An Island Biogeographical Analysis of the Flora in the Faroe Islands

Ein oyggjalívlandafrøðilig greining av floruni í Føroyum

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Úrtak

Útbreiðslan av teimum føroysku leggstreingjagróplantunum varð nágreiniliga kannað í 1960'árunum. Við hesum tilfarinum sum grundarlag hava vit talt, hvussu nógv sløg eru í teimum 18 oyggjunum.

Tað ber til at vísa á, at talið á plantusløgum í Føroyum er treytað av víddini á teimum einstøku oyggjunum, soleiðis at í eini oyggj, sum er tíggju ferðir størri, eru tvær ferðir so nógv plantusløg. Ella fyri at vera neyvari: Talið á sløgum (S) er í lutfalli til víddina á oyggjunum (A), sum víst í líkningini $S = 73{,}8A^{0{,}20}$.

Við teirri treyt, at útbreiðslan av plantusløgum í oyggjunum er tilvildarlig, hava vit gjørt eina støddfrøðiliga lýsing, sum er grundað á títtleikan av sløgum, eina lýsing, sum samanumtikið fer at greiða betur frá, hvussu nógv sløg eru í oyggjunum. Tað kunnu vera aðrar grundir til frávik frá hesi null-hypotesu enn bert tað, at útbreiðslan er treytað av vídd. Eitt nú vísir kanningin, at tað eru fá sløg í teimum norðaru oyggjunum, meðan tað harafturímóti eru sera nógv sløg í Koltri.

Tann støddfrøðiliga null-hypotesan er eisini grundarlag undir einum samanburði av floruni í oyggjunum. Úrslitið er nógvar upplýsingar um floruna í teimum einstøku oyggjunum, t.d. at Skúvoy er 'føroyskari' enn hinar oyggjarnar, tá talan er um floru.

Abstract

The distribution of the Faroese vascular plants was thoroughly examined in the 1960s. We have used this material and conducted an enumeration of the number of species found on each of the 18 largest islands.

The number of plant species found on the Faroe Islands may be demonstrated to depend on the area of the island in question, in such a way that an island ten times bigger will contain approximately twice as many species of plants. Or to be more exact: The number of species (S) is proportional to the area of the islands (A) as indicated in the equation $S = 73.8\ A^{0.20}$.

By assuming that the distribution of plant species in the Islands is random, we have made a mathematical description based on the frequency of the species, a description which will by and large provide a better explanation for the number of species in the Islands. Deviations from this 'null hypothesis' may be attributed to other causes than mere dependence on area. The model illustrates for example that the northern islands contain few species whereas Koltur is extremely rich on species.

The mathematical null hypothesis also forms the basis for a comparison of the Islands' flora. The result is much information on the florae of the individual islands, for example that Skúvoy floristicly is the most 'Faroese' of all the islands.

Introduction

Ever since Charles Darwin's voyage to the Galapagos Islands in 1835, remote islands have exerted a magnetic attraction on biologists world-wide. As a rule, animal and plant life on islands is poorer than in areas on corresponding mainlands. Consequently, it is often easier to find biological correlations and patterns on islands than on continents where the biological diversity may seem infinite.

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The number of animal and plant species on remote islands has been the subject of many studies, see e.g. Williamson (1981). That is theoretically interesting, among other things, because many areas, and on the continents as well, may be considered islands in an ocean. Lakes behave like islands in an ocean of land, mountain peeks are to alpine animals and plants like islands in an ocean of lowlands, and forests are like islands in a sea of cultured landscape. Ever since the late 1960s, such island biogeographical speculations have been numerous, and they may also have a practical function, e.g. when assessments must be made as to how many species will become extinct when the tropical rain forest disappears (see e.g. Wilson 1992).

The present article deals with the number of plant species on the Faroe Islands. For several reasons, these islands are very suited to an investigation of the above correlation: The total area of the Faroe Islands is limited (118 by 75 km^2), and there are large distances to the nearest mainland (Norway: 675 km) and to other groups of islands (the Shetlands: 300 km and Iceland: 450 km). By comparison, the distances between the single Faroe Islands are small. Finally, the flora of the Islands is extensively described in many studies.

Other biogeographical studies of the Faroe Islands are Bengtson and Bloch (1983) on birds and area, Bengtson (1982) and Enckell *et al.* (1987) on invertebrates.

In the present article, we shall list the number of Faroese vascular plants listed for each individual island, according to information in Hansen (1966). The result will be used in a common mathematical model concerning number of species and area. Besides, we shall discuss the model, its weaknesses and the underlying causes for the correlation.

Subsequently, we shall introduce an alternative model to describe the correlation between area and number of plant species. In some aspects, this model is more accessible than the currently used model.

Finally, our model will enable us to draw up an index which permits us to make comparisons between the florae of the individual islands.

The material

Information on the number of species all comes from Hansen (1966), who lists the distribution of the vascular plants on the Faroe Islands. The material basically originates from a field survey conducted in 1960-61.

In our study, we have included the plants whose distribution has been listed on dot maps in Hansen (1966), apart from a few exceptions. Consequently, our material is composed of such species which occur naturally, which have been imported or naturalised as well as species which have been established 'on a number of locations' in the Faroe Islands. We have excluded imported species which have not become established (no distribution map) and species which have not been found during Hansens (1966) research activities. Besides, we have treated minor subspecies of hawkweed *(Hieracium sp.)* as one species and the same applies for subspecies of dandelion (*Taraxacum sp.*). A total of 294 species have been included in our study. According to Hansen (1972), the total number of species (minus subspecies) on the Faroes is 329, 262 of which are natural, 22 are imported and naturalised and 45 are not naturalised and non-established species.

Results and discussion

The motive for our choice of material is that it provides a time specific picture of precisely what species made up the Faroese flora in 1960-61. The study was very comprehensive (Hansen, 1964; 1966; 1972). A total of 135 stations were examined, evenly distributed across the Faroe Islands, and some 20,000 single observations were made. Every station comprised a few km^2.

The Faroese flora has doubtlessly undergone changes from 1960 up till the present. One of the most common species today in the Tórshavn region seems to be american willowherb (*Epilobium ciliatum*), which is not even mentioned in Hansen (1966). Nevertheless, we find that many alterations in the distribution maps and even new species will not dramatically change the conclusions of the present paper because it builds on as many as 294 species.

The number of plant species on the individual islands

Based on Hansen's distribution maps (1966), we have counted the number of species localised on each of the 18 major islands. See Table 1.

	Number of species	Area, km^2
Suðuroy	238	166.0
Stóra Dímun	65	2,7
Skúvoy	112	10.0
Sandoy	222	112.1
Mykines	107	10.3
Vágar	211	177.6
Hestur	118	6.1
Koltur	108	2.5
Nólsoy	145	10.3
Streymoy	221	373.5
Eysturoy	207	286.4
Kalsoy	139	30.9
Kunoy	151	35.5
Borðoy	163	94.9
Viðoy	136	41.0
Svínoy	128	27.4
Fugloy	126	11.2
Lítla Dímun	12	0.8

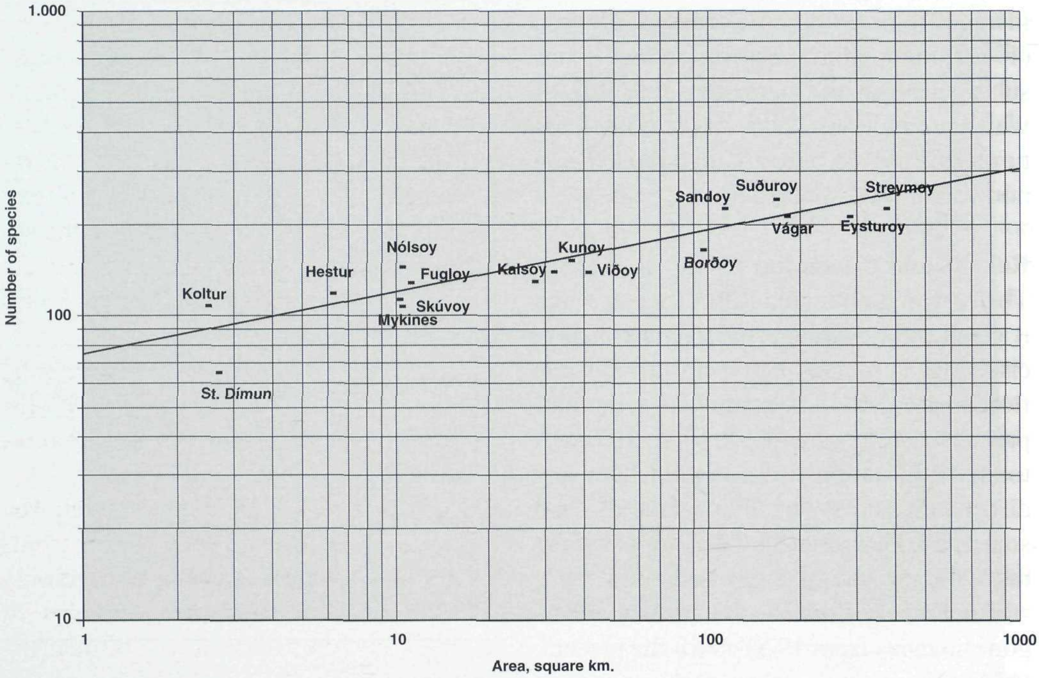
Table 1. *Number of species and areas of the 18 largest Faroe Islands.*
Talva 1. Talið á sløgum og víddin á 18 oyggjum í Føroyum.

In the survey period, 112 species of vascular plants were found on the island of Skúvoy, and the island covers 10 km^2. Mykines is of similar size (10.3 km^2), and even though the two islands are quite unlike each other, the number of species on Mykines is almost the same as that of Skúvoy, i.e. 107 species. Sandoy is about ten times bigger (112.1 km^2), and slightly more than twice the amount of species were localised here, i.e. a total of 222.

This seems to indicate that twice as many species can be found on areas ten times as big. The correlation may be formulated more precisely which is the subject of the following chapter.

The species-area equation $S = cA^z$

In the early days of plant ecology, attempts were made to find the precise form of corresponding materials. Arrhenius (1921) claimed that the correlation could be described by the exponential function S =



Figur 1. The correlation between the area of the Faroe Islands and the number of plant species. The equation of the line is $S = 73.8\ A^{0.20}$. Lìtla Dímun has neither been included in the graph nor in the calculations.
Mynd 1. Sambandið millum víddina á Føroyum og talið á plantusløgum. Líkningin til linjuna er $S = 73{,}8\ A^{0{,}20}$. Lítla Dímun er hvørki við á farmyndini ella í útrokningini.

cA^z, in which S is the number of species and A the area investigated. c and z are constants depending on groups of organisms and of places on the planet. If you extract the logarithm on both sides of the equation sign, you get $\log S = \log c + z \log A$, and if you depict the result in a double logarithmic system of co-ordinates, the set of points would ideally fall in a straight line with the gradient z and would intersect the ordinate in the point logc.

Figure 1 shows the Faroese material and the equation of the line is $S = 73.8\ A^{0.20}$. The correlation coefficient $R = 0.91$, which tells us that the set of points would fit the straight line quite well.

We have not included the island of Lítla Dímun. According to Hansen (1966) the island contains only 12 species which is an obvious error. According to Dorete Bloch *in litt.* (1984), a total of 40 species have been registered on the island.

The values agree reasonably well with figures from other materials. According to Wilson (1992), it is the constant z which is the interesting factor. It varies between 0.15 and 0.35 for the flora and fauna of the world. The before-mentioned rule-ofthumb i.e. that a tenfold increase of the area results in a doubling of the number of species, corresponds to a z value of 0.30.

In areas composed by parts of continents or lying close to same, values of 0.12-0.19 may well be expected according to MacArthur and Wilson (1967). The reason is that such non-isolated areas will have a number of uncommon species which are not adjusted to the area, but nevertheless present because they may be found well-established not too far away. These species in transit will increase the immigration speed and thus raise the number of species. As the number of species of the small areas is increased relatively more than that of the bigger areas, the result will become a reduced z. On the other hand, the more isolated the islands are, the greater the z value.

MacArthur and Wilson (1967) further maintain that if the islands are located closely to other islands in the group, lower z values must be anticipated. The islands will influence each other in terms of an increased immigration rate from one island to another. The closer the islands are located to each other, the higher the immigration rate and the number of species will thus increase on the small islands.

The Faroese z value of 0.20 is quite consistent with the above. As a whole, the Faroes are isolated islands, which would tend to give a high z value. On the other hand, the group of islands is very compact, which would bring down z.

Criticism of the depiction method

Some criticism has been directed against the way in which materials have been depicted in Figure 1. Connor and McCoy (1979) have examined 100 sets of data corresponding to the present in the literature and they find that only 43 are best described via the logS-logA model. In the remaining cases, the set of points depicts a straight line just as well or better (or the deviation is less pronounced) via an untransformed (S-A), a depiction via S-logA or a logS-A.

In the case of the Faroese material, the fact, however, is that it is the logS-logA method which best transposes the points into a straight line.

But it is a rough depiction method: The method will tend to depict any set of points as something which appears linearly if only the dependent variable (here: number of species) varies considerably less than the independent variable (here: area).

There are problems in both ends of the graph, i.e. for very large and very small areas. Even insignificant fluctuations in terms of number of species for small areas bring about dramatic changes in the line's equation. If Lítla Dímun is included in the calculations, it means that the equation will be changed to $S = 45\ A^{0.314}$. As already mentioned, we have omitted Lítla Dímun, on the grounds that there are doubtlessly more than 12 species on the island.

At the other end, the graph is stable way beyond what must be considered reasonable. An alteration of e.g. the number of species on Streymoy to the double amount will cause only a minor alteration of the line's equation compared with the scenario in which Lítla Dímun would be included.

Why are there more species on bigger islands?

According to Begon *et al.* (1990), there are at least two possible explanations to the above island biogeographical correlations. The first explanation is pretty obvious: the number of (plant) species on an island reflects the conditions of life, the habitats of the island. The bigger the island, the more habitats and the more species will be found on the island.

The second explanation has been delivered by MacArthur and Wilson (1967). It is based on the assumption that there is a continued immigration to the island and that this process is neutralised by the fact that other species will constantly become extinct from the island. There will always be an exchange of species, but the total number for the individual island will remain at the same level.

In the case of a group of islands such as the Faroes, the immigration of species is probably the same for all islands, given the fact that the distances from the individual islands to the different sources of dispersion (Norway, Iceland and the British Isles) are approximately the same. On the other hand, the areas of the islands vary considerably and species become extinct much more often on smaller than on larger islands. Consequently, the island theory predicts a correlation between the number of species on a island and its size.

Bengtson (1982) expounds the theory very well and offers illustrative examples from the Faroese invertebrate fauna.

Some sets of data will support the first explanation whereas others will support the second one, see e.g. Williamson (1981) and Begon *et al.* (1990). The latter writes that the two explanations are in fact complimentary; they are both valid. We have studied two consequences of the Faroese material which both seem to be incompatible with the island theory.

Two consequences of the island theory

The z value of the Faroese plants is, as already pointed out, 0.20. If the Faroe Islands were moved closer to the continent, we would experience a larger immigration from the continent to all islands according to MacArthur and Wilson (1967). Hereby the z value would drop to a value below 0.20.

The Shetlands and the Orkneys are groups of islands which have roughly the same areas, number and variety of habitats and similar location in the same plant geographical region as the Faroe Islands.

Johnson and Simberloff (1974) have listed area and number of plant species for all major islands in the British group of islands wherever they have been available. As regards the Shetlands, the study comprises: Shetland, Yell, Unst, Fetlar, Bressay, Foula and Whalsay. Fair Isle is a small island lying between the Shetlands and the Orkney Islands. Without Fair, the Shetlands will have a z value of 0.20. With Fair, z will be 0.14. For the Orkneys (Orkney, Hoy, S. Ronaldsay, Westray, Sanday, Stronsay and N. Ronaldsay) the z value is 0.41; if Fair is included the z value will drop to 0.24.

The material is limited, and just as Lítla Dímun altered the picture completely as regards the Faroes, we observe that the small island of Fair (5.2 km^2) completely changes the z values. Nevertheless, if we choose to accept the values, the z value of the Shetlands should be smaller than that of the Faroes, and that of the Orkneys still smaller yet. And if we decide to omit Fair, the z value of the Orkney would prove dramatically different from what we expected.

Adsersen (1990) points out that the vascular plants form a very non-homogeneous group in terms of biological distribution. He suggests that it might be a good idea to pick out groups of plants which are more homogeneous. We have selected 27 species all characterised by effective dispersion of seeds or spurs, namely the 11 species of fern (*Pteropsida*), 3 club moss (*Lycopsida*), 6 species of horsetail (*Equisetaceae*) as well as 7 orchids (*Orchidaceae*).

Species having a very effective dispersion should be better equipped to immigrate than other species. According to the island theory, we would be inclined to anticipate that the z values of those species would be lower than the overall Faroese material. A calculation of z as regards the 27 good dispersers, however, is z = 0.24 (correlation coefficient R = 0.89). The value is not too different from the z value of the overall material of 0.20 but it is certainly not smaller.

A null hypothesis

In order to find something more palpable than the equation $S = cA^z$, we have prepared a model on the assumption that each species is randomly distributed, independently of the other species.

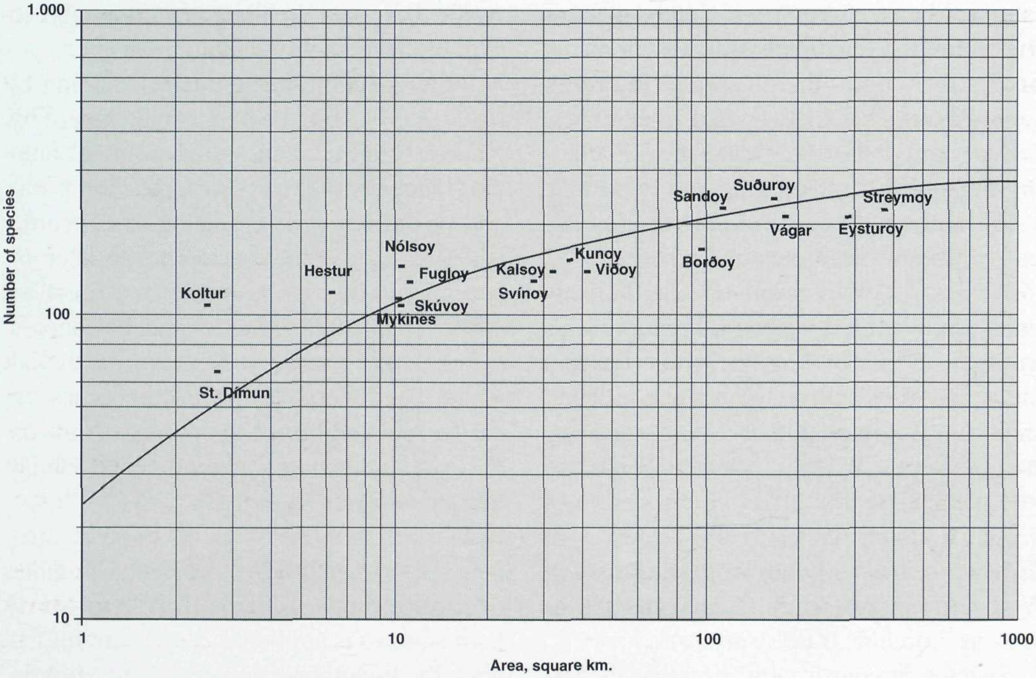
By using such a model as a 'base line', it would be easier to find deviations and to explain the deviations biologically.

Different plant species have different frequencies. We have been informed hereof by Hansen (1966) and have taken into account the frequency of the species into their probabilities of being or not being at a specific island of a specific area. The number of species can thus be described as a function of the area, and the function can be adapted to the actual number of species on the islands. The function – the null hypothesis – can be seen in Figure 2. For more details on the calculations, see appendix and Christiansen and Hansen (1983).

The null hypothesis seems to be an adequate approximation to the actual number of species on the islands. If the method of least squares is applied as a measure for fitness, the hypothesis will produce a slightly poorer result than $S = cA^z$ (12 000 as opposed to 9 000), but the null hypothesis has only one constant that can be adapted to the points (the area unit), whereas the equation $S = cA^z$ has both c and z.

It appears from Figure 2 that the z slope of the line varies. It can be demonstrated that z approximates 1 when the area approximates 0. If the area approximates an infinite number, z approximates 0. In a large area, z maintains a relatively homogeneous value close to 0.20, which we also established in $S = cA^z$. The variation of z along with the area in this model explains why small z values are observed for very large areas, e.g. continents.

Others have worked with corresponding null hypotheses. Adsersen (1990) has e.g. demonstrated that ferns (*Pteridophyta*) in



Figur 2. The correlation between the area of the Faroe Islands and the number of plant species. The solid line corresponds with the graph of the null hypothesis. Lítla Dímun has neither been included in the graph nor in the calculations.

Mynd 2. Sambandið millum víddina á Føroyum og talið á plantusløgum. Tann óbrotna linjan samsvarar við farmyndina til null-hypotesuna. Lítla Dímun er hvørki við á farmyndini ella í útrokningini.

the Galapagos Islands are distributed at random among the islands. In this context, the 'islands' are understood as the area of the island lying 200 metres above sea level because this is the only place where the ferns are found.

Deviations from the null hypothesis graph

Table 2 shows the number of species of the islands and the corresponding, calculated number of species according to respectively $S = cA^z$ and the null hypothesis. If the number of species deviates from the null hypothesis, it must be due to non-accidental causes, i.e. causes of a biological nature.

First the north-south location of the islands is dealt with. Of the 6 most northerly islands, 5 have a smaller number of species than calculated, only Fugloy has more, Figure 1. By contrast, the southern islands have more species than calculated in terms of the area alone. Southern islands, in this context, means Sandoy, Skúvoy, Stóra Dímun and Suðuroy. Lítla Dímun has not been included in these calculations.

A Mann-Whitney U-test (Siegel,1956) may demonstrate that the deviations of the northern islands are significantly different from the number of species of the remaining islands ($p<0.01$). The deviations of the southern islands in percent, however, are not significantly larger than the other islands ($p>0.05$).

The underlying cause why Fugloy has not fewer species, may be due to an imperfection in the calculation method. The registration efforts carried out on Fugloy have been greater than on other, northerly islands, in relation to its area. In Hansen (1966), it may be observed that Fugloy has two stations where e.g. the more than double-sized Svínoy has only one.

The height of the island is relevant, too. In order to investigate whether high islands have fewer species, the same test may be applied. By a so-called high island, we understand an island which contains stations in the high mountain zone, i.e. above 600 metres according to Hansen (1966). This definition includes Suðuroy, Vágar, Streymoy, Eysturoy, Kalsoy, Kunoy, Borðoy, Viðoy and Fugloy. There appears to be a statistically reliable tendency for high islands to have fewer species than low islands.

We have been unable to establish whether the northerly islands have a lower number of species than anticipated on account of their location or their relief, but most likely it is a combination of both factors.

In terms of the height of the islands, the flora of the intermediate and mountainous

	Area km^2	Number of species	Number of species acc. to $S = cA^z$	The null hypothesis	% diff $S = cA^z$	% diff The null hypothesis
Suðuroy	166.0	238	202.0	224.7	17.8	5.9
Stóra Dímun	2.7	65	89.8	53.4	-27.6	21.8
Skúvoy	10.0	112	116.2	110.2	-3.6	1.7
Sandoy	112.1	222	187.0	210.1	18.7	5.7
Mykines	10.3	107	116.8	111.5	-8.4	-4.0
Vágar	177.6	211	204.7	227.1	3.1	-7.1
Hestur	6.1	118	105.4	87.9	12.0	34.3
Koltur	2.5	108	88.4	50.6	22.2	113.3
Nólsoy	10.3	145	116.8	111.5	24.1	30.1
Streymoy	373.5	221	237.0	252.3	-6.8	-12.4
Eysturoy	286.4	207	224.9	243.8	-8.0	-15.1
Kalsoy	30.9	139	145.1	158.3	-4.2	-12.2
Kunoy	35.5	151	149.1	164.1	1.3	-8.0
Borðoy	94.9	163	181.0	203.7	-9.9	-20.0
Viðoy	41.0	136	153.4	170.0	-11.3	-20.0
Svínoy	27.4	128	141.7	153.3	-9.7	-16.5
Fugloy	11.2	126	118.8	115.2	6.1	9.4
Lítla Dímun	0.8	12	70.6	19.8	-83.0	-39.4

Table 2. The number of species in the Faroe Islands compared with the number of species in the Islands as calculated by the two models $S = cA^z$ and the null hypothesis, based on the areas of the islands.

Talva 2. Talið á sløgum í Føroyum samanborið við talið á sløgum í Íslandi, sum tey eru roknað út við tveimum myndlum, $S = cA^z$ og null-hypotesuni, grundað á víddina á oyggjunum.

zones is generally more sparse than the flora of the lowlands. Hansen (1966) finds that out of 262 naturally occurring species on the Faroe Islands, 83 species have a line of 300 metres above which they do not occur and 79 species are confined to areas lying lower than 300-600 metres. Alternatively, a mere 16 species solely occur above 300 metres. In the lowland zone, a total of 246 species are found, in the intermediate zone 173 species and in the mountain zone a total of 100 species.

An island with a high relief profile contains at least one habitat more than an island without the mountain zone, but it takes place, so to speak, at the expense of lowland areas, considering that the latter areas are floristicly most diverse, islands dominated by high mountains will hold fewer species.

The soil conditions of the islands are so homogeneous that it can barely have an impact to account for the different number of species of the islands. The common isolation of the individual islands is apparently irrelevant to the number of species on the islands. Possibly because the islands are located so near one another.

Apart from the geographical location (north-south) of the islands and their relief profile, it is difficult to account precisely for the deviations from the null hypothesis. Six islands deviate more than 20%. In the latter group are Borðoy and Viðoy – both northerly and high and they deviate in a negative respect. Stóra Dímun, Hestur and

Figure 3. *Koltur has far more species than could be anticipated. The reason is probably that it has a lot of fertile lowland, and despite its smallness, it reaches a height of 479 m. Finally its accessibility has the effect that it is possible to find many species within a short time.*

Mynd 3. Í Koltri eru nógv fleiri sløg, enn vit skuldu væntað. Grundin er helst, at har er sera nógv fruktagott láglendi, og hóast oyggin er lítil, er hon 479 m til hæddar. Eisini hevur tað, at hon er so atkomilig, við sær, at tað ber til at finna nógv sløg eftir stuttari tíð.

Koltur are among the smallest islands, and the model is probably less reliable for small areas. Nólsoy also deviates significantly (Table 2) and we are unable to account for the underlying cause.

The model is directly misleading in the case of Koltur, which has as many as 108 species on its 2.5 km^2 which according to the null hypothesis 'should' have held an estimated 51 species. In our opinion, the underlying causes are multiple.

Koltur is a fertile island which would allow for a higher number of species. Bengtson and Bloch (1983) mention that Koltur is priced at 17 merkur from ancient times, whereas Hestur despite its more than double size is priced at only 18 mercur. Mörk (pl.: merkur) is an old Faroese measure for soil fertility.

If you study the island's profile (Figure 3) it seems obvious that here must be many species. There is plenty of lowland and this is where the many species are found. But the island also has an intermediate zone, because Koltur reaches 479 metres despite its very limited area. Finally, the fine accessibility of the island has the effect that it was possible to find many species within the allocated time when the investigation was being conducted.

One way to compare island flora

The starting point in every comparison between the flora or fauna of two regions must always be a list of the organisms of the regions. Subsequently, a measure is presented – based on different criteria – as to how many different species occur in both regions. The subject is thoroughly described in e.g. Connor and Simberloff (1978). By the development and selection of a suitable similarity index, it has been a recurring problem to assess the indexes, and as often a biological null hypothesis has been missing.

In the present section, we shall briefly introduce a way in which to compare the florae of two regions – a similarity index, if you will. The method is based on the previously described null hypothesis.

The nature of the species as well as the total number of species are well-known for each of the islands. The number of common species for the two islands is also well-known, let us refer to that by the letter u. You can also *calculate* the number of common species on the two islands based on the predictions of the null hypothesis in terms of which common species 'ought' to be on these two islands, considering their given areas. We shall call this figure v.

If one island contains x species, the area A_1, which the island 'ought' to have according to the null hypothesis, is determined. This also applies for the other island having y species and 'area' A_2. The null hypothesis now gives the number of species anticipated, k, in a region of an area A_1+A_2 and $v = x + y - k$.

u-v is thus an expression of whether the florae of the two islands are more or less similar than could be anticipated.

But it is not possible to apply the expression directly for comparisons, as the variance differs from one pair of islands to another. In order to compensate for this, we have constructed a variance, see appendix.

Table 3 shows a comparison of all 153

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1: Suðuroy																		
2: *Stóra Dímun*	-0.6																	
3: Skúvoy	0.4	1.5																
4: Sandoy	-1.7	0.6	0.2															
5: Mykines	-0.5	3.1*	-0.8	-3.8*														
6: Vágar	-1.8	-0.8	0.8	-2.6*	0.0													
7: Hestur	0.5	1.7	1.0	-0.7	1.7	-0.2												
8: Koltur	1.1	2.3*	1.4	-0.4	4.4*	0.6	3.5*											
9: Nólsoy	-1.7	1.4	0.3	-0.9	-2.0*	-1.6	0.3	-0.1										
10: Streymoy	-1.8	-1.3	1.1	-5.0*	-0.6	1.6	-0.8	0.2	-1.0									
11: Eysturoy	-4.9*	-1.5	-0.8	-5.3*	-1.6	-1.7	0.1	-2.2*	-3.9*	-0.1								
12: Kalsoy	-1.4	-0.4	-0.4	-4.5*	-2.5*	0.4	0.0	-0.9	-3.2*	0.8	1.7							
13: Kunoy	-7.1*	-1.7	-2.9*	-7.8*	-2.3*	-3.9*	-1.9	0.4	-4.2*	-3.2*	-1.1	2.5*						
14: Borðoy	-4.4*	-0.5	-1.2	-6.0*	-2.1*	-1.8	-1.8	0.0	-3.0*	-0.7	-0.9	1.9	0.3					
15: Viðoy	-2.2*	-0.2	-0.7	-4.2*	-0.6	-1.3	0.8	1.0	-2.2*	0.1	1.0	3.6*	1.7	3.0*				
16: Svínoy	0.7	1.4	0.1	-3.7*	-0.2	-0.8	2.0	1.3	0.5	0.9	1.1	2.8*	1.0	0.7	3.2*			
17: Fugloy	0.0	1.5	1.5	-1.4	-0.3	-0.3	2.3*	1.6	1.3	1.5	1.5	2.1*	-0.6	0.1	1.9	4.6*		
18: Lítla Dímun	0.2	2.5*	0.6	0.2	0.7	0.4	1.3	0.1	0.8	0.4	0.4	0.0	-1.4	0.7	0.1	0.3	0.3	

Table 3: *Similarity index of the florae in the 18 Faroe Islands. The index describes the number of common species of the two islands minus the* ***calculated*** *number of common species, divided by a variance, which depends on the number of common species. An asterisk (*) indicates that the florae of the islands are significantly different. Positive values indicate that the florae of the two islands are more alike than anticipated on the basis of the null hypothesis.*

Talva 3. Líkleikayvirlit yvir floruna í teimum 18 oyggjunum í Føroyum. Yvirlitið lýsir talið á sløgum, báðar oyggjarnar hava í felag, minus tað **útroknaða** talið á sløgum, tær hava í felag, býtt við einum fráviki, sum er treytað av talinum á felags sløgum. Ein stjørna (*) vísir, at munurin á floruni í oyggjunum er signifikantur. Positiv virði vísa, at floran í báðum oyggjunum er líkari enn væntað, um null-hypotesan verður løgd sum grund.

pairs of islands. If the difference of flora on the two islands is statistically significant, the number is marked by an asterisk.

Treatment of the comparisons

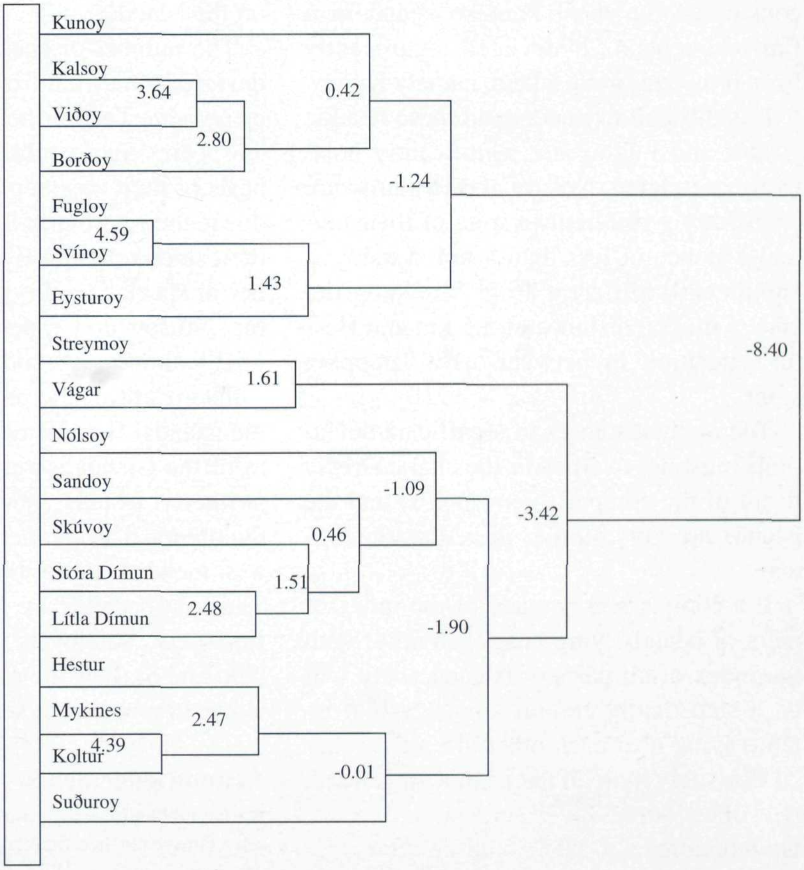
In order to have a clearer picture of Table 3, we have conducted a cluster analysis, see Figure 4. The technique applied is that you focus on the two islands displaying the largest similarity indexes; subsequently these two islands are combined into one, just as if they were in fact one island. The index between this 'new' island and the others are then calculated. Subsequently you focus on the islands which now have the largest index. You combine them, calculate new indexes, and the calculations are continued until all islands have been related to each other.

A group of northern islands is distinctly separated, i.e. Kalsoy, Kunoy, Viðoy, Borðoy, and Svínoy-Fugloy, islands which are most like each other of all islands but which as a group distinguish themselves slightly from the other, northerly islands.

Eysturoy is clearly different from the southerly islands, but rather indifferent in relation to the northerly islands.

The southerly islands from Streymoy and southwards constitute another large group of islands; it is not as homogenous as the northerly group. Streymoy does not de-

Figure 4. Cluster diagram showing the floristic differences and similarities between the Faroe Islands.
Mynd 3. Stabbamynd ið vísir munir og líkleikar á floruni millum tær ymsu oyggjarnar í Føroyum.



viate significantly in a positive manner in relation to any one island, but it is significantly different from both Sandoy and Kunoy. Nólsoy does not deviate positively, either, but it is significantly different from Mykines, Eysturoy as well as the northerly islands, excepting Svínoy and Fugloy. Vágar exemplifies the same picture, i.e. no similarities at a significant level, and it deviates significantly from Sandoy and Kunoy.

Sandoy is the most isolated island, floristicly, of all the islands, as it is significantly different from as many as 9 islands. It is in no instance significantly positively correlated to the other islands.

Suðuroy is significantly different from Eysturoy, Kunoy, Borðoy and Viðoy and it is not positively correlated with any other island at any significant level.

The small islands Mykines, Koltur, Hestur and partly Stóra Dímun, too, are floristicly related, displaying significantly positive relations between Koltur–Mykines/-Hestur/Stóra Dímun and Mykines–Stóra Dímun. Of all the islands Skúvoy must be considered the most Faroese island in a floristic context. It deviated significantly from only one single island, namely Kunoy.

It is difficult to understand these results: Hestur and Fugloy are significantly positively correlated. Nólsoy and Eysturoy are significantly different in spite of their mutual distance of less than 4 km. Sandoy is significantly different from Streymoy despite a mutual distance of 5.5 km and Hestur's position in between as a 'stepping stone'.

The many instances of significant deviations must not overpower the characteristic result of the comparisons which is that the islands are very similar in a floristic context.

If a comparison is made of the index of pairs of islands lying near each other with the index of all pairs of islands, there will be a statistically certain tendency that islands lying near each other are more related floristicly than all the islands in general.

Conclusions

As regards the 17 largest of the Faroe Islands, the proportion between the area (A) of the islands and the number (S) of vascular plants may be described by the equation $S = 73.8 A^{0.20}$. On the basis of the frequency of the various species and on the assumption that the distribution of the species is random, a term can be set up (the null hypothesis), which is largely able to describe the proportion between the area and the number of species.

This means that the area of the islands is by far the most decisive factor when it comes to explaining the number of species on the islands.

The number of species on some islands deviates somewhat from a sheer dependency on area. The northerly islands have fewer species than could be predicted on the basis of their area, a phenomenon which is due to their northerly location (climate) and their steep relief profile (height). The number of species on the small islands of Hestur, Nólsoy and especially Koltur is distinctly above what could be anticipated.

The result of the present comparison of the islands' flora demonstrates that the flora of the islands is very homogenous. The northerly islands, however, deviate from the others. The southerly islands constitute a somewhat more heterogeneous group. The small islands are most closely related, floristicly. Sandoy is the most deviant island and Skúvoy the most Faroese of all islands, in a botanical sense.

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APPENDIX

The mathematical background

For each of the 294 species Kjeld Hansen lists the frequency at which they are found in a total of 237 locations.

The basis of the null hypothesis is the assumption that the probability of finding species no i within an area unit E is a constant s_i. The best estimate for s_i must be:

$$s_i = \frac{\textit{number of finding places for specie no i}}{237}$$

The probability of finding species no i within an area AE is then

$$1 - (1 - s_i)^A = 1 - e^{Au(i)},$$

in which $u(i) = \ln(1 - s_i)$

The anticipated number of species in an island of an area AE is thus:

$$1)\ N(A) = \sum_{i=1}^{294}(1 \div e^{Au(i)}) = 294 \div \sum_{i=1}^{294} e^{Au(i)}$$

For a fixed area, A, the variance of N is:

$$2)\ \mathrm{Var}(N) = \sum_{i=1}^{294}(1 \div e^{Au(i)})e^{Au(i)}$$

In this model the z-value depends on the area, A:

$$z(A) = \frac{d(\ln(N))}{d(\ln(A))} = \div \frac{A}{N} \sum_{i=1}^{294} u(i)e^{Au(i)}$$

The area unit E is defined in such a way that the species-area-graph and the 17 measuring points observed correlate best (the method of least squares) and E becomes 5 km^2.

Similarity Index

If island no 1 contains x species and island no 2 contains y species, the islands 'ought' to have the areas A_1 resp. A_2, defined by formula 1) :

$N(A_1) = x$ and $N(A_2) = y$. The two areas are found by numerical calculation.

The calculated, expected number of common species in the two islands is now:

$$v = x + y - k$$

in which k is the calculated number of species in an island of an area of $A_1 + A_2$.

If we compare the observed number of common species, u, we shall see that u-v is negative for 77 pairs of islands and positive for 76 pairs of islands.

The sizes of u-v, however, cannot be applied as similarity index because the variance of v differs from one pair of islands to another. As we have been unable to find Var(v) we have applied the following equation as an approximation for every single pair of islands:

$$\text{“Var(v)”} = \frac{Var_1 \cdot Var_2}{Var_1 + Var_2}$$

in which Var_1 is defined by formula 2), as we sum up over the 294 - x species which are not found on island no 1, and the area is A_2.

Var_2 is defined correspondingly. In simple cases "Var(v)" is controlled by direct calculation, and it seems that it is slightly smaller than the actual variance.

As similarity index we apply:

$$\frac{u - v}{\sqrt{\text{“Var(v)”}}}$$

Example of a result:

Skúvoy, number of species x = 112, is compared to the other islands:

Name of island	Number of species observed on the island	Total number of species y species z on the two islands (obs)	Number of common species (obs) u = x + y - z	Calculated number of common species: v = x + y - k	'dispersion' sp = $\sqrt{\text{“Var(v)”}}$	Index (u - v)/ sp
Suðuroy	238	239	111	110.5	1.3	0.4
Stóra Dímun	65	121	56	51.9	2.7	1.5
Sandoy	222	224	110	109.6	1.9	0.2
Mykines	107	142	77	79.4	2.9	- 0.8
Vágar	211	213	110	108.7	1.6	0.8
Hestur	118	142	88	85.2	2.9	1.0
Koltur	108	136	84	80.0	2.9	1.4
Nólsoy	115	160	97	96.1	2.8	0.3
Streymoy	221	222	111	109.5	1.4	1.1
Eysturoy	207	212	107	108.3	1.7	-0.8
Kalsoy	139	158	93	94.0	2.7	- 0.4
Kunoy	151	173	90	97.9	2.7	- 2.9
Borðoy	163	177	98	101.1	2.6	- 1.2
Viðoy	136	157	91	93.0	2.8	- 0.7
Svínoy	128	150	90	89.8	2.8	0.1
Fugloy	126	145	93	88.9	2.8	1.5
Lítla Dímun	12	113	11	10.1	1.4	0.6