Journal of Arid Environments 125 (2016) 80–87

Contents lists available at ScienceDirect

Journal of Arid Environments

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

Patterns of herbaceous species richness and productivity along gradients of soil moisture and nutrients in the Indian Thar Desert

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ARTICLE INFO

Article history:
Received 22 July 2014
Received in revised form
15 September 2015
Accepted 13 October 2015
Available online 24 October 2015

Keywords:
Community dynamics
Grazing intensity
Humpback hypothesis
Pulse
Events
Phytodiversity-biomass relationship

ABSTRACT

For the temperate vegetation community, herbaceous biomass and species richness relationship has been eminent as a humpback response hypothesis. This appraised higher level of herbaceous richness at an intermediate level of biomass. However, no such study has been made in the sultry parched ecosystem. Hence, in the present study this kinship have been explored in the Indian hot, arid desert using three distinct seasonal events. Different community and soil parameters were quantified during different pulse events by following the touchstone methods. Based on dominant herbs, selected grazing lands were categorized under sub-climax stage, where 30, 24 and 18 species were recorded during pulse (rain), inter-pulse (winter) and non-pulse (summer) events, respectively. ANOVA analysis blabs significant variations in herbaceous biomass and in different soil components that brought by events, sites as well as by their interactions. Kaiser-Meyer-Olkin test and Bartlett test of spehericity proves the worthiness of factorial analysis used in this study. Result substantiates that unimodal relationship between herbaceous richness and biomass hold true in the Indian arid Thar Desert. Herbaceous biomass ranging from 101.77 to 123.5 gm^{-2} supports the maximum herbaceous richness with combination of different pulse events. Relationships of soil components and grazing intensity with richness and biomass were illustrated.

1. Introduction

In stressful habitats (such as desert), water availability in the phase of precipitation serves as pulse events (Austin et al., 2004; Synder et al., 2004). Such events are stochastic and vary from year to year (Welzin and McPherson, 2000). Goldberg and Novoplansky (1997) suggested the "two-phase resource hypothesis" for the natural selection of annual plants in desert environments, and explained the period when resources are usable as 'pulse' and the resource scarce period as 'inter-pulse'. Within arid and semi-arid environments, resource availability can be depicted under three distinct phases i.e. pulse, inter-pulse and non-pulse events (Chesson et al., 2004; Synder et al., 2004; Mathur and Sundarmoorthy, 2009). These resource gradients may be the primary environmental factors to which plant responds (Holmgren et al., 2006).

From an ecological view, there are two pertinent factors: (a) the depth to which soil-water potentials are elevated to levels that promote biological activities (pulse depth), and (b) the length of time over which water potentials remain at biologically relevant levels (pulse duration). Both characteristics describe the quantity of "pulse size", i.e. larger pulse events usually affect greater soil volumes and last longer. According to different environmental settings, five different functional relationships would be possible between herbaceous biomass and richness viz., uni-modal (humpback), multimodal, monotonically increasing, monotonically decreasing, or no relationship. A humpbacked species richness-curve is a functional relationship between species richness on the one hand and one of various characteristics of ecological communities on the other, including latitude, environmental gradients, predation intensity, disturbance, productivity and time. Further, Huston (1994) has discussed resource and regulator gradients associates with these relationships. Working mechanism of both these gradients differs, for example, nutrients (resources) are depleted by organism, whereas regulators gradients affecting the physiology of the organism. Mathur (2014) have provided the conceptual basics of how different direct and indirect

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http://dx.doi.org/10.1016/j.jaridenv.2015.10.011
0140-1963/

environmental gradients as well as resource gradients affect the plant growth, endurance and their potential distributions. In general, humpback model predicts that herbaceous species richness is highest at an intermediate level of biomass that corresponds to moderate competition or disturbance. Oba et al. (2001) have tested the humpback prediction in the northern Kenya arid region and confirmed that even in arid grazing lands, species richness declines when biomass exceeds 500 gm^{-2}, as predicted by the humpback model. Changes in species richness and productivity in Mediterranean grasslands (Israel) with relation to temporal and edaphic changes have been studied by Henkin et al. (2006). Their findings pointed out that soil resources like phosphorus positively related to the productivity and herbaceous richness, they also described the positive relationships of biomass production with species richness.

In present study the relationship between herbaceous biomass and species richness in view of the humpback hypothesis was tested. The major objectives were (1) to test whether or not the humpback response hypothesis holds true for the Indian hot, arid region with combination of various seasonal events and (2) to ascertain the roles of different biotic, soil and habitat factors likely affecting richness and herbaceous biomass.

2. Materials and methods

A study was conducted at 12 open grazing lands which were sampled during pulse (rainy period July), inter-pulse (winter, January) and non-pulse events (summer, May). During the study period temperature varied from 11.7 °C (inter-pulse) to 40.7 °C (non-pulse event). Relative humidity was 23% during the inter-pulse to 86% during pulse event. 260.3 and 52 mm rains were recorded during pulse and the inter-pulse events, respectively. Geographical coordinates, habitat types, soil texture, and succession stages of each site are depicted in Table 1. Most of the sites are located in older alluvial plain (with a higher proportion of sand), followed by younger alluvial plain and hummocky undulating terrains.

2.1. Community parameters

At each site and during each event 10 quadrates of 1 m × 1 m were randomly placed and the data were collected for quantification of various community parameters as recommended by Saxena and Aggarwal (1983); Mann and Shankar (1994) and Narita and Wada (1998). Species richness and diversity indices were computed using Shannon and Weaver Index, Simpson Index, and Evenness (Ludwig and Reynolds, 1999). The species richness is defined as the total number of species per sampling unit (Maranon and Garcia, 1997; Oba et al., 2001; Bhattarai et al., 2004). Analysis of Variance was conducted to estimate significant variations for species richness and for other diversity parameters quantified during various events.

2.2. Biomass quantification

All the herbaceous species rooted inside the 1 m^2 plots were recorded, and standing, above-ground biomass were clipped at ca. 0.5 cm above ground level. Harvested materials from all plots dried on a sunny and windy spot. Dry weight taken 10 days after harvesting and continued until a constant weight obtained (Bhattarai et al., 2004). Analysis of variance (ANOVA) was carried out in a strip plot design, which sacrifices precision on the main effects of both factors (sites and temporal events). The interaction is valued more accurately by this method compared to randomized complete block or split-plot design (Gomez and Gomez, 1984).

2.3. Soil analysis

Soil samples were collected from upto 30 cm depth at all sites during all events. Soil moisture was estimated by gravimetrical method (%) immediately, while prior to quantification of other parameters, samples were air–dried and sieved through 2 mm sieve (Pandeya et al., 1968). The water-soil suspension (5:1) was used to measure electric conductivity (mSm) and pH with respective Digital meters at room temperature. Soil texture analyses was out by the sieve method (Jackson, 1973). Soil organic carbon and total nitrogen were quantified by modified Walkley and Black's and Micro-kjeldahl's methods, respectively (Jackson, 1973). Available phosphorus quantified by development of molybdenum blue color (Allen et al., 1976).

2.4. Habitat assessment

Habitat conditions were measured as per parameters developed by Kumar (1992). Parameters include per cent bare surface area, litter quantity, litter conditions (litter accumulating ranked 1, replacing stage ranked 2, while none of them ranked 3; Kumar, 1992) and grazing intensity (score of 1, 2, 3 and 4 were assigned to light, moderate heavy and very heavy grazing, respectively).

2.5. Multivariate analysis

To assess the suitability of factor analysis, two tests, namely Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) were carried out. Principal Component Analysis (PCA) was carried out as a data reduction technique. Appropriate regression equations were

Table 1
GPS locations, habitat types and other attributes of sampling sites.

Site no.	Coordinates		Habitat types	Soil Textures (%)				Sub-Climax species (arrange in descending order of RIV)
	N	E		Clay	Silt	Sand	Gravel	
1	26^{0} 12′ 29.5″	73^{0} 04′ 24.8″	Hummock undulating terrains	28.5	4.335	66.07	1.10	*Cenchurs biflorus, Indigofera cordifolia, Aristida funiculata*
2	26^{0} 15′ 1.8″	73^{0} 59′ 29.8″	Old alluvium plains	29.61	1.35	68.78	0.25	*C. biflorus, Lasiurus sindicus*
3	26^{0} 12′ 48.4″	73^{0} 4′ 7.8″	Old alluvium plains	26.39	17.89	35.58	20.13	*Dactyloctenium aegyptium Eragrostis ciliaris*
4	26^{0} 11′ 33.4″	73^{0} 3′ 6.1″	Younger alluvium and river bed terrain	17.09	25.43	23.53	33.54	*E. cilliaris, Lepidagathis cristata*
5	26^{0} 14′ 47.01″	73^{0} 0.0′ 58.9″	Old alluvium plains	28.72	21.31	31.29	18.80	*D. sindicum, I. cordifolia*
6	26^{0} 14′ 12.4″	73^{0} 01′ 24.2″	Old alluvium plains protected	29.18	18.56	43.3	10.26	*E. ciliaris*
7	26^{0} 21′ 54.5″	73^{0} 03′ 48.9″	Younger alluvium and river bed terrace	25.35	15.48	37.46	21.47	*E. ciliaris, A.funiculata*
8	26^{0} 12′ 33.7″	73^{0} 4′ 8.4″	Old alluvium plains	27.61	26.87	30.37	14.84	*E. ciliaris, D. aegyptium*
9	26^{0} 14′ 31.6″	73^{0} 01′ 21.1″	Old alluvium plain	33.35	17.83	42.77	4.99	*E. ciliaris, Euphorbia granulata*
10	26^{0} 18′ 47.0″	72^{0} 60′ 35.1″	Piedmonts area	29.5	4.23	43.02	23.25	*I. cordifolia, A funiculata, C. biflorus*
11	26^{0} 17′ 2.5″	72^{0} 56′ 5.9″	Younger alluvium plain	27.76	3.63	61.55	7.055	*E. ciliaris, D. sindicum I. cordifolia*
12	26^{0} 20′ 58.9″	73^{0} 3′ 57.2″	Hummocky undulating terrains	30.17	10.61	56.4	2.765	*C. biflorus, D. sindicum I. cordifolia*