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Article

Dune flora can emerge from seed islands (Concon, Chile)

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SUMMARY

The study of species within natural communities, which has progressed remarkably in recent decades, is of great interest in the field of ecology. Through the process of characterizing dunes, mounds of sand formed by the wind, and their plant communities we can get to know the physiognomy and floristic composition of the territory. However, little is known about how these plant communities originate. Based on the hypothesis that dune flora can emerge from seed islands: holes in the sand 6 cm deep containing a mixture of seeds, broken branches of shrubbery, and rabbit feces, during spring, we determined the composition of 20 seed islands in the sand dunes of Concon, Chile and measured how many seeds germinated in each one. In support of our hypothesis, we found that, on average, four seeds germinated in each seed island.

INTRODUCTION

Among the many types of dunes that exist, this study advocates to sand dunes, defined as mounds of sand formed by the wind. Dunes are created by accumulations of sand carried by the wind to wide open spaces such as deserts and seashores. Coastal dunes form downwind of a small obstacle around which sand accumulates. Within coastal dunes, plant species adapt to the sandy substrate, wind, and action of the waves, growing in topographically favorable places such as the horizontal surface of marine terraces (1). These dunes are located near sandy beaches in places above high tide level, where winds that blow from the sea transport sand to South America. They contribute to the landscape diversity of the coastal area, constituting a natural heritage of the coastlines. Although dunes span most of the coastlines of South America, Chilean dunes are scarce because rocky shores and cliffs predominate. The dunes account for about 3% of the country's surface (2).

The sand dunes of Chile are located in the three cities of Iquique, San Pedro de Atacama, and Concon, where the climate is Mediterranean-like with warm, dry summers and mild winters (3). The dunes of Concon are a well-developed system in Valparaíso, covering an area of roughly 21 hectares of Chile's fifth region. Due to their location between the towns of Ritoque and Viña del Mar (about 30 km north of Valparaíso city), they are designated as urban to peri-urban. The Concon dune system is mainly fed by fine-grained sands from the Aconcagua River Basin, to a lesser extent from weathering material of coastal rocks, and potentially from sediment of the Aconcagua Estuary (2).

The dunes of Concon are unique in that they are not being fed by sands from the beach because they are separated by a cliff, making them fossil dunes, or ancient desert dunes **(Figure 1)** (4). More than 120 endemic species belong to the region of the dunes, unlike other dunes that exhibit less biodiversity (5). However, it is not immediately clear how these species emerge in the Concon dunes. Our exploration of the dunes by foot led to the discovery of seed islands **(Figure 2A)**, which are holes in the sand 6 cm deep containing a mixture of seeds, broken branches of shrubbery, and rabbit feces. Seeds are fundamental for plant propagation, especially for the dune vegetation in Concon, as there is scarce fauna that can propagate the seeds by ingesting and then defecating them as organic matter (1). Therefore, we hypothesized that dune flora can emerge from seed islands.

To test our hypothesis, we determined the composition of 20 seed islands and how many seeds germinated in each one. We concluded that seeds account for only 30% of the total content of seed islands, and the majority consists of branches and rabbit feces. Despite this, on average, four seeds germinated in each seed island. This outcome supports our hypothesis **(Figure 2B).**

Figure 1: Sand dune from Concon. Coordinates 32 ° 54 '30" and 32 ° 58'50" south latitude and 71 ° 30' 40" and 71 ° 34 '46" west longitude. Nearby cities: Viña del Mar

RESULTS

The rationale of the experiment lies on the idea that if we can prove that flora can emerge from seed islands, seeds islands must be ecologically preserved. We chose 20 seed islands for analysis. Then, we separated the seeds from

each seed island from branches and rabbit feces by flotation to determine each component's percentage. Each seed island had a different percentage of seeds, branches, and rabbit feces, but on average; we considered quantification as units of seeds, broken branches, and rabbit feces; 30% corresponded to seeds, 18.7% to broken branches, and 51.3% to rabbit feces **(Table 1)**.

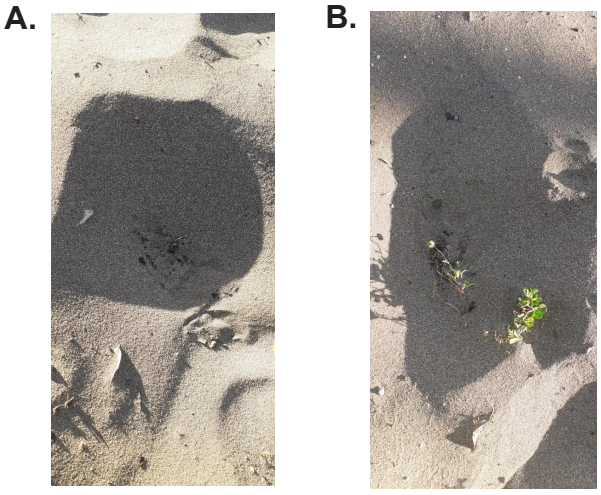

Figure 2: Seed island from Concon. A. Found at coordinates 32 ° 54 '30" and 32 ° 58'50" south latitude and 71 ° 30' 40" and 71 ° 34 '46" west longitude. Nearby cities: Viña del Mar. B. Found between coordinates 32 ° 54 '30" and 32 ° 58'50" south latitude and 71 ° 30' 40" and 71 ° 34 '46" west longitude, showing seeds that germinated.

Later on, we observed seed islands daily over a 12-day period under ideal temperature, humidity, and substrate during spring. We chose spring because it is when seeds from dune flora usually germinate (1).

We established a concept to determine how we we consider germination: germination was defined as the hatching of a seed or sprout of a seed. Our observations demonstrated that seeds do germinate from seed islands but in different quantities; on average, four seeds germinated per island, with an average percent germination of 12% (**Table 2)**. The seed island that experienced the highest percent germination was number six with a percent germination of 26%. Furthermore, the seed island that experienced the lowest percent germination was number eight with a percent germination of 4.88%.

The variance of the Nº of seeds that germinated indicates that the data is not spread out and numbers are close to each other, which means that the number of seeds that germinated are similar in amounts. On the other hand, the variance of the total of seeds and the variance of the percent of seeds that germinated are higher with values of 37 and 23.16 respectively, which means that they do not tend to homogeneity.

DISCUSSION

Regardless of the geographical or climatic zone where dune systems develop, they present a set of environmental characteristics. Coastal dunes exhibit highly dynamic characteristics and interactions, including influence from wind, accumulation or erosion of sand, mobility of the substrate, presence of water, sea spray, saline soils, floods, water stress, very permeable and coarse-grained substrates with low capacity, and nutrient poverty. These characteristics affect the composition and abundance of dune vegetation and the characters of the plants that form it, the latter referring to different processes in their life cycle: germination, implantation, growth, development, dispersal, and senescence (6).

A.

Seed Island	% of seeds	% of branches	% of rabbit feces
1	41	10	49
2	35	14	51
3	37	19	44
4	21	23	56
5	18	25	57
6	21	12	67
7	27	9	64
8	38	30	32
9	31	11	58
10	24	24	52
11	34	15	51
12	26	22	52
13	30	13	57
14	24	17	59
15	32	23	45
16	29	19	52
17	41	17	42
18	23	22	55
19	35	23	42
20	33	26	41
Average	29,4	18,7	51,3
Variance	46,2	32,5	65,9

B.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
% of seeds	20	559	29,4	46,2
% of branches	20	364	18,7	32,5
% of rabbit feces	20	977	51,3	65,9

C.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10324,8772	2	5162,4386	102,724138	3,93786E-19	3,16824597
Within Groups	2713,78947	54	50,2553606			
Total	13038,6667	56				

Table 1: A. Percent composition of seeds, branches, and rabbit feces in seed islands. B. Summary of the above data. C. Statistical analysis using ANOVA.

Germination is essential to all plant life cycles in dunes; this leads us to center the investigation in the number of seeds that germinated per seed island. The experimental results showed that seeds germinated from each seed island with an average percent germination of 23.7%. It supports the hypothesis that dune flora can emerge from seed islands; because out of 20 seed islands that were studied, seeds germinated from each one of them in different proportions. Based on the findings we concluded that because dune flora can emerge from seeds islands, their preservation is essential for the dune ecosystem. The results of our research impact what is known about how seeds from the dunes of Concon germinate, bringing up the idea that seeds germinate in seed islands in the company of broken branches and rabbit feces. Rabbit feces have a high amount of nutrients, including

nitrogen, phosphorus, potassium, calcium, magnesium, and zinc (6). Therefore, it is highly probable that the rabbit feces within the seed islands provide necessary nutrients that help the germination process and future proliferation of dune flora.

Seed island	Nº of seeds that germinated	Total of seeds	% of seeds that germinated
1	6	35	17,14
2	3	29	10,34
3	4	44	9,09
4	5	37	13,51
5	3	31	9,68
6	7	26	26,92
7	3	38	7,89
8	2	41	4,88
9	4	33	12,12
10	5	26	19,23
11	5	34	14,71
12	4	43	9,3
13	2	31	6,45
14	4	29	13,79
15	3	37	8,11
16	4	31	12,9
17	3	29	10,34
18	4	27	14,81
19	6	44	13,64
20	3	24	12,5
Average	4	33,5	12
Variance	1,7	37	23,16
Total	80	669	11,96

Table 2: Number of seeds that germinated in each seed island in a 12-day period, including the total number of seeds and proportion of seeds that germinated.

Factors that could have influenced our research can be classified into two major categories: biological and non-biological factors. First, a living factor that was not considered was the presence of predators like humans, who perform sports such as sandboarding in sand dunes. Sandboarding is a sport that consists of descending dunes with special boards. It is considered an extreme sport that damages the dune flora because sliding the board on the sand alters its composition and changes the location of the seeds and other elements necessary for dune flora proliferation (3). Next, the manipulation of seeds islands for the purpose of this research could have led to the loss or inactivation of some of the seeds during the flotation process. Third, regarding non-living factors, the large number of commercial constructions that are invading the Concon dunes may have a great impact on how the dune flora develops. Lastly, another non-living factor to consider is the wind. Because of its altitude of 80 m above sea level, the dune field receives strong winds all year long (5). Wind is a driving force behind the dynamics of the dune field, transporting sand, saline spray, debris, and burying vegetation. For that reason, wind could have carried seeds to or from other environments and altered the characteristics of the seed islands, which may have influenced our results.

Based on the information mentioned previously, it is necessary to emphasize the negative impact of human intervention on the dune field, which involves both the construction of commercial buildings and sports like sandboarding. Commercial buildings are invading the dune field, leaving construction debris in the sanctuary. Additionally, tourists do not take necessary environmental precautions when visiting this sanctuary. These events can eventually lead to an extinction of the seed islands and a reduction in the amount of dune flora, thus modifying the environment and altering the habitat of many animal species. Further research on seed islands can corroborate the importance of their conservation. Experiments we would like to complete in the future would involve determining the genus and species of the seeds found in sand dunes as well as analyzing the specific mechanism of reproduction of each species. Since flora emerges from seed islands, if seeds islands become extinct because of the factors mentioned above, species of seeds that require seed islands may also become extinct.

MATERIALS AND METHODS

The dunes of Concon are located at coordinates 32º56´30´´S 71º32´57´´W and the seed islands were found in the tip of the sand dune between coordinates 32°56'26.3"S 71°32'51.7"W and 32°56'24.4"S 71°32'51.7"W. We selected 20 seed islands, all approximately 6 cm deep. First, each seed island was fenced in a circular way with pieces of wood, at a height of 10 cm. Subsequently, each wood fence was marked with a number between 0–20 to identify the seed islands, after which twenty 2.3 L plastic containers were brought to the sand dune. Each container was marked with the seed island identifier. Later on, each seed island was carefully taken from its hole using a shovel before being put in the matching plastic box filled with 1 L of mineral water. By flotation, the seeds were separated from the branches and the rabbits' feces. This procedure was repeated with each seed island, taking an average of 72 hours per box. Lids were placed on the plastic boxes to prevent wind from altering the results.

The seeds that floated in each plastic container were transported to a 100 mL metallic box marked with the corresponding seed island number. In the new container, the seeds were counted individually, after which the information was collected. We quantified composition by counting each of the elements; seeds, branches and rabbit feces. Then we calculated the percent using the rule of three simples considering seeds, branches and rabbit feces as independent units. Seeds were put back into their respective holes. Then, the branches and rabbit feces were strained with a strainer that matched their seed island number, to separate them from water. Later on, the branches and rabbits feces were put back into their respective seed island to maintain the original composition. The reconstituted seed islands were covered using 1 L translucent glass boxes with tiny holes to prevent seeds from blowing away and to allow air flow. The seed islands were observed with binoculars for a 12-day period to assess the number of seeds germinating, hatching of a seed, in each seed island once daily at 9 a.m.

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