Effects of sandplain revegetation on avian abundance and diversity at Skogasandur and Myrdalssandur, South-Iceland

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SUMMARY

In a European context, Iceland has some of the highest levels of desertification (due primarily to historic overgazing, frequent volcanic eruptions and subsequent erosion) and also vast naturally occurring barren areas (mainly formed and maintained by flooding of glacial rivers). Since 1988 efforts have been made, by the Icelandic Soil Conservation Service, to reduce sandstorms by revegetation on some sandplains in the region of South-Iceland. Action includes sowing strips of Nootka lupin *Lupinus nootkathensis*, and lyme grass *Leymus arenarius* and other grasses, with repeated fertilization. Very few bird species occur on Icelandic barren sands and if present, occur only at low densities. The effects of revegetation on avian abundance and diversity were evaluated by comparison to adjacent barren areas. Revegetation has a clear and a positive effect on some species which benefit from vegetated land. Meadow pipit *Anthus pratensis* and common snipe *Gallinago gallinago* occurred in high densities, particularly in mature strips of lupins, and other species of birds were colonising. These bird species are absent from barren sandplains.

BACKGROUND

Large parts of lowland Iceland are barren due soil erosion attributable to anthropogenic influences (such as historic overgrazing and *Betula*/*Salix* woodland clearance) or natural phenomena, primarily, volcanic eruptions and flooding of glacial rivers. Floods are either seasonal, usually in summer due to snowmelt, or occur irregularly due to geothermal heat or volcanic eruptions under icesheets and glaciers (Larsen 2000). Natural vegetation succession takes place to a varying extent according to local conditions and time between eruptions and subsequent flood events. Glacial rivers carry large quantities of sand and other inorganic matter. This has both an eroding effect and the substrate is often unstable, thus it is very hard for plants to colonise the sand unaided. Much of coastal areas of South-Iceland (Suðurland), are barren sands for these reasons. Organised efforts to control land degradation in Iceland started in 1907 (Sveinsson & Cambell 1958). This has involved local revegetation of some sandplain areas in the South-Iceland region. After 1990 increased efforts have been made to control sandstorms, which affect road systems and some human settlements in this area. Nootka lupin *Lupinus nootkathensis* (native to North America) and lyme grass *Leymus arenarius* have been used successfully for vegetation restoration in Iceland. The lupin, being a N-fixing legume, in particular has shown good potential for colonising land poor in nutrients, and with frost heave (Arnalds & Runolfsson 2004).

The purpose of this study was to assess the effects of revegetation actions on avian abundance and diversity on South-Iceland barren sandplains and to investigate bird colonisation of these newly formed patches of vegetation. This was done by comparing densities in treatment strips of vegetation to densities on the surrounding barren sandplains, incorporating additional relevant previously published data.

ACTION

Study sites: Studies were carried out in several revegetated strips of vegetation and on adjacent barren areas on the sandplains of Skogasandur (midpoint approx. 63°30' N, 19°25' W, area approx. 3,500 ha) and Myrdalssandur (midpoint approx. 63°27' N, 18°43' W, area approx. 38,000 ha) in South-Iceland (Fig. 1). Both areas are under influence of nearby volcanoes and glacial runoff, which effectively maintain large barren areas with little potential for natural revegetation over short time-scales. The conditions at Skogasandur were considered to be fairly favourable for restoration of vegetation, with less sand drift and water erosion (hence a more stable surface) and being much smaller than the Myrdalssandur. In contrast, on Myrdalsandur conditions for restoration of vegetation were very hostile for plants at the start of reclamation efforts; intense sand drift and sand storms were frequent on this 38,000 ha ‘desert’, closing the road for traffic at numerous times over a given year.

Revegetation efforts: The first revegetation trials were carried out on the Skogasandur plain in 1955 (Sveinsson & Cambell 1958) and on Myrdalssandur in 1979 (Runolfsson Sveinn pers. com.). More organised efforts on the revegetated strips at both sites began in 1988 when the first strips of sandplains were sown with lyme grass. In 1992 the first strips of lupin were sown, at both sites, and some sowing has been carried out most years since so plots of different age were available for study. Along with lyme grass a mixture of the non-native grass *Deschampsia beringensis* with other less common species has been used widely. All types were drill seeded with Aitchison Seedmatic drills, specially re-enforced for tough soils. The amount of seeds used for each treatment for lyme grass was 65 kg of silica coated seeds/ha, for lupin was 4 kg seeds/ha + *Rhizobium* bacteria, while for *Deschampsia beringensis* and other grasses was 50 kg seeds/ha. Lupin were not fertilized during seeding but all other were fertilized with 26% nitrogen + 14% phosphorus fertilizer at 200 kg/ha. Treatments, exept for lupin, were re-fertilized on several occasions after establishment with the same amount and type of fertilizer, bringing the total amount of fertiliser up to about 1 tn/ha. The study strips (plots) are several kilometres from other vegetated land.

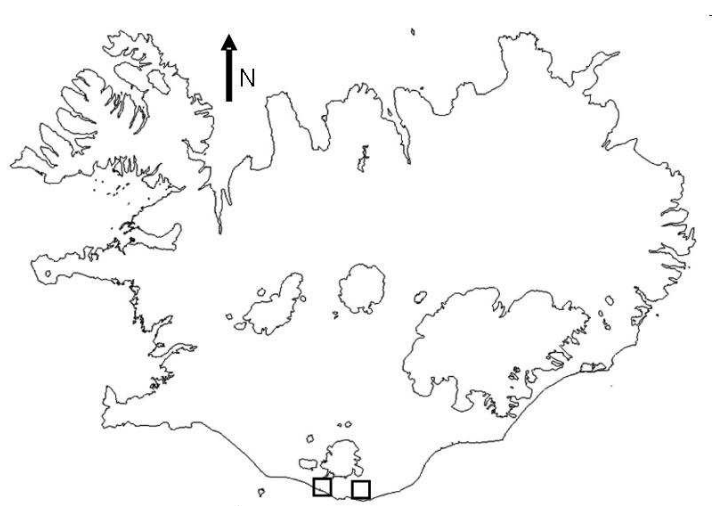

Figure 1. Map of Iceland showing the postition of study sites (in squares) of Skogasandur (to the west) and Myrdalssandur (east) on sand-plains in South-Iceland.

Bird surveys and analysis: Surveys took place on 10-11 June 2009 between 09:00-22:00. The weather was fine (relatively calm with clear visibility) throughout the survey period. Bird counts were made on transects in the five dominant habitat categories: barren sandplains, strips of lyme grass, strips of other grasses, strips of scattered lupins and dense strips of lupins (Fig. 2). Except for dense lupins, where 7 transects (= plots) were made, 5 transects were made in the other treatments. Between 1,800 and 3,370 m were walked in each habitat, mostly evenly distributed between transects. A two belt method was used with a 50 m inner belt (on each side of the observer), which was suitable for the width of the strips being surveyed, and an indefinite outer belt. A negative exponential model was used for correction of raw densities as most treatment strips had barren plains (with few or no birds) on each side so densities declined sharply with distance from the transect line (Bibby *et al*. 1992, Greenwood 1996). All birds within the inner belt and outside of it were recorded and their behaviour noted to aid the interpretation of counts. Birds overflying were excluded from analysis. Estimates of density are reported as individuals/km^2. Distances to each bird were estimated visually, perpendicular to the transect line (Bibby *et al*. 1992). To estimate the accuracy of distance estimates a test was carried out beforehand where an assistant placed out 16 flags (1 m tall bamboo canes with yellow tape on top) at known distances from a transect line (between 1 and 150 m), in a strip of dense lupins. The bird surveyor then walked the transect line and estimated the distance to the flags. The correlation between actual and estimated distances was r = 0.98 (P< 0.001) and the slope of the regression line was close to 1 (y = 0.9516x + 2.9551), indicating that estimated distances were fairly accurate. It should be borne in mind that, while flags are still, birds are often in flight, but this never the less suggests that visual estimation of distances is not likely to be systematically biased within the range of distances recorded in this study.

A general linear regression model (GLM) of corrected densities in the different habitats was constructed in SPSS (14). Posthoc tests (LSD procedure, SPSS 14.0) were run to reveal difference between habitats for individual species. Alpha levels were 0.05.

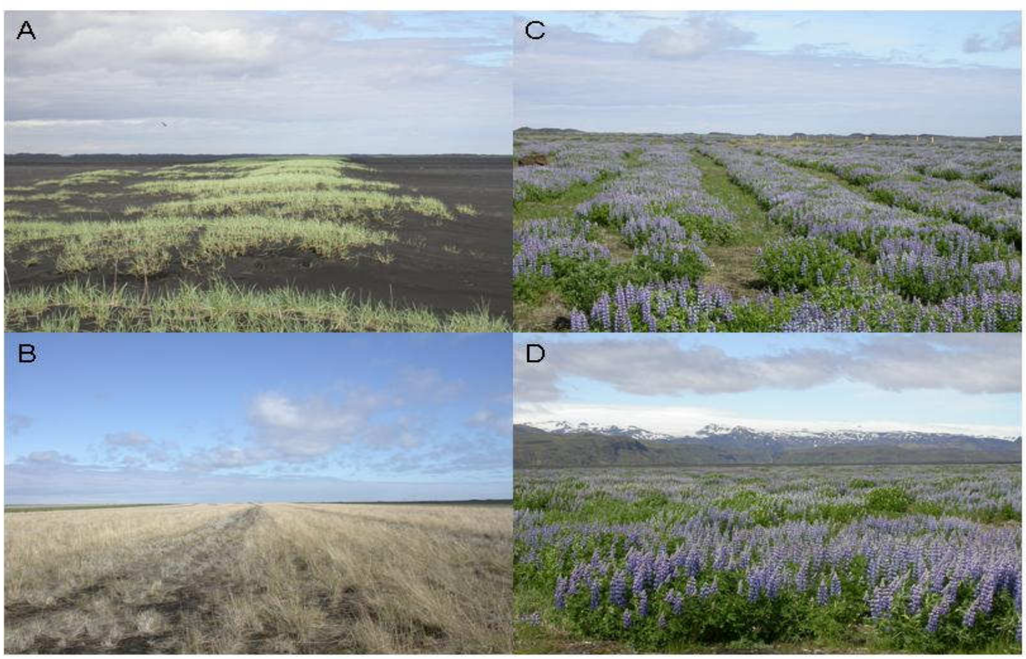

Figure 2. Example photographs of the four treatment types (barren sand not shown). A) strips of lyme grass *Leymus arenarius*, B) strips of grasses, mainly *Deschampsia beringensis*, C) strips of scattered Nootka lupin *Lupinus nootkathensis* and D) strips/clusters of dense Nootka lupin.

CONSEQUENCES

No birds were recorded on the inner belt on barren sandplains or in strips of lyme grass. In total, eight species of birds were recorded on the inner belt in all habitats and meadow pipit *Anthus pratensis*, common snipe *Gallinago gallinago* and redshank *Tringa totanus* were by far, the most abundant species (Fig. 3) and the only ones common enough to calculate densities to compare between habitats. Meadow pipit was recorded on the inner belt, on one of five grass plots, as were arctic tern *Sterna paradisea*, and great skua *Stercorarius skua*, but otherwise all birds were found in scattered and dense lupin strips. Highest densities of the three most common species were found in dense lupins; on average 210 meadow pipits/km^2, 46 snipe/km^2 and 19 redshank/km^2. Scattered lupins had 83 meadow pipits/km^2 and 13 snipe/km^2 (Fig. 4). The GLM was only significant for meadow pipit (Table 1). Post hoc tests showed that meadow pipit was significantly more common in dense lupins than in all other habitats except in scattered lupins where the difference was marginally non-significant. Snipe was more common in dense lupins than in other habitats but redshank did not show a significant difference in density between habitats (Table 1). Most meadow pipits (92%) and snipe (90%) recorded were males performing aerial displays. So, sex ratios being equal (an untested assumption), it is likely that the actual number of individuals, of these two species, on the study sites is underestimated by 40-50%. Redshanks did not show display behaviour but were both recorded in one's (75% of occasions) and two's (25% of occasions) making it more difficult to make inferences about actual numbers present. The numbers observed of the two most common species, meadow pipit and snipe, increased with the age of the lupin patches (Fig. 5).

Table 1. Results of general linear models comparing densities of the three most common bird species between the five habitat types (see results of post-hoc tests in text).

Species	F	R	P	DF
Meadow pipit	5.64	0.556	0.004	4
Common snipe	2.75	0.379	0.060	4
Redshank	0.88	0.164	0.493	4

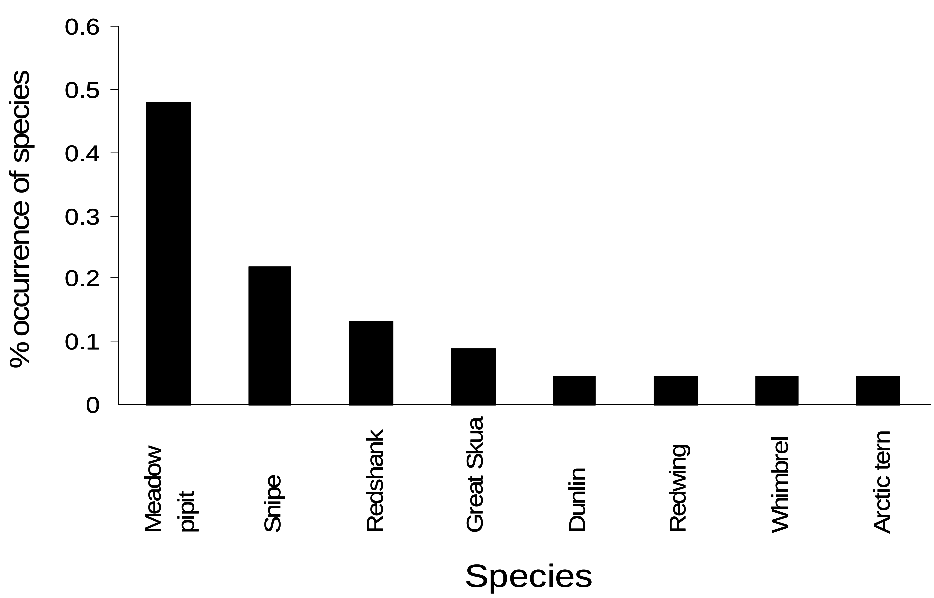

Figure 3. Proportional occurrence (in 27 study plots) of all species recorded on inner trasect belt in all habitats.

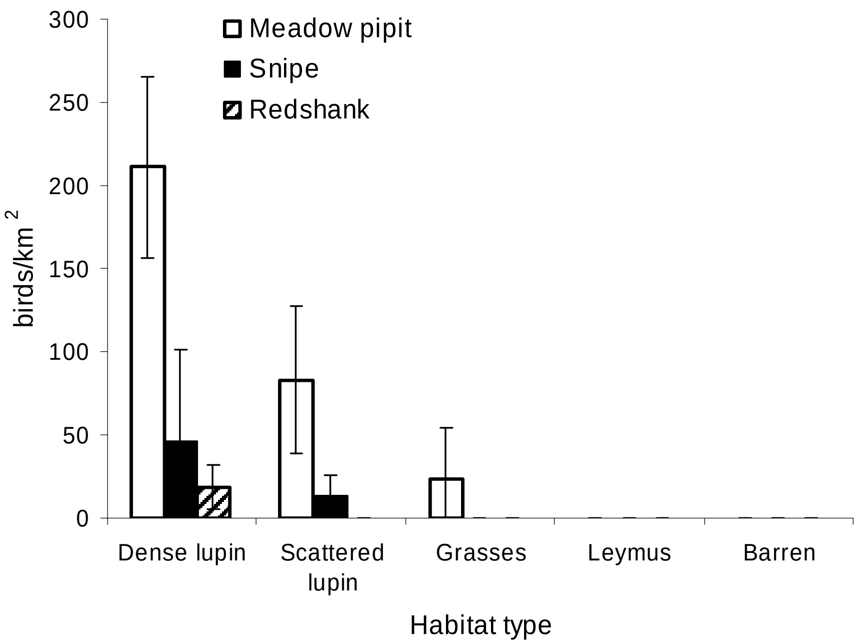

Figure 4. Corrected densities of individuals of the three most common bird species on transects in different habitat types (see text for details).

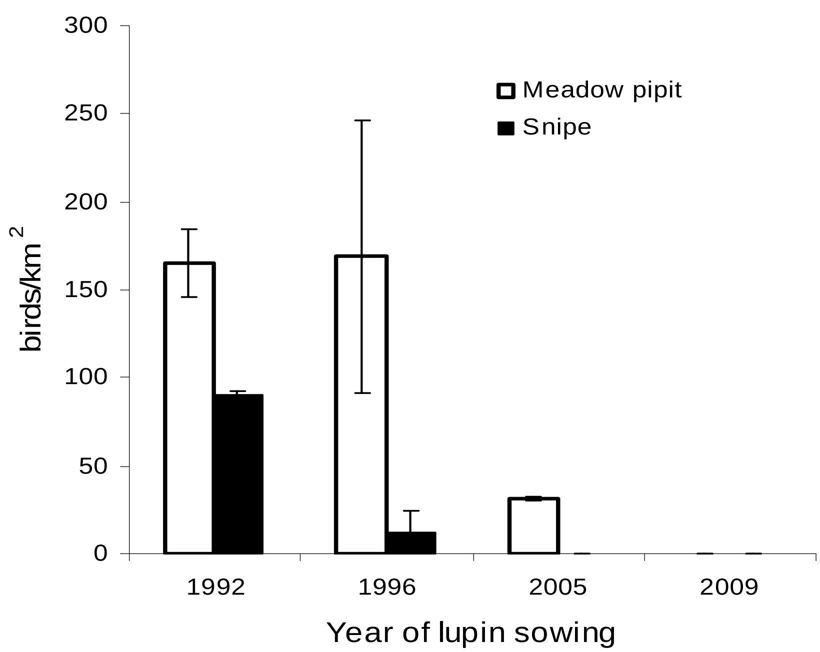

Figure 5. Densities of meadow pipit and common snipe in relation to the age of lupin patches.

Discussion: Studies of meadow pipits on hundreds of random sampling points in lowland Iceland have shown that the average density of individuals, in all habitats, is around 22 per/km^2 and that meadow pipits show a clear avoidance of unvegetated land (Gunnarsson *et al*. 2008). On vegetated land, average densities of meadow pipits tend to be around 180 individuals (or 80 pairs) per km^2 (Magnusson *et al*. 2006). This study showed that this species is, on average, super abundant (>200 individuals/km^2, most being displaying males) in mature patches of lupins (still less than 20 yrs old). Younger lupin patches had, on average, 4-fold the average lowland densities of meadow pipits, whereas strips of lyme grass and other grasses had much fewer. Snipe densities in dense lupins were similar or higher to those recorded on average on vegetated land in lowland areas, roughly 40 pairs/km^2 (Magnusson *et al*. 2006) but in scattered lupins colonisation of snipe had progressed much less. Redshanks had started to colonise the mature lupin patches but this species and others still occurred too rarely in other habitats to consider further. It is likely that much of the colonisation takes place through natal dispersal processes, at least for the waders which are mostly site faithful as adults.

On unvegetated land in lowland Iceland, very few meadow birds occur and in fact, most species of waders and passerines show a strong avoidance of such habitats (Gunnarsson *et al*. 2006). It is clear the the revegetation action taken on sandplains in South-Iceland has a clear and a positive effect on the abundance and diversity of some species, notably meadow pipit and snipe, quite early in the succession process. It is particularly the patches of lupins that seems to be attractive for these species. Meadow pipits are probably highly dependent on foliar arthropods for food, and were seen taking advantage of a strong flush of *Eupithecia satyrata*, a dayflying moth. Snipe on the other hand, feed mainly on soil-dwelling invertebrates, notably earthworms *Lumbricus* (Granval *et al*. 1999). During lupin colonisation of unvegetated land, it takes a few years for a soil layer to build up. Studies on earthworms in lupin patches in Iceland show a strong increase in earthworm biomass with assymtotic levels after around 15 years from sowing (Sigurdardottir 2004). This does correspond quite well with the rate of snipe colonisation in the lupin patches studied here.

Very few species of birds occur naturally on barren sands in South-Iceland. It is mainly arctic skua *Stercorarius parasiticus* and great skua, which utilize such habitats for breeding but obtain most of their food from the sea. Care should be taken to consider breeding colonies of these species when planning revegetation actions. The Nootka lupin has been used extensively and successfully by the Icelandic Soil Conservation Service for reducing soil erosion in Iceland and is also sown or planted widely by enthusiasts in an uncontrolled manner (Magnusson *et al*. 2003). In it's native North America the Nootka lupin is mostly found on disturbed sites, e.g. on gravel bars along rivers and coastlines and on dry slopes (Magnusson 2006). The species is classified as invasive in Iceland and potentially invasive over much of Scandinavia as it has the potential to colonise, mostly vegetated land in some areas, particularly if some of the ground is bare (Magnusson *et al*. 2003, Magnusson 2006). The Nootka lupin has the ability to quickly form tall continuous stands and overgrow native vegetation, rapidly decreasing the plant species diversity as a consequence (Magnusson 2006). In such cases it is likely that lupins can have an adverse effect on local avian abundance and diversity but further studies are needed to elucidate such processes.

In conclusion it is clear that the revegetation actions taken on the barren Skogasandur and Myrdalssandur sand plains has had the effect of increasing the avifauna both in diversity and abundance. It is particularly the more mature patches of lupin that have these effects. Very large areas of Iceland, particularly in the south, but also elsewhere, remain barren so there is much potential for positively affecting biodiversity with vegetation restoration at large spatial scales. Some of the barren sandplains of southern Iceland have been shown to develop native vegetation cover naturally over relatively short time scales (e.g. Svavarsdottir & Thorhallsdottir 2006). Both economical and ecolocial considerations of restoration should take such processes into account.

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