values were measured from each four ecosystems.

Calculation of Ecological Indices

Following ecological indices were calculated further, because in earlier research works they were identified as useful criteria to develop the control methods of some other invasive plant species (Rathnayaka *et al.*, 2014).

Margalef's Species Richness Index

Species richness is the simplest measure of biodiversity, and is simply a count of the number of different species in a given area. It is commonly used, along with other factors, as a measure for determining the overall health of different biological ecosystems. High species richness for a given area indicates a high level of ecosystem stability. Therefore, high levels of species richness in ecosystems typically characterize these ecosystems as healthy and robust (Anon, 2013).

$$I_{Margalef} = (S - 1)/\ln(N)$$

Where, S- Total number of species
N- Total number of individuals

Menhinick's Species Richness Index

This species richness index is calculated in a way to reduce the influence by sampling technique. It can give a further description of biological diversity (Anon, 2008b).

$$I_{Manhinick} = S/\sqrt{N}$$

Where, S- Total number of species
N- Total number of individuals

Shannon's Diversity Index

This is an information index which measures biodiversity based on the principle that diversity can be measured much like the information contained in a code or message (e.g., the longer and more complex the code, the grater the diversity). Shannon's diversity index is affected by both the number of species and their equitability, or evenness. A greater number of species and a more even distribution of species both result in an increase in Shannon's diversity. The maximum Shannon's diversity for a sample is found when all species are equally abundant. Values of the Shannon's diversity index for real communities typically fall between 1.5 and 3.5 (Anon, 2013).

$$I_{Shannon} = H = \sum p_i \ln (p_i)$$

Where, p_i- the population of important value of the I[th]species

Shannon's Evenness Index

Shannon's evenness is derived from Shannon's diversity index. Evenness is a measure of how similar the abundances of different species are. When there are similar proportions of all species, evenness approaches a value of 1.0. When the approaches are very dissimilar (some rare and some common species), the value for evenness decreases (Anon, 2013).

$$E_{Shannon} = H/\ln(S)$$

Where, *H*- Shannon's diversity index
S- Total number of species

Simpson's Dominance Index

The Simpson's dominance index measures biodiversity based on the probability that two individuals randomly selected from a sample will belong to the same species (Or some category other than species). Simpson's dominance index ranges from 0 (all taxa are equally present) to 1.0 (one taxon dominates the community completely; Anon, 2013).

$$D_{Simpson} = \sum n_i (n_i - 1)/N (N-1)$$

Where, n_i- Total number of individuals of i^{th} species
N- Total number of individuals of all species

Data Analysis

After calculation part, the Pearson Correlation Coefficient method to examine whether the relationship of ecological indices with *P. juliflora* density were significant at 0.05 probability level. Data were descriptively analyzed by Statistical Analytical System (SAS) version 9.2.

RESULTS AND DISCUSSION

Data collected from eco system without invasion from *P. juliflora* were not included in the analysis. Because, in that eco system *P. juliflora* was absent.

Eco Systems invaded by P. juliflora

Pearson correlation coefficients with *P. juliflora* density and ecological indices of three eco systems are presented in Table 1, Table 2 and Table 3 respectively.

Margalef index, Menhinick index and Shannon index don't express significant correlation with *P. juliflora* density in ES 02. These three indices express the plant diversity in the relevant ES. *Prosopis juliflora* density and evenness index don't show a significant correlation in ecosystem with invasion by *P. juliflora* (Table 1). It indicates that the other plant species populations in that ecosystem are not capable to suppress *P. juliflora* population. *Prosopis juliflora* is a relatively larger tree with large canopy size in these ecosystems compare to other plant species. Hence, they are unable to give a strong competition for *P. juliflora*. Further, there are no previous records of natural enemies and consumption by elephant and other grazing animals and they were not observed during this study as well. That indicates the lack of natural control of *P. juliflora* by primary consumers in these ES. Simpson index is the only one index that shows a significant negative correlation with *P. juliflora*. Accordingly, if some plant species are dominating in this ecosystem, *P. juliflora* population can be suppressed by particular species.

Table 1. Pearson correlation coefficients among *P. juliflora* density and ecological indices of Ecosystem with invasion by *P. juliflora* (ES 02)

Index	Coefficient	Probability
Margalef index	0.4707	0.0657
Menhinick index	0.4392	0.0887
Shannon index	0.1573	0.5605
Evenness index	0.3869	0.1387
Simpson index	-0.5595	0.0367

Margalef index, Menhinick index and Shannon index are expressing significant correlation with *P. juliflora* density (Table 2). It may be due to higher plant species richness developed in this ecosystem. Further, two years after removal *P. juliflora,* Simpson dominance index has negative significant correlation with

P. juliflora population. Similar to ES 02 if some plant species are dominating in this ecosystem, *P. juliflora* population can be suppressed by relevant species.

Table 2. Pearson correlation coefficients among *P. juliflora* density and each ecological indices of ecosystem two years after the removal of *P. juliflora* (ES 03)

Index	Coefficient	Probability
Margalef index	0.6846	0.0034
Menhinick index	0.7924	0.0003
Shannon index	0.5816	0.0181
Evenness index	0.4968	0.0503
Simpson index	-0.5372	0.0120

Four years after the removal of *P. juliflora,* Margalef index, Menhinick index and Shannon index do not have significant correlations with *P. juliflora* density (Table 3). Lower non significant positive correlation of Simpson index with *P. juliflora* density indicates that four years after removed of *P. juliflora* no plant species in the ecosystem can be found as dominant enough to suppress the *P. juliflora* population. At the same time correlation between Margalef index, Shannon index and evenness index with *P. juliflora* density has been changed to a negative value in the ecosystem, four years after the removal of *P. juliflora* which indicates that the plant diversity is increasing with a negative effect to the *P. juliflora* population. Therefore, the results indicate that after removal of *P. juliflora* species succession increases the diversity with development of higher population density of non native plant species that are not dominant in the ecosystem. In order to have a dominance against an invasive plant species it is necessary to develop more persistent native plant populations (Rathnayaka *et al.*, 2014).

Table 3. Pearson correlation coefficients among *P. juliflora* density and ecological indices of Eco system four years after the removed *P. juliflora* (ES 04)

Index	Coefficient	Probability
Margalef index	-0.0108	0.9682
Menhinick index	0.0621	0.8191
Shannon index	-0.1026	0.7052
Evenness index	-0.1087	0.6885
Simpson index	0.1778	0.5099

As the Simpson index is having a significantly negative correlationship with *P. juliflora* population density during the early years after the removal of *P. juliflora,* establishment of native dominant plant species to suppress *P. juliflora* may be more successful soon after the removal of *P. juliflora.*

Collected data on pH values of soils in different ES of BNP confirm the previous records and observations made on the capability of *P. juliflora* to survive in the soils with high pH value and salinity (Table 4).

Table 4. Average soil pH values of eco systems

Eco System	Average pH value
ES 01	5.85
ES 02	7.52
ES 03	7.58
ES 04	7.26

CONCLUSIONS

According to the correlationship of Margalef index, Menhinick index and Shannon index with the *P. juliflora* density in the ecosystems of BNP, presently available plant diversity is not capable to show any resistance to the invasion by *P. juliflora.* Absence of some dominant plant species that can suppress *P. juliflora* may be the main reason for that condition. However, within the initial two years after the removal of *P. juliflora,* there is a possibility of controlling *P. juliflora* invasion by using some selected suitable dominant plant species.

Therefore, introduction of dominant plant species can be suggested to start just after the removal of *P. juliflora* in order to control new invasion by the same species.

Further research should be carried out to select the suitable plant species to be introduced and to develop the methodology of introduction and establishment.

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