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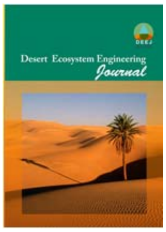

Investigating the Distribution Pattern of Ten Halophytes Species Using Quadrate Indices and Discrete Probability Distribution: A Case Study of Eastern Iran's Desert Ecosystems

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Expanded abstract

Introduction: determining the spatial distribution pattern of species in their environment is regarded as an important aspect of quantitative plant ecology. On the other hand, evaluating vegetation and arid land reclamation attempts requires awareness of the type of distribution pattern. Moreover, the study of plant distribution patterns significantly contributes to the assessment of the plants' environmental uniformity or heterogeneity, reproduction type, distribution, competition, and behavioral patterns, helping to determine appropriate methods for measuring quantitative properties of vegetation such as coverage and density. However, studies on the distribution patterns of plant species are mainly focused on forest and rangeland ecosystems, and desert ecosystems are under-researched in this regard. Therefore, this study sought to determine the distribution pattern of ten halophyte species in eastern Iran's desert ecosystems using quadrate methods and the probability distribution function.

Materials and Method: This study was carried out in the halophyte habitats in the rangeland and desert ecosystems of Ferdows, Khosf, and Zirkouh in South Khorasan province and Zabol in Sistan and Baluchistan province. After visiting the study area and identifying its dominant species, the sampling of the region's vegetation habitats was performed in the spring of 2022 using a random systematic method. To this end, sixty 4*4-meter quadrats were placed in the key area of each habitat, where the density of the dominant species was calculated by the counting method. Then, after measuring the density of ten species of dominant halophytes in each habitat under study, the mean and variance of species density were calculated.

After that, Index of Dispersion (ID), Lexis's Index (I_L), Charlier's Index (I_{Ch}), Index of Cluster Size (ICS), Green's Index (GI), Index of Cluster Frequency (ICF), Index of Mean Crowding (IMC), Index of Patchiness (IP), Morisita's Index, (I_M) and Standardized Morisita (I_p) were calculated based on mean ($\bar{x}$), variance (s^2), and sampling plot number (n).

Moreover, coefficients a and b distribution patterns were determined for ten halophyte species based on Taylor's power law model or the linear logarithmic relationship between mean ($\bar{x}$) and variance (s^2). In addition, Iwao's patchiness regression model was used to calculate the relationship between the mean ($\bar{x}$) and the Index of Mean Crowding (IMC), based on which α and β coefficients were determined. Finally, invers K indices of negative binomial distribution and deviation from the Poisson distribution (I_D) were determined, and the fit of plant density data was examined regarding three discreet statistical distributions, including Poisson, binomial, and negative binomial distributions.

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Results: The results of the analysis of quadrate indices and probability distribution function revealed that *Salsloa tomenosa*, Suaeda Monoica, *Salsloa kali*, *Aeluropus Littoralis,* and *Tamarix Stricta* had a clumped pattern, *Sedilitzia Rosmarinus* and *Haloxylon Ammodendron* followed a random pattern, and *Salsola richteri*, *Hammada Salicornica,* and *Tamarix aphylla* enjoyed a uniform pattern. Moreover, *Aeluropus littoralis* was found to have the highest amount of all the indices (except ICF).

On the other hand, the results of the analysis for IP and IM indices were close to each other. Furthermore, according to the halophyte species density data obtained from the analysis of the probability distribution function, *Aeluropus littoralis* and *Suaeda monoica* were the only species that followed the negative binomial distribution which indicates a clumped pattern. On the other hand, *Sedilitzia rosmarinus* and *Haloxylon ammodendron* were the only species that followed the Poisson distribution which indicates a random pattern. Moreover, *Salsola richteri*, *Hammada Salicornica*, and *Tamarix aphylla* were found to have followed both Poisson and binomial distribution functions. However, based on the linear relationship between mean logarithm and variance logarithm (R^2adj = 0.94, P <0/0001) and the linear relationship between the mean and Index of Mean Crowding (IMC) of density data (R^2adj = 0.94, p <0/0001), the overall distribution pattern of the studied halophyte species was identified to have a clumped pattern.

Discussions and Conclusion: This study used quadrate, regression, and possibility distribution methods to identify the plants' distribution patterns. Accordingly, the results of the quadrate method indicated that out of the ten species studied, six species had a clumped pattern and four species enjoyed a uniform pattern. Moreover, almost all the methods used in the study area showed that *Aeluropus littoralis* and *Suaeda monoica* followed the clumped distribution pattern. On the other hand, *Tamarix stricta* were found to exert a negative influence on the soil due to salt accumulation and possibly prevent the growth and germination of the surrounding plants, thus contributing to the plant's patchiness. The findings of the study also revealed that *Sedilitzia rosmarinus* and *Haloxylon ammodendron* followed a random distribution pattern. On the other hand, while a random distribution pattern is rarely observed in natural ecosystems, the distribution of seeds through wind and livestock, and germination and rapid reproduction of the *Haloxylon ammodendron* in the regional sites of the study area may be regarded as possible reasons for the random distribution of the species.

The results of the analysis of regression methods suggested that the halophyte species generally followed a clumped distribution pattern, indicating the patchiness of nutritional sources and the soil's physical and chemical properties such as moisture, salinity, and texture. It should be noted soil moisture and salinity are considered the main constraining factors of plant communities in desert ecosystems that affect the physiological and morphological properties of halophyte and *psammophyte* plants and limit their distribution, probably contributing to the heterogeneous distribution of plant species. Therefore, the effects of environmental stress on the vegetative and functional properties of plant species and their distribution pattern should be taken into account in developing desert greening and saline land reclamation plans.

Keywords: Spatial Pattern, Poisson Distribution, Index of Dispersion, Halophyte.