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RESEARCH ARTICLE

An Evaluation of the Short-Term Progress of Restoration Combining Ecological Assessment and Public Perception

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Abstract

Ecological restoration centers on the reestablishment of ecological processes and the integrity of degraded ecosystems, but its success also depends on public acceptance and support. In this study, we evaluated the short-term ecological effects of different restoration treatments in Iceland. Furthermore, we tested the public perception of aesthetic and recreational values of these revegetated areas. Predefined soil and vegetation indicators were measured, and a survey, based on a questionnaire and photographs of the different areas, was used for gauging public perception. Our results indicate that different restoration treatments triggered different succession trajectories. The vegetation composition of areas seeded with grasses seemed to be on a trajectory toward relatively undisturbed reference ecosystems, whereas areas seeded with nonnative lupine seemed to be developing a novel ecosystem. Results of the survey demonstrated that people valued the appearance of revegetated areas higher than that of the eroded control areas, with the exception of areas seeded with lupine. The visual perception of each restoration treatment corresponded well with the ecological factors and revealed both a social and an ecological rationale against the use of lupine in land restoration. The results indicate that the design of restoration projects should be based on both an analysis of sociocultural priorities and an understanding of possible trajectories of ecosystem development associated with the available restoration methods to avoid results that are neither socially acceptable nor ecologically feasible.

Key words: **aesthetic values, ecological evaluation, ecological restoration, public opinion, sociocultural evaluation, soil degradation.**

Introduction

In his book “Collapse; How societies choose to fail or succeed,” Jared Diamond (2005: 197) states: “Iceland is ecologically the most heavily damaged country in Europe. Since human settlement began, most of the country’s original trees and vegetation have been destroyed and about half of the original soils have eroded.” Evidentially, the country and its inhabitants have suffered from ecosystem degradation for centuries (McGovern et al. 2007), but that is not unique to Iceland. A large-scale degradation of ecosystems is a worldwide problem, caused by centuries of overexploiting the Earth’s natural capital (MA 2005). In many cases, the restoration of the systems’ functions and structure is nevertheless still possible (Benayas et al. 2009), and ecological restoration has been promoted as a solution to regain ecosystem services which have been lost from degraded areas (Palmer et al. 2004).

Reestablishment of ecological processes and the integrity of degraded ecosystems are the core components of ecological restoration (SER 2004). However, sociocultural obstacles can be even more difficult to overcome than biophysical ones (Holl et al. 2007). Therefore, restoration progress also relates directly to the level of public acceptance and support (Clewell & Aronson 2006; Harris & van Diggelen 2006). It is widely accepted that restoration projects aiming for sustainable outcomes should be based on an integrated approach toward social and ecological factors that later can be used to monitor and evaluate the progress of restoration (Holl & Cairns 2002; Hobbs 2007).

Ecological indicators used to evaluate restoration progress include species composition, biotic integrity, ecological function, and the stability of the physical environment (Herrick et al. 2006). The choice of social parameters is however not as clear (Aronson et al. 2010). The value of restored ecosystem services can be used for evaluating the economic benefits of restoration (Farley & Gaddis 2007), but the opinions of stakeholders can also give important signals of progress (Reed 2008). Landscapes perceived as aesthetically pleasing

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are, for example, more likely to be appreciated within communities than landscapes perceived as less attractive (Gobster et al. 2007), and factors such as aesthetic preferences and perceptions are valuable for estimating the level of community support for restoration (Junker & Buchecker 2008; Lindemann-Matthies et al. 2010).

This paper presents the results of a study where an evaluation of short-term ecological effects of restoration treatments was combined with an assessment of the public perception of aesthetic and recreational values that were thought to provide indications of public attitudes toward the restoration work. The study was done in Iceland; a country with a long history of restoration or rehabilitation of degraded land (Aradóttir 2009). As elsewhere, however, the results have mainly been evaluated in terms of ecological aspects (e.g. Gretarsdottir et al. 2004). In this study, ecological parameters were measured, and the local perception of the visual appearance of the different restoration methods used was surveyed, to answer the following research questions:

- What are the short-term effects of different restoration methods on vegetation succession and soil properties?
- Does the local public have different opinions of the visual appearance of vegetation created by different restoration methods?
- What is the value of combining ecological assessment and a study of public perception for the evaluation of restoration progress?

Study Area

The restoration area is located in West Iceland (lat 64°N, long 21°W), at 20–40 m elevation above sea level and 1.5–5 km from the sea. The whole area is approximately 2,500 ha, of which 60% was classified as degraded or eroded before restoration efforts were started (Pétursdóttir 2007). Mean annual temperature for the nearest weather station for the period 1998–2005 was 5.2°C, with mean January temperature of 0.9°C, mean July temperature 11.4°C, and mean annual precipitation of approximately 1100 mm (Icelandic Meteorological Office, unpublished data).

The area is characterized by a mosaic of sparsely vegetated gravel surfaces interspersed with remnants of previous vegetation types such as shrubland, dominated by Downy birch (*Betula pubescens*), grassland, and wetland. The soil of the barren areas is classified as Cambic Vitrisol (Arnalds & Óskarsson 2009), displaying a high clay and sand content and often highly affected by freeze-thaw cycles in winter (Arnalds & Kimble 2001). The soil of the remaining vegetated areas is classified as Histic Andosol (Arnalds & Óskarsson 2009), which was probably the area's main soil type before its degradation (Arnalds & Kimble 2001).

Historical references indicate that two centuries ago the area had far more extensive vegetation cover than it has at present. They also indicate the occurrence of long-term land degradation, caused by unsustainable livestock grazing and use of wood from previously forested land (McGovern et al. 2007). When the restoration project was initiated in 1999 the area was used for free-roaming sheep grazing during the summer.

Because the area is privately owned by several adjacent farms, the restoration project was instigated by the local authorities. The local farmers and other stakeholders established a consortium to organize, implement, and secure funding for the project from both private and public sources. Restoration of the degraded ecosystem was intended to provide multiple benefits, such as enhancing usable grazing land, reducing wind impact, and improving the aesthetic value of the area. Half the area was fenced off to exclude sheep grazing, with managed grazing during summer continuing on the other half. Restoration practices were applied from 1999 within both the grazed and non-grazed areas and involved several different treatments, commonly used in restoration work in Iceland (Aradóttir et al. 2000) (Table 1).

Methods

Data Collection

Vegetation and soils were sampled in August and September 2005. A map of the research area showing the distribution of restored patches and untreated eroded patches in both grazed and protected part of the area was used to randomly position five 10 × 10–m plots within each treatment and their coordinates used to locate them in the field (Table 1). Plots from the same treatment were in all cases located in up to five different patches. Ten 0.5 × 0.5–m quadrats were randomly placed within each plot, for visual estimation of total vegetation cover (to the nearest 5%). The cover of individual vascular plant species was also visually estimated in all quadrats using the following scores; 1: <1%, 2:1–5%, 3:6–10%, 4:11–15%, 5:16–25%, 6:26–50%, 7:51–75%, and 8:76–100%. Within five of the quadrats, aboveground biomass was cut, dried, and weighed, and soil cores were sampled at 0–10 cm depth. The samples from each plot were combined, oven-dried at approximately 60°C, and sieved through a 2-mm sieve. Soil pH was measured with a glass electrode in samples rewetted with deionized water. The soil organic carbon content was quantified by dry combustion with a Leco-CR 12-carbon analyzer, and Kjeldahl's procedure was used to determine the total nitrogen content (Bremner & Mulvaney 1982).

In September 2006, five reference plots were established from non-eroded patches within the protected area, and their vegetation was sampled using the same procedure as described above.

A survey based on a questionnaire and photographs of the different restoration treatments, together with area treated only with fertilizer, was administered during the winter 2005–2006. A number of prospective photo plots were selected from a map of the research area depicting the distribution of different restoration treatments, with the final selection taking place in the field in June. The photographs were taken from similar angles to show the visual appearance of the dominant vegetation in the landscape but not the landscape itself. A pair

Table 1. Overview of land use and restoration treatments within the research area.

Label	*Land Use*	*Method*	*Species Sown*	*Seed (kg/ha)*	*Age Years*[a]	*Initial Application (kg/ha)*	*Annual Fertilizer Application*	*Fertilized No. Years*
CG	Grazed	Control						0
CP	Protected	Control						0
SG	Grazed	Surface Seeding	*Festuca rubra* *Poa pratensis*	25 25	5–6	N: 78 P: 18.3[b]	N 52 P: 12.2	4
SP	Protected	Surface seeding	*F. rubra* *P. pratensis*	25 25	6	N: 78 P: 18.3	N: 52 P: 12.2	2
DG	Grazed	Drill seeding	*F. rubra* *P. pratensis* *L. multiflorum*	25 25 5	5–6	N: 57 P: 13.4	N:52 P: 12.2	4
DP	Protected	Drill seeding	*F. rubra* *P. pratensis* *L. multiflorum*	25 25 5	5	N: 52 P: 12.2	N: 52 P: 12.2	2
LP	Protected	Drill seeding	*Lupinus nootkatensis*	4	6–7			0

[a] An estimate of the vegetation cover of plots where restoration was initiated over two consecutive summers did not reveal significant differences between them; hence they were considered a single treatment.
[b] Applied as P_2O_5.

of photographs was made for each restoration treatment; one showing the overall surface with the restoration treatment in the foreground and a close-up view (Fig. 1). The photo-pairs were printed on photo-quality paper and labeled with randomly selected letters. The questionnaire consisted of five questions, designed to capture whether any particular visual appearance seen on the photo-pairs was valued higher/lower than the others and if there was a noticeable difference in the perception of various ideological and utilitarian aspects of the untreated versus treated sites. The participants were asked to rank the photo-pairs with regard to: (1) harmony with Icelandic nature, (2) aesthetic value of the vegetation, (3) diversity of the vegetation, (4) recreational value, and (5) suitability for building a summer cottage. For each question, the participants were asked to first select the photo-pair they preferred the most and the one they preferred the least; then to select the photo-pair they felt as the second best and the second worst, leaving one pair that received a median grade. The ranking method was based on a simplified version of the Q-method (Brown et al. 2008). The participants were asked to write down a few words next to each question explaining their choice of the most and the least preferred photo-pairs. The participants were informed of the survey's purpose but no additional explanations were given regarding the restoration methods or the sites.

A sample of 300 people from 18 to 70 years old was randomly selected from nearby communities and the survey mailed to them. The response rate was low (<40%) and the average age of those who replied rather high. The sample size was increased by including 164 students from randomly selected classes at two, local universities; about one-third of which were studying agricultural or environmental science and about two-thirds studying business or law. The survey was handed to the students in class and they were asked to complete it before leaving the classroom.

Data Analysis

Plots were the experimental units used in the ecological part of the study; hence plot means were used for all analyses. Cover scores were transformed to percentages by using the central value of the range represented by each score, before calculating the average cover of each species per plot.

Effects of all treatments and untreated controls were compared with one-way analysis of variance (ANOVA) and Tukey's HSD ($p \leq 0.05$) used for mean comparison. Furthermore, the effects of different methods (drill seeding, surface seeding, and untreated eroded control) and grazing were tested with two-way factorial ANOVA. Lupine plots were excluded from the second analysis as they were only present in the protected areas. The data were square-root transformed where needed to stabilize variances and meet conditions of normality. Species composition (percentage cover of vascular plants species) of all treatments was analyzed with detrended correspondence analysis (DCA) using CANOCO 4.5 for Windows (ter Braak & Smilauer 2002). Species occurring only once were excluded and rare species down weighted. A separate DCA included all restoration treatments, the eroded control plots and the additional reference plots in non-eroded shrubland patches.

The effects of different treatments on species composition were analyzed with constrained ordinations (redundancy analysis or RDA), using a forward selection and Monte-Carlo tests with 999 unrestricted permutations for significance testing. Partial data sets were used to partition variance in species composition due to grazing and restoration treatments with a series of RDA analysis (cf. Lepš & Smilauer 2003).

A Friedman test was used to assess whether the ranking of the photo-pairs was identical (Conover 1980). The test was performed independently for the local and the student groups. Where differences in ranking of the treatments were significant ($p < 0.05$), the treatment means were compared

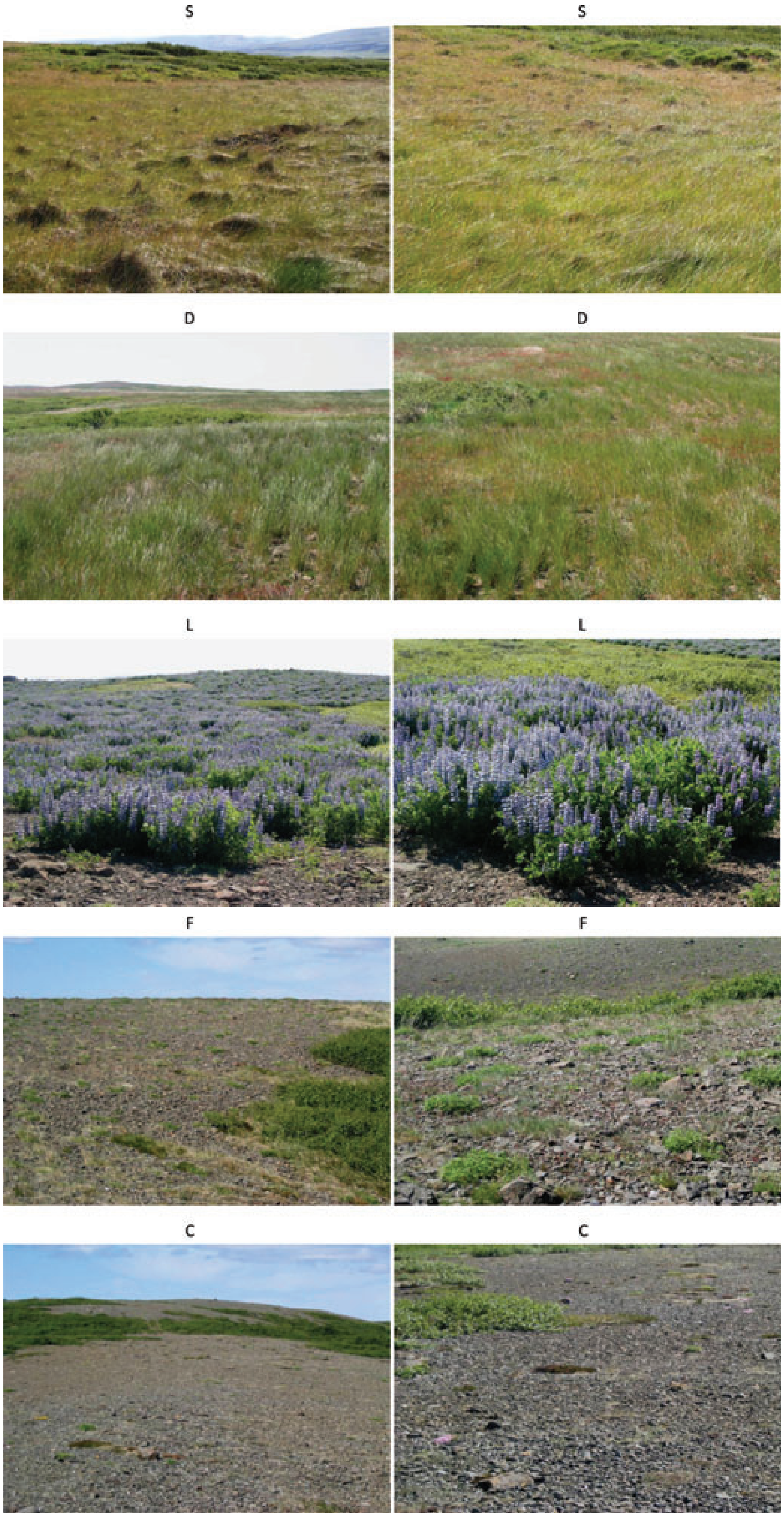

Figure 1. Photo-pairs used in the survey (S, surface seeding; D, drill seeding; L, lupine seeding; F, fertilized-only; C, control). Each restoration treatment is represented by two photographs printed together on A4 paper. The photograph to the left presents an overview of the area's visual appearance, whereas the one to the right shows the surface in more detail.

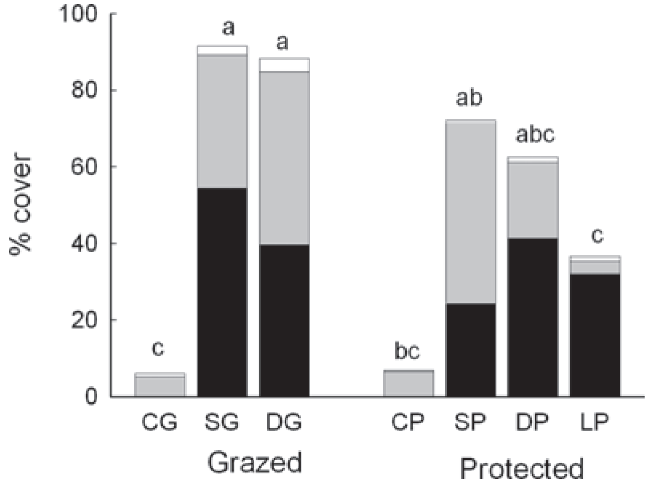

Figure 2. Average cover of sown species (black), native vascular plants (gray) and mosses, lichens, and biological soil crust (white) in 5- to 7-year-old restoration treatments and untreated controls on a severely degraded area. Different letters indicate significant differences in cover of native vascular plant species (Tukey's HSD, $p \le 0.05$).

according to the procedure described by Conover (1980). The arguments participants used to rationalize their ranking within each category were grouped.

Results

Soil and Vegetation

Total vegetation cover of untreated controls was around 6% and their surface was characterized by sand and gravel. The results showed no significant difference in vegetation cover or soil quality between the grazed and protected control plots (Fig. 2), which demonstrates the homogeneity of the area and validates the use of these plots for baseline comparison. All treatments had significantly greater vegetation cover than the controls (Fig. 2; Table 2).

Over 90% of the vegetation cover in the lupine plots consisted of sown lupine, but sown grasses accounted for 34–67% of the total cover of other restoration treatments (Fig. 2). The cover of native vascular plant species was 3%, slightly lower in the lupine plots than the controls. Treatments sown with grasses and fertilized had 20–47% cover of native vascular plants (Fig. 2).

The cover of native vascular plant species was neither significantly affected by seeding method (surface vs. drill seeding) nor grazing (Table 2). The richness of vascular plant species was low; with on average eight species in each 100 m^2 plot and an average density of 2.8 species in the 0.25 m^2 quadrats (excluding seeded species). Neither species density nor species richness was significantly affected by treatments (Table 2).

Carbon content in the top 10 cm of soil was 1.1–1.2% in untreated controls and drill-seeded plots and 1.3–1.5% in plots with surface seeding of grasses and lupine, but this difference was not statistically significant (Table 2). The C:N ratio in the top 10 cm of soil was significantly higher in plots sown with grasses than in untreated controls and lupine (13.8, 13.4, and 12.4 in drill-seeded, surface-seeded, control and lupine plots, respectively). Average soil pH was 5.9 (H_2O) and 5.5 (KCl) and was not significantly affected by treatment or grazing.

Unrestricted ordination (DCA) of vascular species composition showed considerable variation among the different treatments (Fig. 3). The first DCA axis was most strongly correlated with total amount of fertilizer applied, cover of vascular plant species and C:N ratio of top 10 cm of soil. The second DCA axis was negatively correlated with species density. The native grasses Common bent (*Agrostis capillaris*) and Viviparous sheep's fescue (*Festuca vivipara*), and the seeded grasses Red fescue (*F. rubra*) and Common meadow-grass (*Poa pratensis*) had the highest scores on the first DCA axis. The seeded lupine had the lowest score.

Constrained ordination (RDA) including data from all treatments showed that canonical axes explained 55% of the variance in species composition ($F = 5.7,\ p = 0.001$). When lupine was included as the only explanatory variable,

Table 2. Results of one-way ANOVA of all treatments and two-way factorial ANOVA testing the effects of revegetation method and grazing on selected vegetation and soil parameters (omitting lupine treatments). Shown are F-values and their significance: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; NS not significant. Species density refers to number of species per 0.25 m^2 subplot (quadrat); species richness refers to number of species per 100 m^2 plot (excluding the seeded species).

	One-Way ANOVA		*Two-Way ANOVA*					
Dependent Variable	*Treatment*		*Grazing (G)*		*Method (M)*		*G × M*	
df	*[6, 28]*		*[1, 24]*		*[2, 24]*		*[2, 24]*	
Total vegetation cover	32.4	***	20.4	***	140	***	5.4	*
Native vascular species	9.8	***	0.4	NS	11.5	***	3.2	NS
Mosses	2.6	*	7.7	*	4.1	*	0.9	NS
Species density	2.1	NS	1.0	NS	0.4	NS	3.2	NS
Species richness	0.7	NS	0.0	NS	0.9	NS	1.0	NS
Aboveground biomass	13.6	***	16.8	***	52.0	***	5.5	*
% C in 0–10 cm of soil	0.9	NS	0.1	NS	0.2	NS	0.9	NS
% N in 0–10 cm of soil	1.3	NS	0.1	NS	0.5	NS	0.8	NS
C:N ratio in 0–10 cm of soil	4.0	**	0.8	NS	8.0	**	0.1	NS

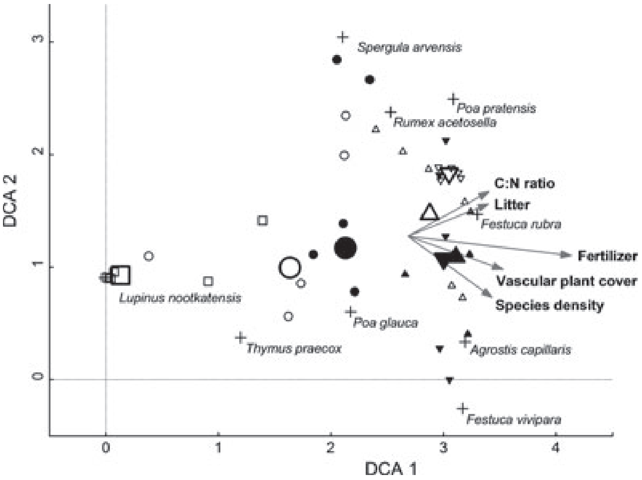

Figure 3. DCA of vascular species composition (% cover). Eigenvalues for the first and second axes were 0.953 and 0.407, respectively. Small symbols show individual plots, large symbols show centroids of treatments (circles = controls; square = lupine; up triangles = surface seeding; down triangles = drill seeding; filled symbols = grazed; open symbols = protected from grazing). Vectors show vegetation and soil properties with >|0.4| correlation with the first and second axes. Crosses indicate the position of species with >2% weight in the ordination.

it explained 18% of the variability of the species data ($F = 7.0$, $p = 0.003$). Next, the lupine data were excluded and all other treatments included as explanatory variables, which explained 40% of the variability in species data ($F = 5.7$, $p = 0.001$). Most of that variability, or 34%, was explained by restoration treatments (surface seeding, drill seeding, and untreated controls) and this was highly significant ($p = 0.001$).

Unrestricted DCA of vascular species composition for all the treatments showed that the eroded control plots and the reference plots in protected shrubland had a very long first axis of 5.9, whereas lupine plots had the lowest scores but shrubland plots had by far the highest scores (Fig. 4).

Public Perception

A total of 262 participants answered the questionnaire; 98 locals (average age 48 years) and 164 students (average age 28 years). In addition to those defined as "locals," at the time this study was made, the vast majority of the students were also residents in the nearby community. Ranking of the photo-pairs was significantly different for all the five questions and both groups ranked the photo-pairs in a similar way (Table 3). The majority of the participants within both groups preferred photo-pairs showing vegetated areas, rather than sparsely vegetated or barren areas, with the exception of the lupine which was consistently ranked very low (Table 3).

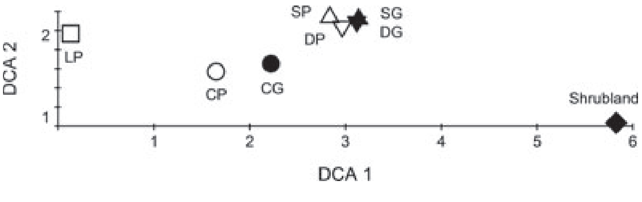

Figure 4. Results for DCA of vascular species composition (% cover) of treatments and adjacent reference plots in protected shrubland. Symbols show centroids for individual treatments (see Table 1). Eigenvalues for the first and second axes were 0.955 and 0.389, respectively.

Drill- and surface-seeded areas received the highest ranking with respect to diversity of vegetation but the control and the lupine areas were ranked lowest (Table 3). The grass seeding areas were described as colorful and showing a diverse flora (Table 4) but the lupine was seen as too dominating and the control areas too barren (Table 5).

All photo-pairs received similar ranking with respect to feasibility for recreation, except the surface-seeded area which was ranked slightly higher by the student group and the lupine area which was ranked significantly lowest by both groups (Table 3). The participants most frequently mentioned the broad vista and openness as arguments for those photo-pairs ranked highest (Table 4), but argued the lupine created vegetation that was homogeneous and difficult to walk through (Table 5).

Surface-seeded and fertilized-only areas received the highest ranking with respect to harmony with Icelandic nature, followed by fertilized-only areas. The lupine and the control areas were ranked lowest (Table 3). The participants felt that the surface-seeded and fertilized-only areas showed a combination of typical Icelandic vegetation features (Table 4) but argued that the photo-pairs of the control and the lupine areas showed only eroded land and an introduced, nonnative species (Table 5).

When asked about suitability for building a summer cottage, most participants ranked surface- and drill-seeded areas highest but, as before, the lupine and the control areas were the least preferred choices (Table 3). Participants felt the grass seeding areas were promising for cultivation (Table 4) but described the lupine and the control areas as too homogeneous and not suitable for cultivation (Table 5).

Surface- and drill-seeded areas received the highest ranking with respect to aesthetic value, whereas the control and the fertilized-only areas were ranked the lowest. The participants perceived the surface- and drill-seeded areas as "truly Icelandic"; with a mixture of vegetated and gravel surface (Table 4). Conversely, the control and the fertilized-only areas were perceived as dull and grayish (Table 5).

Discussion

Understanding the interactions between social and ecological factors is essential for both designing and implementing new restoration projects and for monitoring and evaluating their progress (Aronson et al. 2010). In this study, we combined different approaches to assess the short-term progress of several different restoration interventions, using soil and vegetation parameters to evaluate ecological progress in combination with a survey to evaluate people's perception of the areas' visual appearance.

Table 3. Average ranks of photo-pairs for each question of the survey. L = local people (N = 98), S = students (N = 164). Different superscript letters within each column represent significant differences between average ranks ($p < 0.05$).

	Diversity of Vegetation		*Feasibility for Recreation*		*Harmony with Icelandic Nature*		*Feasibility for Summer Cottage*		*Beauty/Aesthetical Value*	
	L	*S*	*L*	*S*	*L*	*S*	*L*	*S*	*L*	*S*
Lupine	2.5^{b}	2.5^{a}	1.5^{a}	1.7^{a}	1.5^{a}	1.7^{a}	2.4^{a}	2.4^{b}	2.6^{b}	2.4^{b}
Surface seeding	3.6^{c}	3.6^{c}	3.5^{b}	3.8^{c}	3.9^{d}	4.0^{d}	4.3^{d}	4.6^{d}	4.0^{c}	3.4^{d}
Drill seeding	4.0^{d}	3.5^{c}	3.3^{b}	3.2^{b}	3.2^{bc}	3.1^{b}	3.7^{c}	3.7^{c}	4.0^{c}	3.7^{c}
Fertilized-only	2.9^{b}	3.1^{b}	3.5^{b}	3.2^{b}	3.5^{c}	3.4^{c}	2.4^{b}	2.4^{b}	2.3^{ab}	2.5^{b}
Control	2.0^{a}	2.3^{a}	3.2^{b}	3.2^{b}	2.9^{b}	2.8^{b}	2.2^{a}	1.9^{a}	2.0^{a}	2.0^{a}

Table 4. Examples of the arguments participants made for reasoning their selections on the most preferred appearances to each of the five questions of the survey.

Survey Questions	*Surface Seeding*	*Drill Seeding*	*Fertilized Native Flora*
Diversity of vegetation	"Many vegetation communities—colorful"	"Seems like many types of vegetation—colors and texture"	"Low vegetation cover but high diversity—diverse flora"
Feasibility for recreation	"Diverse land—enjoyable walk—birdlife and diverse vegetation"	"Pretty landscape, broad view—comfortable"	"Easy to walk and diverse—stones are beautiful amongst the wild flora"
Harmony with Icelandic nature	"Seems like a true Icelandic heathland—lot of Icelandic vegetation"	"Grassland, moor and scrubs—very green"	"Ongoing natural succession—wild flora plays the main role"
Feasibility for summer cottage	"Good basic flora for tree planting—diverse flora, view and good for walk"	"Has to be vegetated land for frisbee and football—pretty land, a broad view"	
Beauty/aesthetic values	"A true, Icelandic environment—pretty, homey and Icelandic"	"Grass and gravel, just as it is—a perfect Iceland"	

Table 5. Examples of the arguments participants made for reasoning their selections on the least preferred appearances to each of the five questions of the survey.

Survey Questions	*Lupine Seeding*	*Control Plots*	*Fertilized Native Flora*
Diversity of vegetation	"One species dominating—mainly lupine; will shade out the native flora"	"Little of everything except stones—sparse vegetation cover; gravel"	
Feasibility for recreation	"Hard to walk within lupine patches—seen one lupine, seen all of them"	"Monotonous, not much to see—not much vegetation to observe"	
Harmony with Icelandic nature	"An introduced plant in the main role—does not show what nature can offer"	"A desert—little vegetation, all barren—too little green"	
Feasibility for summer cottage	"Too much of lupines has made this beautiful flower intolerable—too aggressive"	"Not a tempting landscape—deserted, very difficult to revegetate	
Beauty/aesthetic values	"The lupine is ugly—an alien appearance"	"Not a pretty sight—gravel surface not exiting nor pretty"	"The lupine is bad but the gravel is worse—desolated and frigid environment"

Ecological Succession within Different Restoration Treatments and Possible Future Trajectories

The SER International Primer on Ecological Restoration lists nine attributes as a basis for determining the trajectory of ecosystem development (SER 2004). Enhanced vegetation cover is one of the first signals of primary success within restoration areas (Prach & Pysek 2001). We found significant differences in total vegetation cover, cover of native species, and species composition, between treated areas and control plots. Vegetation cover was significantly higher within the grazed area than the protected area, probably due to greater fertilizer additions to the grazed area. The annual summer grazing within the grazed part did not appear to impede soil and vegetation development, as the grazed and the protected areas were not significantly different in the measured parameters except with regard to vegetation cover. Other research in Iceland has shown that the vegetation of eroded and/or sparsely vegetated land can recover in the presence of moderate grazing if growing conditions are favorable (Magnússon & Svavarsdottir 2007).

There appeared to be a slight trend of enhanced carbon content in the soil of treated areas when compared to untreated controls, but the difference was not significant. Conversely, the C:N ratio of areas seeded with grasses and fertilized was significantly higher than that of the control plots, indicating that the artificial fertilizer had created certain imbalance between available nitrogen and carbon in the soil of seeded areas, causing slower decomposition of organic matter (Brady & Weil 1999). Restoration of soil quality is, however, a long-term process (Zedler & Callaway 1999), and substantial changes in soil properties after only 5–7 years were not anticipated. Owing to their Andosol volcanic origin, most soils in eroded areas in Iceland have the capacity to store high quantities of carbon (Arnalds 2004), and potential carbon sequestration is seen as one of the benefits of restoration (Aradóttir et al. 2000). Even though our measurements showed no significant difference in carbon content between untreated controls and revegetated areas, there was a trend toward carbon accumulation in the treated areas, indicating carbon sequestration as found in many other restoration areas (Arnalds et al. 2000).

According to the SER Primer (SER 2004), restoration interventions can lead to ecological restoration as long as the restored ecosystem sustains itself structurally and functionally and is in balance with its surrounding landscape. Our results indicate that the ecosystem of the research area was in the early stages of primary succession, but the effects of fertilization and sown species were still quite high. This finding is consistent with earlier studies in Iceland, where fertilization maintains high cover of sown grasses (Arnalds et al. 1987) that decreases within a few years after the fertilization is discontinued and subsequently facilitates the colonization and spread of native species (Gunnlaugsdóttir 1985; Gretarsdottir et al. 2004).

Different restoration treatments seemed to trigger different succession trajectories of the vegetation at our study site; areas seeded with grasses and fertilized appeared to be on a trajectory from the control areas toward the reference ecosystems, whereas areas seeded with lupine had significantly different species composition from all other treatments and seemed to be developing in a different direction. The lupine is a tall non-native pioneer species that has been defined as invasive in Iceland (Magnusson 2006). Growing in dense patches, the lupine can spread quickly and, when growing under favorable environmental conditions, can severely limit the establishment of native species (Magnusson 2006). Therefore, the lupine seeding at our research area may not result in ecological restoration as defined by SER (2004) but instead lead to the formation of a novel ecosystem (Hobbs et al. 2006).

Public Opinion of the Visual Appearance of Different Restoration Methods

The survey participants were required to distinguish clearly between the five different photo-pairs of the questionnaire by simplified Q-ranking. Photographs have, for a long time, been used to evaluate public preferences regarding different landscape features (Dakin 2003), and the validity of such and other surrogate methods has been extensively studied (Hull & Stewart 1992; Daniel & Meitner 2001). Some studies have found the results of photo-assisted methods to be as reliable as those obtained from evaluations in the field. Other researchers (e.g. Hull & Stewart 1992) have discussed their limitations; for example, they only show a limited and framed view of the surroundings, captured at a specific moment in time. It should be noted, however, that the photographs in our study were not used to evaluate different landscapes on a large scale, but only the visual appearance of different vegetation composition within a relatively homogeneous background landscape.

The survey revealed a clear perception of the different restoration treatments by the participants. Both groups of respondents generally valued the appearance of the sparsely vegetated control areas less than the treated areas, with the exception of the lupine area. Some previous studies (e.g. Arriaza et al. 2004) have shown that people tend to value vegetated land higher than sparsely vegetated land, but this was not always the case in our study. Appearances perceived as the most natural were preferred, despite the high proportion of seeded grasses and fertilizer effects within them. This corresponds to results from previous studies (e.g. Junker & Buchecker 2008; Lindemann-Matthies et al. 2010) where people's aesthetic preferences were to a large extent found to be shaped by their perception of what they consider to be natural. Despite the substantial differences between the two groups in the sample, their ranking of the photographs was consistent. Other studies have shown that preference for natural landscape often varies with age and educational level (e.g. Van den Berg et al. 1998; Van den Berg & Koole 2006), but in this study the difference was not significant. Hunziker et al. (2008) also found no difference due to age or cultural background between different social groups.

As the majority of the survey participants were rural residents, the strong preferences for vegetated land above sparsely vegetated land are possibly influenced and shaped by utilitarian views, related to the respondents' general closeness to farming activities. The current research, however, does not provide any data to support this interpretation. This preference could also be a reflection of the wider discourse in Iceland about nature and landscape, itself the product of a certain sociocultural *milieu* (Árnason 2005) and suffused with moral concerns. From the mid-19th century, but especially during the 20th century, "Icelandic nature" has emerged as a central source of identity and nationalist sentiments. Although large parts of Iceland—including the large unvegetated areas—seem to fit better the aesthetic category of the sublime than that of pastoral beauty (cf. Brady 2010), this Icelandic discourse of nature has been colored as much by utilitarianism as romanticism. An important element was the threat posed in the past to people's livelihood by soil erosion. In the 20th century increased efforts were put into restoring eroded land and increasing public awareness about the importance of restoration (Arnalds 2005). In this context, vegetated land was understandably valued much higher than barren or sparsely vegetated land. For a long time, revegetation was seen as an unquestioned goal in itself, using whatever species that had proven their ability to grow in Iceland. In search for new methods that could yield quick results, lupine—as well as several nonnative grass species—was introduced for land restoration. Of all the species that were tried, the lupine was the only one that was not as easily managed as expected (von Schmalensee 2010). The plant was initially viewed positively by the public and most specialists, and was introduced widely in barren areas. Its seeding grew over time and in the 1990s the lupine had become a striking feature in the landscape (Magnusson 2006). In parallel, doubts gradually mounted regarding its use, and intense debates have taken place amongst scientists and the general public over the past two decades about whether further spreading of the lupine in Icelandic landscapes can be justified (von Schmalensee 2010). In 2010, the plant was declared an "invasive and alien species" by the Icelandic Ministry for the Environment and efforts are underway to curtail further dispersion.

Hilderbrand et al. (2005) have pointed out that raised awareness amongst the public regarding how invasive species can slow down or inhibit the development of native vegetation can lead to a reversal in the acceptance of their use by society. This reasoning could be a factor in Iceland. Parallel to the shift in views of environmental scientists and managers, the public has begun to question the use of nonindigenous species that alter existing landscapes and ecosystems. It may be concluded that our results show evidence of gradually shifting cultural preferences, that are partially rooted in changing scientific discourses and guided by complex emotional reactions (cf. Brown & Sax 2004; Stromberg et al. 2009).

Adding Public Perception to the Ecological Evaluation of Restoration Progress

Restoration of ecological integrity and function is, by definition, the essential basis for all restoration projects and often results in a radical change in the appearance of the area (SER 2004). Our results showed that most of the restoration interventions used at the study site enhanced ecological structure and function and they also showed a reasonably good correspondence between trajectory of ecosystem development and the visual perception of the restoration treatments in short term. But ecological restoration is a dynamic process that develops over a period of decades (SER 2004). Earlier Icelandic research has shown that fertilization early in restoration process can trigger abundant vegetation growth that decreases once the spreading of fertilizer is discontinued and subsequently the cover of vascular plants decreases (Arnalds et al. 1987). This process is usually associated with substantial changes in visual appearance.

A combined evaluation, as used in this study, can be quite sensitive to timing. The sociocultural considerations must, however, be taken into account to ensure the public support and awareness needed for long-term progress and such considerations should be included from the beginning of a project's design (Hobbs 2007). The outcome of ecological restoration depends on how well the project is designed and managed. A simple survey of aesthetic preferences and perceptions such as used in this study would be of more value at the planning stage to select methods that can meet both social and ecological priorities and to identify conflicts that could decrease social support for restoration instead of in the later stage when implementations have already taken place.

Implications for Practice

- Every restoration project is a part of a unique social–ecological system.
- Analyzing and understanding the interaction within the social–ecological system enhances the likeliness of a long-term sustainable outcome.
- If a choice of several restoration methods is possible, those that are not accepted by the community should be avoided.

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