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Comparison of Different Methods for Measuring Density of *Salsola Laricina* in Rudshoor Steppe in Saveh

Tayebeh Entezari,
MA in PNU
Yunes Asri,
Faculty Member of Research Institute of Forests and Rangelands
Gholam Reza Khaniki,
Faculty member of PNU
Morteza Akbarzadeh
Faculty Member of Research Institute of Forests and Rangelands

ABSTRACT ─ This research studied the density of Salsola laricina subsp. by using five methods linear transect, Byte and Ripley method, T-square, ordered distance and point-quarter in order to compare the efficiency of these methods in terms of accuracy, precision and time. Rudshure steppe in Saveh was selected for comparison of methods and sampling was done on Salsola laricina in June 2008. Mathematical analysis of data obtained by these methods showed that the density of population heavily depends upon distribution pattern which may be random or non-random. Student t-test was used in order to compare the methods. The results between high-density and low-density modes are as follows: in high-density mode, all methods linear transect, Byte & Ripley, ordered distance , T-square and point-quarter presented the nearest estimations relative to control value and in low-density mode, T-square, linear transect and ordered distance showed the nearest estimation to control value but both Byte & Riley and point-quarter methods have significant difference in probability %1; therefore, if accuracy index is considered, point-quarter method in best method in terms of accuracy of estimated density in both high-density and low-density modes.
KEYWORDS: coverage, measurement methods, *Salsola laricina*, Rudshur Saveh

Introduction

Density is an important evaluation characteristic for description of characteristics and changes in plants during different periods, interpretation of plant reaction to different managerial operation, measurement of canopy, determination of species, estimation of production and biomass in ranges. Density is number of individuals of each species in determined area which we can measure it by counting the number of individuals of each species in quadrat, along with transect and measuring the distance between individuals or by sampling points (Moghadam, 1998). Density measurement is necessary for accurate estimation of number of individuals in species, their conditions and distribution. The study of species density, in addition to purposes like plant sociology studies, has important role in analysis and description of vegetation characteristics, effects of climate on plants, sequence studies and plant geography. Mac Aller et.al (1993) have pointed that results obtained from distance methods for density estimation can provide important information about the relationship among plants. Warren (2002), in a study about effect of grazing systems on the density of grasses and bushes in a semi-arid area, have used nearest-neighbor and nearest individual methods for estimating the density of plants. Joset (2004) stated that center-point quarter method is a suitable and ideal method for rapid measurement of plant density, even in non-uniform habitats. Sandgol (1995) compared random pairs, nearest individual, nearest neighbor, stray point quarter, regular angel, quadrat and Buchler methods in five Iranian-Turonian regions (Pelor, Hamand Absard, Khojir, Roodshur, Valadabad in Qazvin) and concluded that regarding the size of sample, regular angle has the smallest size among compared methods. Borhani (2001) conducted six measurement methods including nearest individual, nearest neighbor, random pairs, center-point quarter, regular angle and quadrat in steppe area (Mooteh, Aloijeh) in Isfahan and concluded that nearest neighbor and random pairs methods estimate density with good accuracy and regular angle method has higher estimation than real value and it has significant difference with real density of the area. In addition, in uniform communities, estimated density with different methods is higher than control. Regarding the size of sample, nearest individual method has the largest size of sample followed by nearest neighbor and random pairs, center-point quarter and regular angle methods and regarding time with same sample size, highest times was related to regular angle and center-point quarter methods.

Basiri and Karimian (2001) compared four distance methods for measuring density including center-point quarter, random pairs, nearest neighbor and stray quarter methods in three areas with different densities in order to determine the most suitable method for measuring shrub density in arid areas and concluded that among studied methods, three methods center-point quarter, random pairs and stray pairs methods have significant difference with control method and only nearest neighbor method is same with control method in three areas and shows no significant difference. Sa'datfar et.al (2007) compared eight distance methods for measuring density in Bardsir in Sirjan. These methods were nearest individual, nearest neighbor, random pairs, regular angle, and center-point quarter, near to third, varied and stray transect. Results showed that the most accurate distance method for density estimation is nearest to third method and the fastest or cheapest method is regular angle method. The most correct method for estimating density is nearest neighbor method and in certain cases that accuracy is desired, random pairs is the most efficient method. Rabie'e showed that quadrat, ordered distance, T-square and Byte & Ripley methods presented the nearest estimation, while linear transect and point-quarter methods have the highest difference with control. Kaviani stated that in *Artemisi seiberi*, the estimation obtained by T-square and point-quarter methods have no significant difference with control. T-square, linear transect, Byte and Riley methods and ordered distance methods has significant difference in 0.1% level and point-quarter method has significant difference with point-quarter method in %5 level, compared to control method. Arefian did not recommend the transect method because it is time-consuming and has low accuracy. Point-quarter method was not good in terms of time but it is recommended in terms of accuracy of density. He introduce ordered distance method in low-density Calligonum areas and low-density almond areas with highest accuracy and lowest difference with control among various methods. This method is recommended in terms of time. T-square method has the highest accuracy in almond average density and Calligonum average density region. Hashemi (2010) studied the *Atriplex canescens* density estimation method and concluded that Byte and Ripley method has no significant difference with control and this method can be used for measuring density in each three regions.
Pearson and Sternitzck stated that the feasible method for forest and ranges should provide highest accuracy in least time.
Material and methods

Study area

Rudshur enclosure is located in south of Robat Karim in 60 kilometers of Tehran-Saveh road with an area of 30 hectares and the position 53' 50˚ east longitude and 26' 35˚ north latitude. Height of enclosure is about 1120 meters above sea level. In the steppe region the average annual rainfall is about 204.6 mm. Absolute maximum and minimum of temperature, is -18 and 44.5 ° C, respectively and the average number of frost days per year is about 62 days. Almost dry season begins in early April and will continue until mid-October (Akbarzadeh, 2005). The soil of Rudshur enclosure in terms of classification is of brown eroded soils and their primary ingredients are old alluvial. The soils in terms of appearance are among the plateaus. Surface soil with loamy clay texture is placed on the soil with heavy texture of gravel. Soil depth is relatively high and does not exceed one meter. Soil pH of this region is 7.7. The enclosure is constructed from 1965 and is prevented from the arrival of the animals inside the enclosure. Outside the enclosure cattle is grazing continuously during winter and spring. The predominant species are *Artemisia sieberi* and in inside are *Artemisia sieberi*, *Salsola laricinia* and *Stipa hohenackeriana* (Akbarzadeh, 2005).

Morisata standard index

Morisata index is one of the best criteria for plant distribution because it is independent of population density and number of plot (Asri, 2005). In order to determine the distribution pattern of Salsola Laricinia, 50 quadrat with dimensions 3*3 were established in region randomly. Number of bass was counted in each quadrat and using obtained figures of plant measurement (x_i) in plots, two limits were calculated for Morisata index by following formula:

Uniformity index: $$M_u = \frac{X^2_{0.975} - n + \Sigma x_i}{(\Sigma x_i) - 1}$$

$X^2_{0.975}$ is chi-square of table with degree of freedom (n-1) that has 97.5 percent of area in right side.
X_i: number of plant bases in plot i (i=3,2,1,…,n)
n: number of plots

Bulk index: $$M_c = \frac{X^2_{0.025} - n + \Sigma x_i}{(\Sigma x_i) - 1}$$

$X^2_{0.025}$: chi-square value of table with (n-1) degree of freedom that has 2.5% of area in right side.

Sampling method:

In order to compare density measurement methods, first we selected four plot with area 1 hectare and border of each plot was determined with a rope. In each plot, number of sagebrush plants was counted. Density obtained in this method was considered as control and estimated density with other methods was compared with control method. Density measurement methods in this research were linear transect method, Byte and Ripley distance method, T-square method, ordered distance method and point-quarter method (Asri, 2005). In linear transect method, 25 basic lines with distance 100m with each other and length 50m with four 15m transects were considered. On transect lines, largest vertical width of plant was measured. In Byte and Ripley method, 25 plot with dimensions 30*30m were considered and 2n-10 points were sampled in each plot. Half of points (n) were selected randomly and their distance to nearest individual was measured. Around half of other points, small plots with dimensions 1*1m were established and inside them, *n* individual were selected randomly and the distance between selected people to nearest neighbor was measured. In T-square method, first we randomly selected five basic lines. Then, 10 random points were selected along each base line and two distances were measured in each point: distance of random point to nearest individual and distance of individual to nearest neighbor with this limitation that the angle between random point nearest individual-nearest neighbor should be higher than 90^0. In ordered distance method, 50 points were selected randomly. Then, nearest first, second and third individuals relative to random point were selected and the distance of random point to nearest third individual was measured. In this method, there is no need to measure the distance between nearest first and second individual and only distance to nearest third individual measures. In point-quarter method, first five base lines were selected randomly. Then, 10 random points were selected along with each base line. Around each random point was divided to four quarters with angle 90^0 and in reach quarter, distance to nearest individual was measured. Vigert method was used to select the best quadrat size. According to Vigert, size of form of optimal quadrat belongs to the quadrat obtained by multiplying relative cost and relative variance.

Minimum required time for taking a sample/required time for taking a sample=relative cost

Minimum standard deviation/standard deviation=relative variance

Calculating accuracy of density

In order to study the accuracy of density, relative difference of estimated density in each method was calculated i.e. density estimation error such that the lower the relative difference of estimated density with control in each method, the higher the accuracy of model (Mosaee, 2004). Real density/control density-estimated density with given method=relative difference of estimated density with control

Time calculation in different methods for density estimation

In order to determine the time for each method, spent time from beginning of each measurement to end was recorded. This time was repeated in 30 measurement points. Then, mean and minimum and maximum range was determined.

Results

Based on counting the bases of sagebrush in established plots, Morisita distribution index was calculated as following:

Morisita distribution index calculation

$$I_d = n\left[\frac{\Sigma x^2 - \Sigma x}{(\Sigma x)^2 - \Sigma x}\right] = 0/019$$

Calculating two limits by using uniformity and bulk indices' formula

$$\mathrm{M}_u = \frac{x^2_{0.975} - n + \Sigma x_i}{(\Sigma x_i) - 1} = 0/953$$

$$\mathrm{M}_c = \frac{x^2_{0.025} - n + \Sigma x_i}{(\Sigma x_i) - 1} = 1/062$$

Since $1>M_u>I_d$; therefore:

$$I_p = -0.5\left[\frac{I_d - M_u}{M_u}\right] = 0/490$$

Since Morisata standard index value is lower than 0.5, we can say with %95 confidence that Salsola laricinia has uniform distribution in sampling plots.

Mean estimated real density for Salsola laricinia by using shrub counting method in 1 hectare limit is 19333 shrubs in hectare. Estimated density with different methods was compared with Student t-test test and SAS (version 14) (table 1). Results showed that among the methods, highest estimated density relates to Byte and Ripley method (19900 bases in hectare).

Table 1: *Salsola laricinia* estimated density in different methods in high-density mode

Density estimation method	Number in hectare	P-value	Test result
Control method			
T-square method		**0/000**	***
Linear transect method		**0/000**	***
Byte & Ripley method		**0/000**	***
Ordered distance method		**0/000**	***
Point-quarter method		**0/000**	***

ns=difference is not significant; * significant difference in 0.1 percent level
** Significant difference in %1 level; *** significant difference in 0.1% level

Table 2: *Salsola laricinia* estimated density in different methods in low-density mode

Density estimation method	Number in hectare	P-value	Test result
Control method			
T-square method		**0/000**	***
Linear transect method		**0/000**	***
Byte & Ripley method		**0/001**	**
Ordered distance method		**0/000**	***
Point-quarter method		**0/006**	**

ns= difference is not significant; * significant difference in 0.1 percent level
** Significant difference in %1 level; *** significant difference in 0.1% level

Comparison of density accuracy among used samples shows that in both high-density and low-density modes, point-quarter method is the most correct method for estimating density among other methods and T-square method has the highest estimated relative difference with control (table 2).

Table 3: comparison of accuracy of Poa sinaica density estimation methods, mean of four modes in high-density mode

Methods	Accuracy
T-square method	**-0/996**
Linear transect method	**-0/995**
Byte & Ripley method	**-0/956**
Ordered distance method	**-0/990**
Point-quarter method	**-0/887**

Table 4: comparison of accuracy of *Poa sinaica* density estimation methods, mean of four modes in low-density mode

Methods	Accuracy
T-square method	**-0/991**
Linear transect method	**-0/989**
Byte & Ripley method	**-0/892**
Ordered distance method	**-0/977**
Point-quarter method	**-0/723**

Number with negative sign shows lower density of given method to control and number with positive sign shows higher density of given method to control Minimum spent time among density estimated methods belongs to T-square method with 1.24 minute and maximum time is for linear transect method with 10.78 minute (table 3).

Table 5: comparison of time in different method for *Poa sinaica* density estimation

Methods	Maximum (minute)	Mean (minute)	Minimum (minute)
Byte & Ripley	**10/48**	**10/25**	**10/04**
Ordered distance	**5**	**3/47**	**3/06**
Point-quarter	**4/15**	**3/50**	**2/46**
T-square	**1/36**	**1/24**	**1/15**
Quadrat (control)	**5/38**	**82/4**	**29/4**
Linear transect	**04/12**	**78/10**	**52/9**

Discussion and conclusion

Different methods cause difference in results that among them, we can point to following: first factor in time period is density of plants because by increasing density and reducing the distance between shrubs, required time for measuring distances decrease. Another factor is plant distribution pattern such that increasing uniformity will decrease the size of sample and influences the spent time. Third factor is nature of method. In some methods like point-quarter method, several distances are measured instead of one distance. Another factor is identifying and finding individual far and near to random point. Borhani et.al showed that in Mooteh, Aloijeh and Dar, except two methods ordered angle and nearest individuals, other methods lack significant difference in 5% probability level with control and suggested point-wheel method for estimating coverage. Sandgol (1995) selected nearest neighbor method to determine density. In this research, *Poa sinaica* density in high-density and low-density modes is as follows: linear transect, T-square and ordered distance have no significant difference in high-density mode relative to quadrat method (control) and Byte & Ripley method has significant difference in 5% probability level. On the other hand, point-square method shows significant difference in %1 level relative to control method. In quadrat method in low-density mode, T-square method shows significant difference in 1% probability level relative to control quadrat. Linear transect, Byte & Ripley and ordered distance methods have no significant difference relative to quadrat. On the other hand, point-square method has significant difference in 1% level relative to control; therefore, control method is suggested as a correct method for estimating density in steppe regions. Besides, if we consider accuracy of index, linear transect method is suggested in low-density mode and in point-quarter method in low-density method. Therefore, control method is suggested for estimating density in steppe regions. In ordered distance method, which is a distance method, difficulty is in finding and determining the distance of third plant from random point in communities that *Poa sinaica* has uniform distribution. Therefore, this method is not recommended in terms of accuracy and time. This result is consistent with result of Sa'datfar et.al (2007) in a study about distance methods for density estimation in Bardsir in Kerman and also with results of Rabie'e study (2008) about distance methods for density estimation in Khojir national park. Linear transect method is not recommended because it is time-consuming and has low accuracy. Judgment about efficiency of used methods depends on the criteria used by the researcher. This criterion may be spending less time, higher accuracy or combination of both. Pearson and Sternitzck (1974) stated that the method used for study in forest and range should be feasible and provide accuracy in least possible time. In *Poa sinaica*, if the criterion as time, control method is accepted and if accuracy is criterion, control method is accepted. Therefore, this can determine the priority of method for each plant species.

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