Plant species richness (PSR) along island biogeographical gradients in inhabited islands of Shinan-gun, Republic of Korea

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Publication Information:
Received 8 July 2024, Accepted 18 July 2024, Available online 25 August 2024 doi 10.21463/jmic.2024.13.2.11

Abstract

The objective of this study is assess the influences of 8 environmental factors, population, coastline length, island area, vegetated area, highest peak, distance to the mainland, longitude, latitude on vascular plant species richness (PSR) of 10 inhabited islands of Shinan-gun, South Korea. In simple regression, the relationships between PSR and distance to the mainland, longitude and latitude were significant at the 5% level. When distance increases, longitude and latitude decrease, plant species richness increases. The relationship between PSR and coastline length, island area and highest peak were not significant at 5% level. But coastline length, island area and vegetated area showed negative relation with plant species richness and highest peak showed positive relation. Relationship between population and PSR was not statistically significant and showed negative relation. This may indicate PSR decrease by the effects of human dynamics, but further research is needed. In stepwise regression method three variables, distance, longitude and latitude, explained 98.0% of the variation in PSR.

Keywords

Plant species richness (PSR) · Distance to the mainland · Longitude · Latitude · population · Stepwise regression

Introduction

The theory of island ecology and their influences on insular species richness have been well tested by empirical studies of a number of islands since they were first propounded by MacArthur and Wilson (1967). Much attention has been given to qualifying environmental factors such as island area, coastline length, vegetated area, distance from mainland or from other islands, elevation (highest peak) and longitude, latitude, population and measuring their effects on insular species richness (Whittaker, 1998; McMaster, 2005; Ihm et al., 2008). The terrestrial biota of islands are considered by ecologists as useful natural experiments, because they are relatively simple, well defined and abundant. Island area, vegetated area, distance and elevation proved to be directly related to species richness (Johnson and Raven, 1973; Buckley, 1985; Kohn and Walsh, 1994; Chung and Hong, 2006).

Shinan-gun includes a UNESCO (United Nations Educational, Scientific and Cultural Organization) Biosphere Reserve, a national park, and a marine protected area (Kim, 2015).

The tidal flats are well developed in Shinan-gun. The active reclamation of the wide tidal flats had started from the late Joseon Dynasty and continued throughout the Japanese colonial rule until the 1980s (Hong, 2012; Kim, 2015). On islands where people had lived with limited resources, it was difficult to get rice, the principal food for Koreans. Therefore, with the reclamation of mud flats, islanders were able to have wider rice fields and several islands were combined into bigger islands.

Table 1. Results of simple linear regressions of plant species richness on independent variables of 10 islands at Shinan-gun of South Korea.

Independent variable	Slope	Intercept	r	Significance level
Population	-0.01727	299.49	-0.183	ns
Coastline length (km)	0.1450	257.75	0.024	ns
Island area (km^2)	-1.908	324.34	-0.217	ns
Highest peak (m)	0.4571	141.56	0.350	ns
Distance to mainland (km)	4.585	145.38	0.774	$P < 0.01$
Longitude	-150.0	73328.8	-0.849	$P < 0.01$
Latitude	-697.14	24537.5	-0.762	$P < 0.05$
Vegetated area (km^2)	-0.4979	273.76	-0.031	ns

ns = not significant

The following characteristics are examined in 10 islands of 72 inhabited islands in Shinan-gun (Table 1, Yang et al. 2023; Ihm et al. 2008). Is. Heuksan-do is located in 95 km away from the mainland. Its island area is 22 km^2. 95% of the island is evergreen forest. Is. Bigumdo is located in 28 km away from the mainland. Its island area is 44 km^2. Island area of Is. Docho-do is 42 km^2 and the island is located in 23 km away from the mainland. Is. Uido is located in southwestern part of Is. Docho-do. Island area is 11 km^2 and the island is located in 38 km away from the mainland. Is. Jaeun-do is located 27 km away from the mainland. Its island area is 52 km^2. Is. Amtae-do is located in 23 km away from the mainland. Island area is 29 km^2. Is. Anjwa-do is located in 9 km away from the mainland. Its island area is 47 km^2. Rice field was developed by sedimentation of littoral current and land reclamation along east coast. Is. Palgeum-do is located in 17 km away from the mainland. Its island area 18 km^2. Island area of Is. Imja-do is 40 km^2. It is located in 11 km away from the mainland. The area of Is. Jaewon-do is 5 km^2. It is located in 11 km away from the mainland.

Morrison (2002) concluded that the three variables commonly used in studies of determinants of insular species richness (total island area, distance and elevation) were relatively poor predictors of plant species richness on small islands in the Bahamas. He proposed that the predictive power of the models tended to be higher for groups of islands that were more sheltered by neighbouring islands. Exposed islands, although separated by relatively small distances from nearby protected islands, may be impacted by storms much more severely and so possess many fewer species.

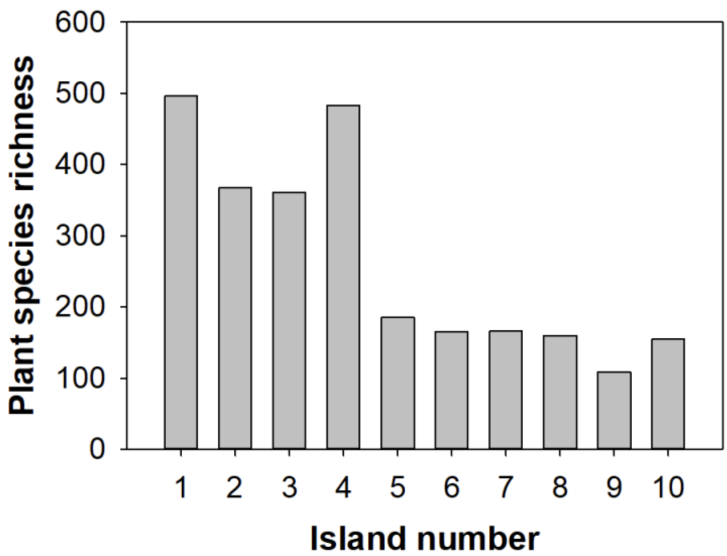

Fig 1. Plant species richness of 10 islands (1–10) in Shinan-gun, Republic of Korea.

The objective of this study is assess the influences of 8 environmental factors, population, coastline length, island area, vegetated area, highest peak, distance to the mainland, longitude, latitude on vascular plant species richness (PSR) of 10 inhabited islands of Shinan-gun, South Korea and propose the basis of the development of predictive tools using stepwise regression methodology.

Materials and Methods

We studied the plant species richness of 10 islands in Shinan-gun (Ihm et al. 2008; Kim 2015; Hong et al. 2024;): Heuksan-do (1), Bigum-do (2), Docho-do (3), Ui-do (4), Jaeun-do (5), Amtae-do (6), Anjwa-do (7), Palgeum-do (8), Imja-do

(9), Jaewon-do (10) (Table 1). Environmental factors and population on each island were collected: population, coastline length, island area, vegetated area, highest peak, distance to the mainland, longitude, latitude (Kim, 1984; Kim et al., 1987; Ihm et al. 2008; Ko, 2012-2016; Lee and Ko, 2018; Yang et al. 2023). Naver maps (2020) were used for each island.

Correlation and simple regression analyses were employed to measure the relative influences of the independent variables on plant species richness. MRA (multple regression analysis) were used to elucidate the relationship between environmental factors and plant species richness in islands of Shinan-gun.

Results

In this studies, population ranged from 175 to 4515 people with average value of 2015 people (Table 1; Yang et al. 2023). Coastline length ranged from 11.0 to 86.4 km with average value of 47.7 km. Island area ranged from 5.0 to 52.2 km^2 with average value of 31.3 km^2. Highest peak ranged from 159 to 405m with average value of 286m. Distance to the mainland ranged from 3.1 to 95.0 km with average value of 27.2 km. Longitude ranged from 125.4273 to 126.1426 with average value of 125.9709. Latitude ranged from 34.6115 to 35.0894 with average value of 34.81788. Plant species richness ranged from 109 to 496 species with average value of 265 species (Ihm et al., 2008; Yang et al., 2023).

Plant species richness in Heuksan-do (1), Bigum-do (2), Docho-do (3), Ui-do (4), Jaeun-do (5), Amtae-do (6), Anjwa-do (7), Palgeum-do (8), Imja-do (9) and Jaewon-do (10) was 496, 367, 361, 483, 185, 165, 166, 160, 109 and 155 and the 4 former plant species richness were higher but the 4 latter were lower.

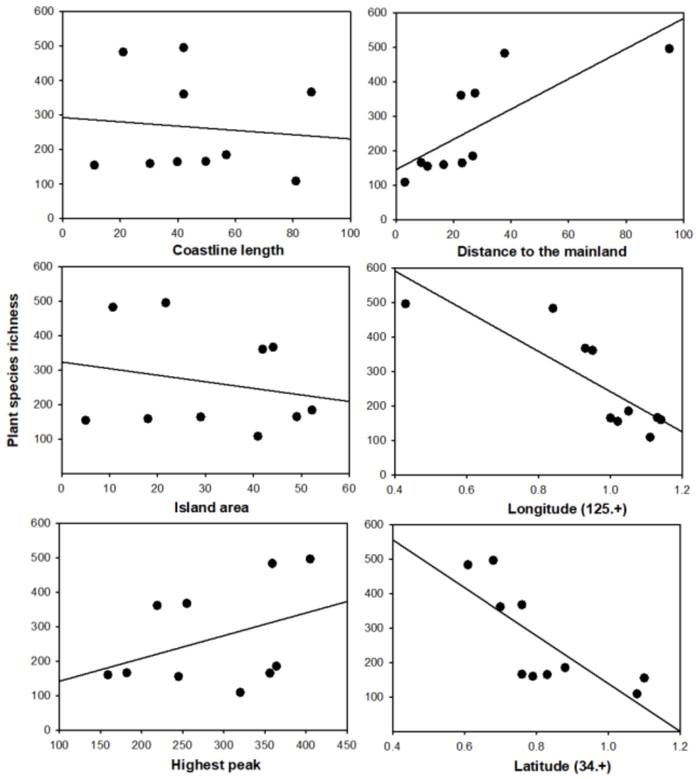

Fig 2. Regression of plant species richness against coastline length, island area and highest peak (left) and against distance to the mainland, longitude and latitude (right).

Relationship between distance to the mainland, longitude and latitude with plant species richness were significant at the 5% level (Fig. 2). Those between coastline length, island area and highest peak were not significant at 5% level. But coastline length and island area showed negative relation with plant species richness and highest peak showed positive relation.

Relationship between population and plant species richness was not statistically significant and showed positive relation (Fig. 3).

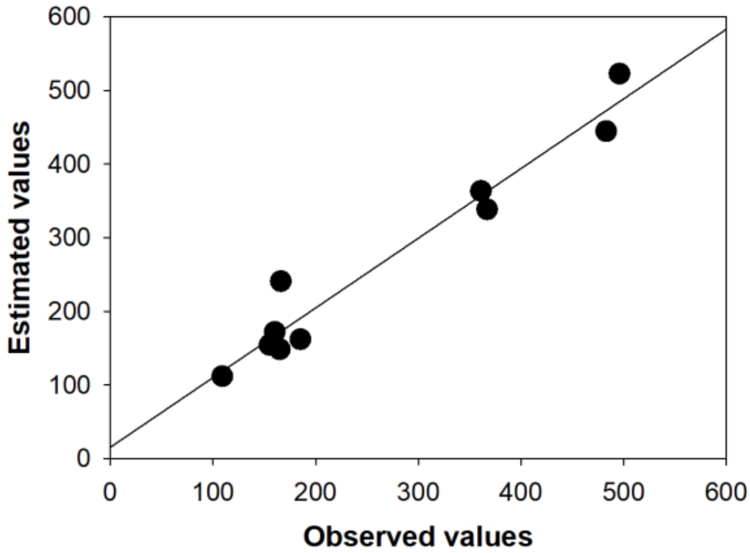

Fig 3. Scatter plot of observed values and predicted values obtained from backward stepwise regression.

PSR = 137040 – 4.795 distance – 942.297 longitude – 515.297 latitude (r^2 = 0.980*)

Discussion

In simple regression, the relationships between PSR and distance to the mainland, longitude and latitude were significant at the 5% level (Fig. 2). When distance increases, longitude and latitude decrease, plant species richness increases. The relationship between PSR and coastline length, island area and highest peak were not significant at 5% level. But coastline length, island area and vegetated area showed negative relation with plant species richness and highest peak showed positive relation. Ihm et al. (2008) reported that PSR was significantly correlated with island area and elevation and in MLR method two variables explained 86.5% of the variation in PSR (r^2 = 0.865). Relationship between population and PSR was not statistically significant and showed negative relation (Fig. 3). This may indicate PSR decrease by the effects of human dynamics, but further research is needed (Buhk et al., 2007). In stepwise regression method three variables, distance, longitude and latitude, explained 98.0% of the variation in PSR (r^2 = 0.980). Distance showed positive relation and longitude and latitude negative relation (Fig. 3).

The three variables commonly used in studies of determinants of insular species richness - total island area, distance, and elevation — were relatively poor predictors in most analyses (Morrison, 2002). Of the expressions of insular area evaluated independently in simple regressions, total area was the third best in the Exumas and the worst at Andros. Distance and elevation always ranked among the worst three predictors overall in simple regressions for all archipelagos and island groups. Vegetated area was frequently among the best single predictors (Morrison, 2002). However, iIn this study vegetated area was significantly correlated with total area at the 5% level. Vegetated area was the worst single predictor and not entered into stepwise regression.

It is apparent that among the habitats there is an effect of area on species richness and that the strength of the relationship varies (Hannus and Numers, 2008). It is obvious that in predicting the species number of an island, the relative occurrence of various habitats will influence the species number beyond the effect of island area alone. Deshaye and Morisset (1988) reported significant differences in the slopes for their set of habitats and emphasized the need for the use of habitats as sampling units rather than whole islands) to be able to discriminate between area mid habitat diversity in predicting island species richness (Ihm et al. 2008).

The low percentage of explained variance by the variables is suggestive of a role for additional factors (Panitsa et al., 2006). In any case, area seems to play a particularly important role. Habitat diversity is often presumed to increase in direct relation to island area or vegetated area (Kohn & Walsh, 1994; Oh et al. 2013). If larger islands support greater habitat diversity, this increased habitat diversity might promote increased species richness (Kohn & Walsh, 1994; Ricklefs & Lovette, 1999). Moreover, island size can influence the presence of particular habitat types (Kohn & Walsh, 1994), thus it might indirectly affect the species number present on the island particularly if a high proportion of the species involved are habitat specialists (Choi. 2000; Panitsa et al., 2006), In principle, habitat availability is one of the main factors influencing species diversity. The description of habitat diversity is quite difficult for plant species, for a detailed analysis should be based on information regarding many physico-chemical parameters of the soil, micro-climatic data, etc., all of which are hard to collect (in many instances, unrealistically so) and usually are not available in the context of extensive biogeographic studies. Also, many dimensions of plant habitat vary at a very fine geographical scale (Triantis et al., 2005; Kim and Hong, 2007).

The relationship between species-island area and species-habitat area has primarily been presented in a log-log space using the power function (Hannus and Numers, 2008). Using the exponential function and log-linear space gives comparable results, sometimes showing higher regression values and sometimes lower. In general when the material contains a higher portion of very small islands with sparse soil cover and vegetation, as in the Getskiir material, the log-linear model gives a greater correlation and the breakpoint model indicates the existence of a SIE. In contrast, when describing species-vegetated area relationships, the power function shows the highest percentage level of explained variance and no SIE (Lee 2020).

In a similar study, Panitsa et al. (2006) recently reported that the best-fit species-area relationship curve was achieved with the power function for total plant richness among a number of linear, non-linear and sigmoid models. They further reported that the exponential curve fitted better for grazed islands, grasses and therophytes, whereas the power function was better for non-grazed areas, halophytes and Leguminosae.

As far as the fields requiring the island-environment are concerned, especially in inhabited islands, it is important to ensure that an interdisciplinary joint study be conducted based on direct and indirect information exchanges and joint investigations (Hong 2012). Interdisciplinary studies involving other fields should be conducted in conjunction with the temporal and spatial interactions between man and nature on islands and in maritime areas. Successful results can be achieved through the conduct of smooth interdisciplinary studies and the adoption of a comprehensive approach that involve other fields of study.

Acknowledgements

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2018R 1D 1A 1B06043748).

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