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Comparing biodiversity of birds in different habitats in South Iceland

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Clarification of contribution

I hereby declare that the statistical analysis and writing of this thesis is my work under the supervision and assistance of my advisors Tómas Grétar Gunnarsson and Ólafur Arnalds.

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Abstract

In a world of rapid anthropogenic land use changes and declining biodiversity, there is an urgent need for understanding the state of biodiversity to aid management and conservation. In order to successfully manage land use in ways that is least harmful for biodiversity it is vital to be able to identify habitats that are of most importance for biodiversity. The knowledge about biodiversity in Iceland is limited, especially in light of accelerating land use changes, which rate among the most rapid in Europe. In this study, bird surveys from 200 random sites in the lowlands of South Iceland, which is of great international importance for several bird populations, were linked to land classification of the Icelandic Farmland Database (Nytjaland) in order to assess the importance of different habitats for biodiversity of birds. Birds were surveyed in the five most common vegetated habitat classes, other than agricultural land: *wetland*, *semi-wetland*, *rich heathland*, *grassland* and *poor heathland.*

In total there were 5128 individuals of 22 avian species recorded and 95% of them were of eight species, seven waders and Meadow Pipit (*Anthus pratensis*). Of those eight species, five (Dunlin (*Calidris alpina*), Snipe (*Gallinago gallinago*), Whimbrel (*Numenius phaeopus*), Black-tailed Godwit (*Limosa limosa*) and Meadow Pipit) occurred in highest density in *wetland* but Oystercatcher (*Haematopus ostralegus*) and Redshank (*Tringa totanus*) occurred in highest densities in *grassland* and Golden Plover (*Pluvialis apricaria*) in *poor heathland*. Total density of the eight species in the five habitats ranged from 274 individuals per km^2 in *poor heathland* to 640 individuals per km^2 in *wetland*. Different measures of the avifauna in South Iceland suggest that wetter habitats are of greater importance for birds than the drier ones. The wetter habitats generally had higher densities and higher mean number of bird species. The Icelandic Farmland database proved to be well suited for the purpose of mapping biodiversity.

Ágrip

Í ljósi aukinnar landnýtingar og hnignunar líffræðilegrar fjölbreytni er afar brýnt að auka þekkingu á henni bæði til að nýta við skipulagsgerð og við verndaráætlanir. Nauðsynlegt er að greina á sem skjótastan hátt þau búsvæði sem mikilvægust eru fyrir líffræðilega fjölbreytni til að minnka neikvæð áhrif landnýtingar. Þekking á líffræðilegri fjölbreytni á Íslandi er brotakennd og ófullnægjandi, sérstaklega þegar horft er til hraða landbreytinga síðustu áratugi. Í þessari rannsókn voru vettvangsmælingar á fuglum á láglendi Suðurlands, sem er alþjóðlega mikilvægt fyrir ýmsar fuglategundir, bornar saman við landflokka í Nytjalandsgagnagrunni Landbúnaðarháskóla Íslands til að greina tengsl líffræðilegrar fjölbreytni fugla við mismunandi gróðurbúsvæði. Athuganir voru gerðar á fimm algengustu gróðurbúsvæðum Suðurlands, fyrir utan ræktað land. Þessi búsvæði voru *votlendi, hálfdeigja, ríkt mólendi, graslendi* og *rýrt mólendi.*

Í heildina voru skráðir 5128 fuglar af 22 tegundum, 95% þessara fugla voru af átta tegundum, sjö vaðfuglar og þúfutittlingur (*Anthus pratensis*). Af þessum átta tegundum voru fimm (lóuþræll (*Calidris alpina*), hrossagaukur (*Gallinago gallinago*), spói (*Numenius phaeopus*), jaðrakan (*Limosa limosa*) og þúfutittlingur) með hæstan þéttleika í *votlendi*. Tjaldur (*Haematopus ostralegus*) og stelkur (*Tringa totanus*) voru með hæstan þéttleika í *graslendi* en mest var af heiðlóu (*Pluvialis apricaria*) í *rýru mólendi*. Heildarþéttleiki þessara átta tegunda í fimm búsvæðum var frá 274 fuglum á km^2 í *rýru mólendi* til 640 fugla á km^2 í *votlendi*. Mælingar á fuglalífi á láglendi Suðurlands benda til þess að almennt séu blautari búsvæði mikilvægari en þurrari, það var hærri þéttleiki og hærri meðalfjöldi tegunda í búsvæði. Nytjaland sýndi skýr tengsl við fuglalíf og virðist henta vel sem grunnur undir kortlagningu líffræðilegrar fjölbreytni.

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1. Introduction

1.1. Biological diversity

Biological diversity (biodiversity) is the variability amongst living organisms and applies to diversity within species, between species and of ecosystems (UNEP, 2013). The importance of biodiversity and its conservation is undisputed as international conventions reflect (Ehrlich and Ehrlich, 1982, 1992). Conservation of biodiversity is important for economic reasons such as in relation to ecosystem services, tourism, provision of raw materials, clean air and water, medication and food security (Pearce and Moran, 1996), but also for ethical and aesthetic reasons (Ehrlich and Ehrlich, 1982, 1992). Ecosystem services are essential for life to thrive on the planet and declining biodiversity will negatively impact human wellbeing by reducing these services (Watson and Zakri, 2005). In the late 1980s the awareness of the importance of biodiversity and the need for its conservation increased thus leading the United Nations Environment Programme (UNEP) to take action resulting in the Convention on Biological Diversity which became effective in the year 1993. The objectives of the convention are conservation of biodiversity, sustainable use of its components and fair sharing of the benefits of genetic resources (UNEP, 2013). Other international conventions also form the viewpoint towards biodiversity and nature conservation such the Ramsar Convention on Wetlands and The Bern Convention on the conservation of European wildlife and natural habitats (The Ramsar Convention on Wetlands, 2013, Council of Europe, 2013). Despite these conventions and special projects aimed at increasing awareness of the importance of biodiversity, e.g. United Nations International year of biodiversity in 2010 and the decade of biodiversity (2011-2020) (UNEP, 2013), biodiversity continues to decrease (Butchart et al., 2010, IUCN, 2013).

1.2. Land use and biodiversity

Land use activities have transformed a large proportion of the Earth´s land surface. Every kind of land use and transformation has an effect on biodiversity; may it be urbanization, de- and afforestation, industry or agriculture (Vitousek et al., 1997, Sala et al., 2000).

Human actions are changing the world´s landscapes in extensive ways to fulfil the ever growing human need for resources; often at the expense of degrading environmental conditions. Agriculture, which involves such impacts or actions as drainage, intense harvesting, monocultures, and chemical fertilizer use, is one of the greatest drivers of biodiversity loss (Amano, 2009). Severe intensification of agriculture in the second half of the 20th century caused a widespread decline in farmland biodiversity across different taxa, such as birds (Donald et al., 2001, Fuller et al., 1995), mammals (Flowerdew, 1997), arthropods and flowers (Sotherton and Self, 2000). Habitat heterogeneity is an important factor in maintaining biodiversity. It has been shown that diverse landscapes usually hold more biodiversity and more efficient ecosystem services than those more homogeneous (Winqvist et al., 2011, Benton et al., 2003). Because of increased global demand for food in recent decades, alongside increasing human population, agricultural development has transformed vast areas into homogeneous agricultural land to enhance productivity. This process has disproportionally affected certain habitats. Since the beginning of 20th century nearly half of the world's wetlands have been lost due to human actions, mostly to agriculture (OECD and IUCN, 1996). Wetlands host a multitude of species and are of great importance for biodiversity (Zedler and Kercher, 2005).

1.3. Ways to monitor biodiversity

Monitoring of biodiversity is in general thought to be important to be able to intervene in case of negative changes. Monitoring different aspects of biodiversity, such as species richness and composition, physical structure of ecosystems and processes, is difficult so a variety of shortcuts have been used where the focus is on one or a few species (Heywood, 1997). One of those shortcuts is using indicator species. Indicator species are supposed to reflect other species in the community and changes that might occur within the habitat. The characteristics of the indicator species such as density, distribution and presence or absence are used as indices of elements which are problematic or costly to measure for other species (Landres et al., 1988). Indicators are measurable substitutes for variables in the environment such as biodiversity. Preferably an indicator should be representative of the chosen taxa and be able to reflect ecosystems health. It needs to be sufficiently sensitive to detect early changes; easy and cost-efficient in practice and process and all its measures easily repeated. Indicator has to be capable of differentiating between natural cycles and influences from anthropogenic stress; have a broad geographical distribution; ecologically relevant and easily understood and interpreted by non-experts (Noss, 1990, Gregory, 2006, Munn, 1988). Birds have been used as indicators on biodiversity. They are common, diverse, widespread and mobile and can be found in all habitats. Birds are high in the food chain and are dependent on other groups of animals and plants, so a decline at the lower ecosystem levels will affect their distribution and abundance. Their ecology and taxonomy is relatively well known so the driving forces behind changes should be identifiable. They are sensitive towards, and therefore reflect, habitat changes and their visibility make them easy to observe and quality data is often available (Larsen et al., 2012, Doxa et al., 2010). Last, but not least, birds have a broad popular appeal so great volume of data gathered by volunteers is often available on which to build and test hypotheses about changes. However, the use of birds as indicators has been criticised for several reasons. Some studies suggest that other species are more suitable as indicators (Lund and Rahbek, 2002) and it has been pointed out that birds do not necessarily reflect the status of other organisms in the focal habitat and some are migratory species, making it difficult to identify drivers of change (Gregory, 2006). But, despite these flaws, it has been argued that birds are indeed the best indicators available (Butchart et al., 2010) even though it is unreasonable to expect any single indicator to provide the complete picture (Moore et al., 2003). By supplementing birds with other taxa, such as invertebrates, the effectiveness of birds as indicators can be improved further (Larsen et al., 2012).

1.4. The importance of remote sensing

In light of the rapid rate and intensity of human driven land changes it is necessary to use methods to evaluate biodiversity quickly and efficiently. Rapid improvement of remote sensing techniques has made them an important tool in ecological research and environmental monitoring (Turner et al., 2003). Remote sensing can be used to identify and analyse complex large-scale variables such as patterns in the mosaic of the landscape which can be hard and time-consuming to do in the field (Gould, 2000). Biodiversity is, among other things, influenced by habitat heterogeneity (Benton et al., 2003) which includes factors such as vegetation cover, fragmentation and land use (Fahrig, 2003, Foley et al., 2005) that remote sensing methods are able to detect and measure (Cohen and Goward, 2004). As the resolution and quality of aerial photographs, and satellite and radar images has increased they have become more suitable for more detailed studies of biodiversity, such as distribution and habitat use of certain species (Turner et al., 2003).

1.5. Biodiversity in Iceland

Geographic nature and position of Iceland, an island in northern limit of the temperate zone and in the middle of the North-Atlantic Ocean, has decisive impact on its biodiversity. The isolation of the country results in low species diversity which can make ecosystems fragile to invasive species and the volcanic activity can alter species communities and even climate (Sadler, 2001, Connor et al., 2012). One of the main factors in altering biodiversity on oceanic islands is human impact (Sadler, 2001). After settlement in Iceland late in the 9th century vegetation cover reduced, likely factors were unsustainable grazing and use of forests, and these factors eventually lead to large scale soil erosion (Arnalds, 1987). Throughout the centuries, human domination of land and natural conditions shaped the landscape to some extent but with mechanization in the 19th and 20th century the effect of land use grew tremendously in the lowlands. Alongside urbanization in the beginning of the 20th century, agriculture grew beyond subsistence (Júlíusson and Ísberg, 2005). The agricultural intensification in Iceland has not reached the one of Europe or North-America and the proportional extent of agricultural land in Iceland is still relatively low (Johannesson, 2010, Thorhallsdottir, 2001). Even so it has been estimated that during the 20th century, around 55-75% of Icelandic wetlands were drained to some extent (Óskarsson, 1998) and nearly 97% of the wetlands in South Iceland (Thorhallsdottir et al., 1998) for agricultural purposes. Moderate agriculture can have a positive effect on biodiversity by increasing heterogeneity of landscapes but with increasing intensification, these effects become negative (Amano, 2009, Doxa et al., 2010, Van Eerden et al., 2010). The difference of the biodiversity status between highly-cultivated land and non-cultivated land in Iceland is less than in other countries in Europe (Thorhallsdottir, 2001). But intensification in agriculture in Iceland is bound to increase along with population growth and increased demand for resources, such as food and energy.

Iceland signed the Convention on Biological Diversity (CBD) in 1994, undergoing extensive obligations related to the conservation and sustainable use of nature's resources. The Icelandic policy statement regarding the execution of the convention emphasises the need for increased knowledge of Icelandic nature by research, documentation and mapping of species distribution and communities, documenting their protective status and building of accessible databases. The policy statement emphasises monitoring of all elements of nature and the resulting evaluation of the need for conservation (Ministry for Foreign

Affairs, 2008). In an audit report, done by The Icelandic National Audit Office (2006), it was stated that the CBD had not been incorporated sufficiently into Icelandic legislation or environmental policy. And that much needed research on biodiversity for fulfilment of the agreement had not been carried out. Iceland also participates in the Ramsar Convention on Wetlands and The Bern Convention on the conservation of European wildlife and natural habitats (Ministry for Foreign Affairs, Ministry for Foreign Affairs, 2013b). It is important that land use development, such as agriculture, conforms to goals of sustainable development and international conventions and the key is to understand the connection between land use and biodiversity. Knowledge of this connection in Iceland is scarce though there have been some studies on terrestrial biodiversity in relation to land use. Large scale habitat association (correlates of occurrence) of birds in lowland has been evaluated (Gunnarsson et al., 2006); habitat preference of the Rock Ptarmigan (*Lagopus muta*) (Nielsen, 1995), Meadow Pipit (Gunnarsson et al., 2007) and Greylag Goose (*Anser anser*) (Gunnarsson et al., 2008); nest site selection of Whooper Swans (*Cygnus cygnus*) (Gunnarsson, 2003); and the connection between flora and fauna and the physical elements and habitats in the highlands (Magnússon et al., 2009).

Issues regarding multiple types of land use and biodiversity conservation in Iceland are mostly bound to lowland areas as most of the highlands are less fertile, colder, severely degraded and in most ways less suitable for human activities. Lowlands are presumably the most important areas for residence, cultivation and industry; therefore conflicts are bound to arise between land use and preservation of biodiversity. South Iceland holds the country's largest lowland areas and has a relatively dense human population, plus the capital area is nearby which holds about 61% of the population of Iceland (Statistics Iceland, 2013). This is reflected in land use demand in the area; in the last century nearly all of the wetlands in southern Iceland were drained (Thorhallsdottir et al., 1998) and during the years 2000-2006 conversion of natural landscapes into man-made surfaces in Iceland increased about 20%, and over 30% in South Iceland, while in most European countries the increase was less than 5% (Wald, 2012). Iceland supports internationally important populations of 21 breeding bird species (Einarsson et al., 2002), and for some is responsible for a large proportion of the world population (Wetlands International, 2006). Iceland also is an important staging area for birds migrating across the Atlantic Ocean on their way between wintering and breeding areas (Einarsson et al., 2002). Near half of

Iceland internationally important species are waders but wader populations have been declining worldwide in recent times (International Wader Study Group, 2003). It is therefore important to increase knowledge on the status of these bird species, and others dependent on Iceland, especially in light of rapid land changes in the last years and the need to take action. In Iceland, birds are the most prominent group of animals and are high in the food chain and their distribution and abundance can indicate productivity of land and abundance of invertebrates at different spatial scales, from micro to macro (Gunnarsson, 2010). The density of waders has been proved to be greatest in the southern lowlands (Gunnarsson et al., 2006), which reflects the importance of the area for biodiversity in Iceland.

1.6. Aims of study

In this study, fieldwork and remote sensing was interweaved to assess density, distribution and community structure of common birds in the mosaic of lowland habitats in South Iceland. The geographic platform of the study was the Icelandic Farmland Database (IFD from now on). This database is well suited for this study, it was based on supervised classification of satellite images (Arnalds and Barkarson, 2003, Arnalds et al., 2003, The Farmland Database, 2013) and it classifies the surface of Iceland into habitats based on land productivity, such as vegetation cover, and it also incorporates land use, such as grazing which is likely to determine the dispersion of biodiversity (Noss, 1990). Even though there are indications of the connection between bird life and land use, there is a need for more detailed measurements to determine whether bird distribution and abundance are correlated with land use and fertility on those scales that are necessary for land use management and ecosystem restoration. Given that birds are good indicators of biodiversity their density and distribution will give an idea whether areas are rich or poor in biodiversity. Estimation of bird´s density in different IFD habitats and different habitat preferences of different bird species and their community structure were carried out in order to assess the value of the habitats for biodiversity of birds. Using IFD gives an opportunity to scale up measurements from this study to other parts of Iceland and also to compare it with other indicators of biodiversity, such as plants and invertebrates. This information is a useful tool for land management, making it possible to organize land use and restoration for maximising the benefits and reducing losses of biodiversity. It will also shed light on the effect of land use on biodiversity, in one of the most extensively cultivated region in Iceland, and how land use changes there can affect biodiversity in Iceland and on an international level. In order to look at the relative importance of South Iceland for bird’s biodiversity on a regional and an international scale the population sizes of the area were also estimated.

2. Methods

2.1. Study area

Bird counts were carried out in the southern lowlands of Iceland which is the largest lowland basin in the country with diverse and conflicting interests in land use. The boundaries of the study area were defined as within the two administrative regions (counties), Árnessýsla and Rangárvallasýsla, and below 200 meters above sea level. The southern lowland landscapes are generally flat, only 2.5% of the area below 400 m a.s.l. has a gradient of more than 20° (Wald, 2012). The climate in Iceland is cold-temperate oceanic with fairly cool summers and mild winters. The southern lowlands have relatively milder climate than other parts of Iceland, with higher temperature and more precipitation. The area is one of the most important agricultural regions in Iceland providing 36% of annual agricultural GDP in the year 2010 (FAI, 2010) and around 10% of land below 400 m a.s.l. are hayfields (Wald, 2012).

2.1.1. Selection of survey sites

Survey sites were selected digitally in a stratified random way from the IFD using the geographical information system (GIS) program *ArgGis 10.1*. The database classifies the surface of Iceland into twelve different classes based on satellite images and field research (Arnalds and Barkarson, 2003). The classification represents variables that reflect productivity of the land, e.g., vegetation cover and soil moisture but is also under influences of land use such as grazing. Those variables are likely to be strongly related to biodiversity (Noss, 1990). The IFD classifies land down to the scale of 196 m^2 (pixel size 14x14m). The IFD is the only available large-scale habitat classification system in Iceland, detailed enough for allowing the scaling-up of measurements and which is based on criteria which are known to be important for biodiversity. Sites were selected from the five most common vegetated habitat classes other than agricultural land on which land-use intensification is likely to affect mostly. These were: wetland (301 km^2), semi-wetland (426 km^2), rich heathland (420 km^2), grassland (384 km^2) and poor heathland (862 km^2) (Table 1) (from now on noted in italic format). These habitat types were together 2,393 km^2 or 58% of the total area of South Iceland under 200 m. Sites were selected so that they covered at least 20 ha of a given habitat type, both to reduce effects of adjacent habitats and to be large enough for bird counts. For practical reasons, sites were selected so they were no more than 2 km from roads but not closer than 0.5 km and they had to be at least 0.5 km apart for independence. In total there were 200 sites, 40 for habitat (Figure 1).

Table 1. Description of the five habitats from the Icelandic Farmland database where counts of birds were conducted in this study (Arnalds et al., 2003).

Habitat type	Characteristics
Wetland	Dominated by sedges (*Carex* spp.) (indicating a high water level), horsetail (*Equisetum* spp.), cotton-grass (*Eriophorum* spp.) and heathland vegetation. Highly vegetated habitat and with a dense sward. The *wetland*s are usually fully vegetated unless they have been overgrazed by horses.
Semi-wetland	Dominated by plants found both in wet and dry land such as sedges, horsetail, wood-rush (*Luzula* spp.), grasses, willow species (*Salix* spp.) and sometimes birch (*Betula pubescence*). *Semi-wetlands* are wetland areas with partial drainage, often at the margin of the *wetlands. Semi-wetlands* have aquic soils but partial drainage leads to a mixture of pure wetland plants and species more common within the dryland vegetation classes.
Rich heathland	Dominated by small shrubs such as common heather (*Calluna vulgaris*) and black crowberry (*Empetrum nigrum*); sparse grasses and moss. Often rather dry and hummocky land. Most of the heath species are not sought after for grazing by sheep, but *rich heathland* also has a significant component of herbaceous plants that are good for grazing, both grasses and forbs. This separates the *rich heathland* from the *poor heathland*.
Grassland	Dominated by grasses and sometimes flowers (indicating a groundwater level too low for sedges). *Grasslands* are often common on alluvial substrate near streams. *Grasslands* occur were growing conditions are favorable, with ample soil moisture. *Grasslands* include some former wetland areas that have been drained.
Poor heathland	Dominated by mosses, small shrubs and sometimes lichen. Dry land and often partly vegetated. *Poor heathland* has largely been shaped by grazing.

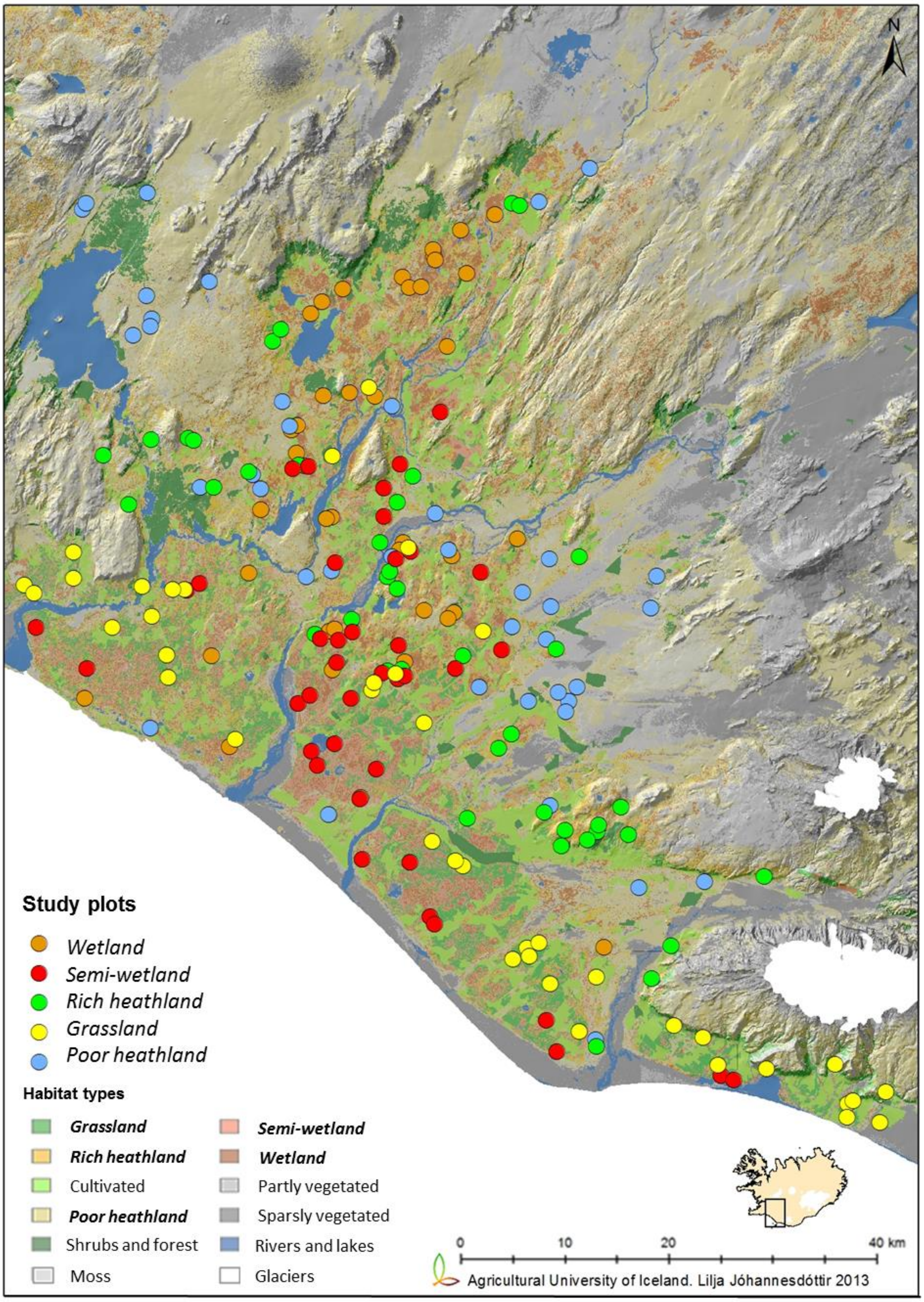

Figure 1. Map of South Iceland, including the study area, showing the position of study plots where birds were counted. Sampling was restricted to areas below 200 m a.s.l.

2.2. Censuses

The survey was conducted from the middle of May until the end of June in 2011 and 2012, which is the peak breeding season for most species. Counts were performed during maximum bird activity, in the mornings from 06:00 to 13:00 and in the afternoon from 17:00 to 22:00 (Davíðsdóttir, 2010). Surveys were only conducted when wind speed was lower than 6 m/s and in dry weather to avoid conditions of low bird detectability (Bibby et al., 2000). At each site, birds were counted on a line-transect (e.g. Bibby et al., 2000) Transects were on average 511 m long (SD 69.4 m). Total length of transects covered was 101 km. The perpendicular distances of birds from the transect line was recorded in five distance bands, 0-25, 25-50, 50-75, 75-100. The observer used Nikon Monarch 8x42 or Swarovski EL Range 8x42 binoculars with a built-in laser range-finder to determine distances to birds.

2.2.1. Within-site habitat variation

Habitat variables were recorded at each site to further assess the variability within habitat types and its relationship with bird density and to see if the IFD classes were readily associated with visual characteristics of the habitat patches. The variables recorded have been shown to relate strongly to bird distribution in lowland Iceland and allow quick estimation in the field (Gunnarsson et al., 2006). The variables explain features of surface topography, vegetation characters and wetness (Table 2).

Table 2. Definition of six habitat variables recorded visually at each study plot.

Variable	Measure	Definition
Hummocks	% cover	5 classes; 0-20, 20-40, 40-60,60-80, 80-100
Bushes	% cover	5 classes; 0-20, 20-40, 40-60,60-80, 80-100
Sward height	cm	visual estimate of sward height in categories: 0-5, 5-10, 10-20, 20-40 and > 40 cm
Grazing	5 classes	none, little, average, intensive, very intensive
Running water	presence/absence	streams and/or ditches present/absent
Water pools	presence/absence	pools with standing water present/absent

2.2.2. Invertebrate surveys

In 2012 a rapid invertebrate surveys were carried out on 58 survey points (average 11.6 survey points per habitat, SD 2.4) to relate bird abundance to variation in food abundance between habitats. A hand net (diameter 39 cm, mesh size 0.3 mm) was used to sample invertebrates with 10 equal strokes through vegetation at three random points on the line transect (at 25, 250 and 450 m). Invertebrates were sorted into groups and counted from the hand net in the field and then released. The groups used were spiders (*Araneae*), beetles (*Coleoptera*), true bugs (*Hemiptera*), butterflies (*Lepidoptera*), flies (*Diptera, Hymenoptera and Trichoptera*), and larvae.

2.3. Data analysis

2.3.1. Bird abundance

Bird densities were calculated using the length of transects and number of observations for each species and their observation distances (Bibby et al., 2000). Birds detected outside the 100 m belt were not included in data analysis. Birds passing by were not recorded, only those who were using the habitat, sitting or displaying over it. The density unit calculated was individuals/km^2, a conservative measure which avoids unknown biases associated with estimation of status (e.g. breeding or foraging). The program *Distance 6.0* was used to estimate bird density on the line transects. The program models the decline in detectability of birds with increasing distance from the transect line and uses this information and transect length to calculate density. Density estimates were only calculated for the eight most common species Oystercatcher, Golden Plover, Dunlin, Snipe, Whimbrel, Black-tailed Godwit, Redshank and Meadow Pipit. This is because a certain minimum number of observations are required to get a sensible outcome from the analysis (Buckland, 2001). These eight species were 95% of the total number of birds sighted on transects. For density analysis of the eight most common species three key functions were calculated; uniform, half-normal and hazard-rate, with either cosine, simple or hermite polynomials adjustment terms. The key function with the lowest Akaike´s Information Criterion (AIC) score was used. When producing density estimates for most accurate comparison of habitats (single estimate) the same detection curve for each bird species (based on its abundance on different distance bands) was used for all habitats. When producing density estimates for individual sites every species was assigned a specific detection curve per habitat, so all the eight species had five different detection curves. Those two methods gave very similar results (correlation coefficents (Pearson r) range: 0.93-0.99, slope of regression range: 0.87-1.06).

Principal components analysis (PCA) was used to group the habitat variables recorded on each transect. The principal component loadings were compared between habitats with an ANOVA to estimate if visible habitat characteristics could separate the IDF classes. The differences in bird densities between habitat types were modelled with generalized linear models with a negative binomial error distribution and a log link function to account for over dispersion (Zuur, 2009).

To test the fit of species-density models, a hold-out cross-validation procedure was used. As single-visit density estimates of breeding birds are subject to a considerable sampling error (e.g. due to season and weather effects) accurate prediction of species density on single sites is not feasible so model predicted means were assessed. The data from both years was randomly split into two parts in a habitat stratified manner. Separate generalized linear models (negative binomial, comparable to the overall models fitted to all the data) were then run on both datasets and habitat specific model predicted means were compared. For each species, Pearson correlation between outputs of both models for each species was calculated. So the procedure was effectively comparing whether two independent datasets, half the size of the complete one, would predict similar average densities in different habitats which would indicate a robust relationship between habitat type and mean species density. The slopes of the relationships are not relevant to the fit as they are sensitive to the random selection of data which constitutes each dataset.

To estimate the relative importance of South Iceland for birds, regional population sizes of common species were estimated, only including the surveyed habitat types. These population sizes are a minimum estimate as several habitat types were excluded but estimate numbers in the most common vegetated habitat types. Population estimates were derived by multiplying the density estimates and 95% confidence intervals obtained using program Distance with the total area of each habitat type in South Iceland.

2.3.2. Bird diversity

Bird diversity was both calculated with a set of standard diversity indices and by grouping the most common species and relating to habitat type. Using all species, a Shannon-Wiener diversity index was calculated (Shannon, 1948) as were total and average species number. The eight most common species were then grouped with a PCA and the principal components compared between habitat types to assess their differences in species composition.

Statistical analysis, other than estimates of species density, were performed in programs SPSS (IBM Corp, 2012) and program R (R Development Core Team, 2008).

3. Results

3.1. Overall difference in bird abundance between habitat types

A total of 5,128 birds of 22 species were recorded on the 200 sites surveyed (Appendix 1). Most of the species were rare and 8 species dominated in numbers, 7 waders and Meadow Pipit made up 95% of the total number of individuals recorded (Table 3). The average density of the eight most common species was highest and similar in *wetland* and *semi-wetland* with around 630 individual birds per km^2 (Figure 2). *Rich heathland* and *grassland* were similar with bird density around 470 individuals per km^2 but *poor heathland* had the lowest density at ca. 250 individuals per km^2.

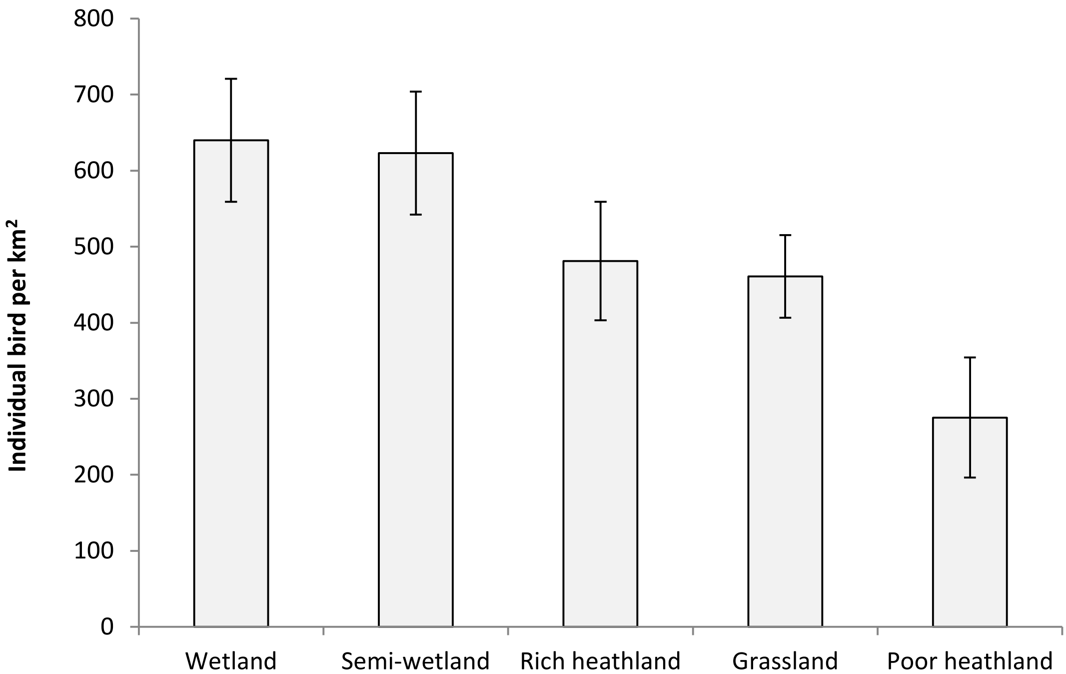

Figure 2. Sum of estimated density of the eight most common bird species in different habitats from the Icelandic Farmland Database (± SE).

Table 3. Number of individuals of the eight most common species per distance interval on line transects.

Species	0-25m	25-50 m	50-75 m	75-100 m	Total
Oystercatcher	37	19	27	15	98
Golden Plover	165	111	94	48	418
Dunlin	189	127	83	42	441
Snipe	215	174	98	37	524
Whimbrel	228	138	127	104	597
Black-tailed Godwit	75	43	47	71	236
Redshank	41	31	29	11	112
Meadow Pipit	1410	753	220	53	2436
Total	2360	1396	725	381	4862

3.2 Species specific difference in density between habitat types

The abundance of most species was similar to the combined pattern with some exceptions. Abundance was generally highest in *wetland* and *semi-wetland* for most species and Dunlin, Snipe, Whimbrel, Black-tailed Godwit and Meadow Pipit occurred in their highest densities in those habitats (Figure 3) but Whimbrel also occurred at similarly high densities in both *heathland* types. Oystercatcher and Redshank occurred in highest densities in *grassland* and the latter also in *wetland* and *semi-wetland*. Golden Plover occurred in highest densities in *poor* and *rich heathland*. All models predicting the abundance of individual species in different habitat types were highly significant as all species showed a significant difference in density between one or more habitats (Table 4 and 5).

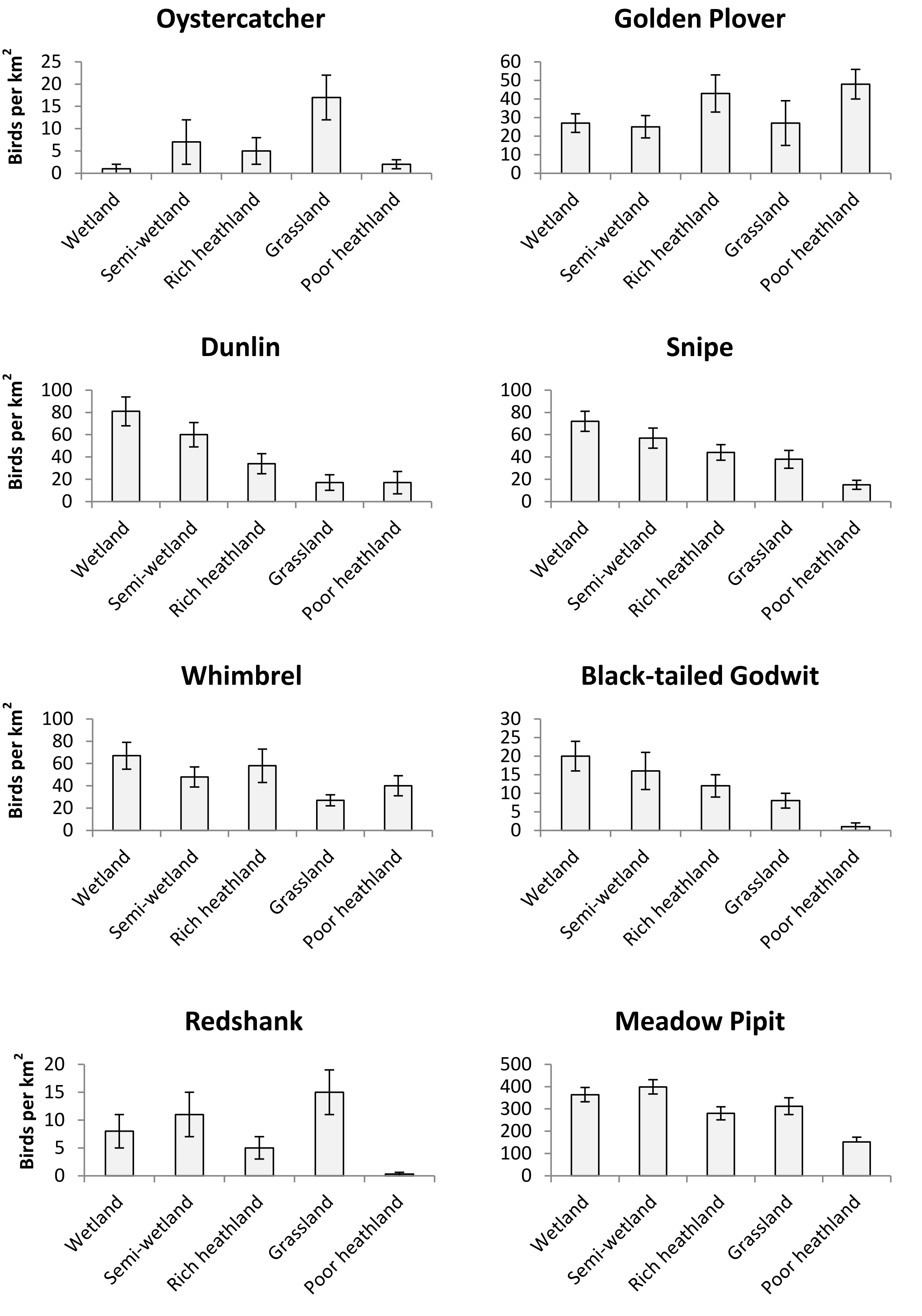

Figure 3. Estimated density of the eight most common bird species in different habitats from the Icelandic Farmland Database (± SE).

Table 4. Results of generalized linear models (negative binomial with log link) predicting species abundance in different habitats (see Figure 3). Number of individual birds per transect was modelled with transect length in km as an offset variable. Reference habitat was wetland. Direction of relationships was determined with Least Significant Difference Post-Hoc tests (see Table 5).

	Oystercatcher				Golden Plover			
	B	**Wald LR**	**DF**	**P**	**B**	**Wald LR**	**DF**	**P**
Grassland	2.850	20.183	1	<0.001	-0.042	0.022	1	0.883
Poor heathland	0.846	1.360	1	0.244	0.591	4.768	1	0.029
Rich heathland	1.610	5.760	1	0.016	0.459	2.835	1	0.092
Semi-wetland	1.947	8.799	1	0.003	-0.105	0.136	1	0.712
Overall model fit (LR Chi-Square)		47.122	4	<0.001		11.411	4	0.022
Deviance/DF	0.983				1.321			

	Dunlin				Snipe			
	B	**Wald LR**	**DF**	**P**	**B**	**Wald LR**	**DF**	**P**
Grassland	-1.584	29.707	1	<0.001	-0.646	6.195	1	0.013
Poor heathland	-1.527	28.141	1	<0.001	-1.57	**29.146**	1	<0.001
Rich heathland	-0.866	10.756	1	0.001	-0.49	3.654	1	0.056
Semi-wetland	-0.302	1.429	1	0.232	-0.257	1.041	1	0.308
Overall model fit (LR Chi-Square)		51.118	4	<0.001		32.121	4	<0.001
Deviance/DF	1.367				0.974			

	Whimbrel				Black-t. Godwit			
	B	**Wald LR**	**DF**	**P**	**B**	**Wald LR**	**DF**	**P**
Grassland	-0.923	11.967	1	0.001	-0.939	9.558	1	0.002
Poor heathland	-0.500	3.793	1	0.051	-2.644	30.578	1	<0.001
Rich heathland	-0.142	0.322	1	0.571	-0.562	3.821	1	0.051
Semi-wetland	-0.330	1.689	1	0.194	-0.260	0.872	1	0.350
Overall model fit (LR Chi-Square)		13.939	4	0.007		48.719	4	<0.001
Deviance/DF	1.085				1.203			

	Redshank				Meadow Pipit			
	B	**Wald LR**	**DF**	**P**	**B**	**Wald LR**	**DF**	**P**
Grassland	0.579	2.845	1	0.092	-0.165	7.435	1	0.006
Poor heathland	-3.135	8.990	1	0.003	-0.862	130.894	1	<0.001
Rich heathland	-0.426	1.133	1	0.287	-0.263	17.776	1	<0.001
Semi-wetland	0.334	0.897	1	0.344	0.068	1.423	1	0.233
Overall model fit (LR Chi-Square)		39.67	4	<0.001		205.035	4	<0.001
Deviance/DF	0.919				4.666			

Table 5. Significance scores from a generalized linear model pairwise comparison of density of common species between habitats (Table 4). Habitats that were significantly different are shown, habitats with significantly higher densities are shown in bold and habitats with significantly lower densities are shown normal. W = wetland, SW = semi-wetland, RH = rich heathland, G = grassland, PH = poor heathland.

	Wetland	Semi-wetland	Rich heathland	Grassland	Poor heathland
Oystercatcher	**SW-RH-G**	W-**G**-PH	W-**G**	W-SW-RH-PH	**SW-G**
Golden Plover	**PH**	**RH-PH**	SW	**PH**	W-SW-G
Dunlin	RH-G-PH	RH-G-PH	**W-SW**-G-PH	**W-SW-RH**	**W-SW-RH**
Snipe	G-PH	PH	PH	**W**-PH	**W-SW-RH-G**
Whimbrel	G	G	G	**W-SW-H**	
Black-tailed Godwit	G-PH	G-PH	PH	**W-SW**-PH	**W-SW-RH-G**
Redshank	PH	PH	**G**-PH	RH-PH	**W-SW-RH-G**
Meadow Pipit	RH-G-PH	RH-G-PH	**W-SW**-PH	**W-SW**-PH	**W-SW-RH-G**

A cross-validation comparison was carried out to inspect predictive ability of the habitat models by comparing two species specific models based on the original data after being randomly split in two. Despite the reduced sample size there was a reasonable fit between the two models and the correlation coefficients of predicted density ranged from 0.54-0.98 for individual species (Table 6) indicating a generally robust relationship between habitat types and individual species average density. The overall relationship between the models was close to unity but few of the individual species, notably Oystercatcher and Dunlin, deviated from the overall pattern (Figure 4).

Table 6. Correlation between model predicted means of species density in different habitats (n = 5 per species) comparing two models based on the original data after being randomly split in two (same modelling approach as in the overall model, Table 4).

Species	Pearson r	P
Oystercatcher	0.536	0.351
Golden Plover	0.957	0.011
Dunlin	0.627	0.257
Snipe	0.857	0.063
Whimbrel	0.975	0.005
Black-tailed Godwit	0.730	0.162
Redshank	0.831	0.081
Meadow Pipit	0.922	0.026

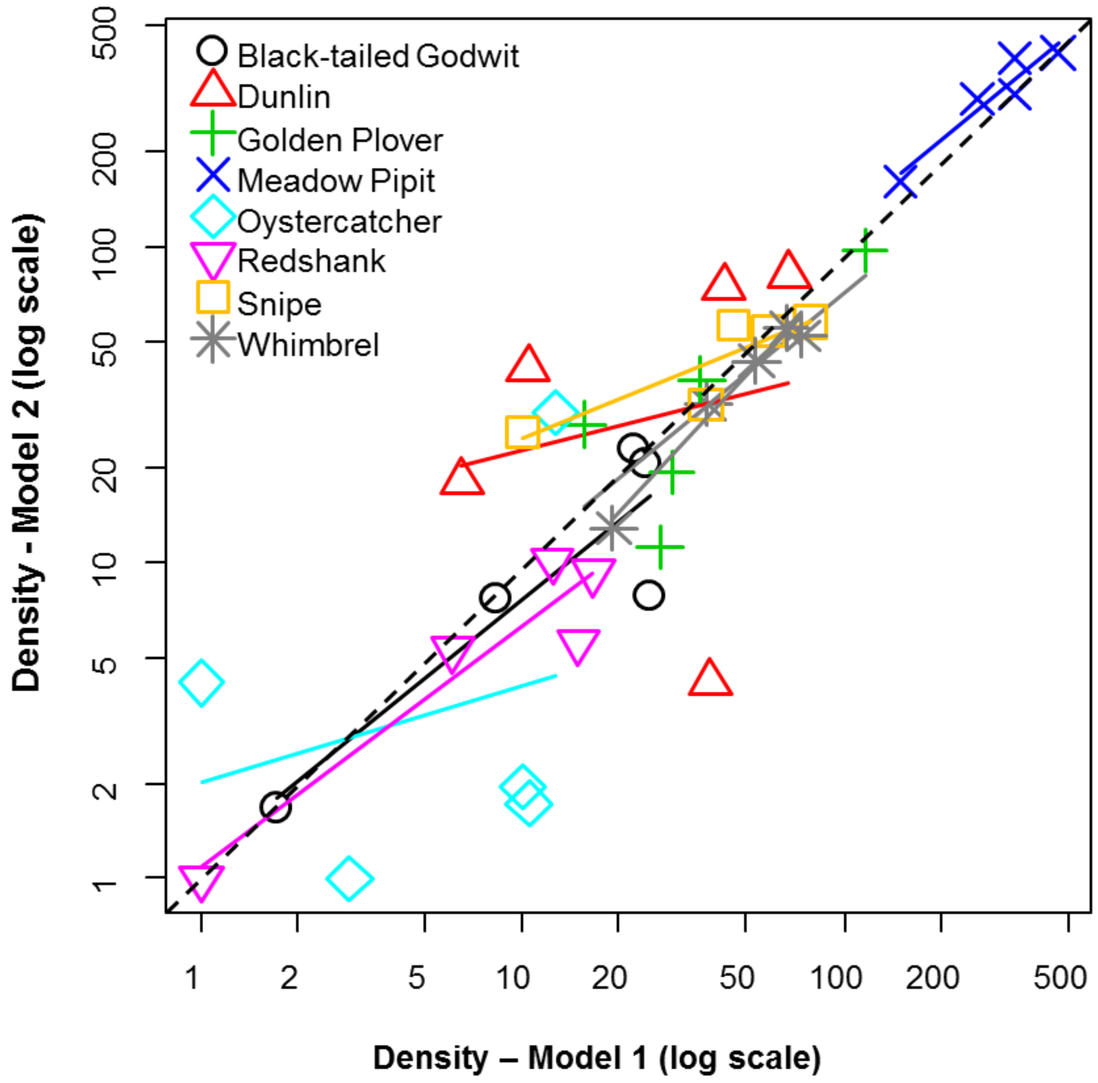

Figure 4. Relationships between model predicted means of species density (individuals/km^2) in different habitat types comparing two models (comparable to the overall model) built with the original data after randomly splitting the data in two. Regression lines are fitted to each species. The dashed line is unity (x=y).

3.3. Estimation of population size

According to this study 25% or more of the Icelandic populations of Oystercatcher, Snipe, Whimbrel, Black-tailed Godwit and Meadow Pipit are in the southern lowlands, including over 50% of Black-tailed Godwit population and at least 30% of Oystercatcher and Meadow Pipit populations (Table 7). Further the southern lowlands accommodate 10-20% of the estimated Europe populations of Dunlin, Whimbrel and Black-tailed Godwit.

Table 7. Estimated population sizes (individuals/km^2) of the eight common species in the five surveyed habitat types in South Iceland. Proportions of estimated Icelandic and European populations in the five habitats in the study area are shown.

	Population estimate	Confidence Interval (95%)	% of Iceland population	% of Europe population
Oystercatcher	14,984	6,655-37,770	37-75*	2-3***
Golden Plover	89,144	57,733-141,004	14**	6-9***
Dunlin	92,471	58,181-153,812	17**	8-12***
Snipe	104,756	75,450-145,978	29**	3-6***
Whimbrel	117,754	75,488-184,598	24**	16-19***
Black-tailed Godwit	27,010	16,111-44,870	54**	10-12***
Redshank	17,637	9,594-33,057	6**	1-2***
Meadow Pipit	703,240	573,013-864,245	35-70*	2-5***

Populations estimates according to *Ministry for the Environment (1992), **Thorup (2004), ***Birdlife International (2004)

3.4. Heterogeneity within habitats

Within the IFD habitat classes, there is considerable variation in vegetation patterns, hydrology and other factors which will affect bird abundance. To better explain current within-habitat variation and link to bird abundance, several habitat variables were recorded in the field. These habitat variables were grouped with a principal components analysis. Two factors were extracted which together explained 51% of the variance in the data (Table 8). The mean factor scores for each of five IFD habitats are shown in Figure 5. Factor 1 was characterised by high sward height, high bush cover and dense hummocks and was strongly positively correlated with *wetland* and negatively with *grassland* and *poor heathland*. Factor 2 was characterised by heavy grazing, running water and pools, which was strongly positively associated with *grassland* and negatively with *poor heathland*. Both factors contributed highly significantly to distinguishing between the IFD habitats (ANOVA on mean factor scores for habitats; Factor 1: $F_{4,195} = 16.902$, $P < 0.0001$, Factor 2: $F_{4,195} = 19.889$, $P < 0.0001$).

Table 8. Component matrix from a principle components analysis of the variables recorded visually at each study plot.

Variable	Factor 1	Factor 2
Hummocks	**0.52**	0.38
Bushes	**0.85**	-0.12
Sward height	**0.86**	0.12
Grazing	-0.36	**0.75**
Running water	0.00	**0.50**
Pools	0.16	**0.46**
% Variance explained	31	20

The three highest loadings for each factor are shown in bold.

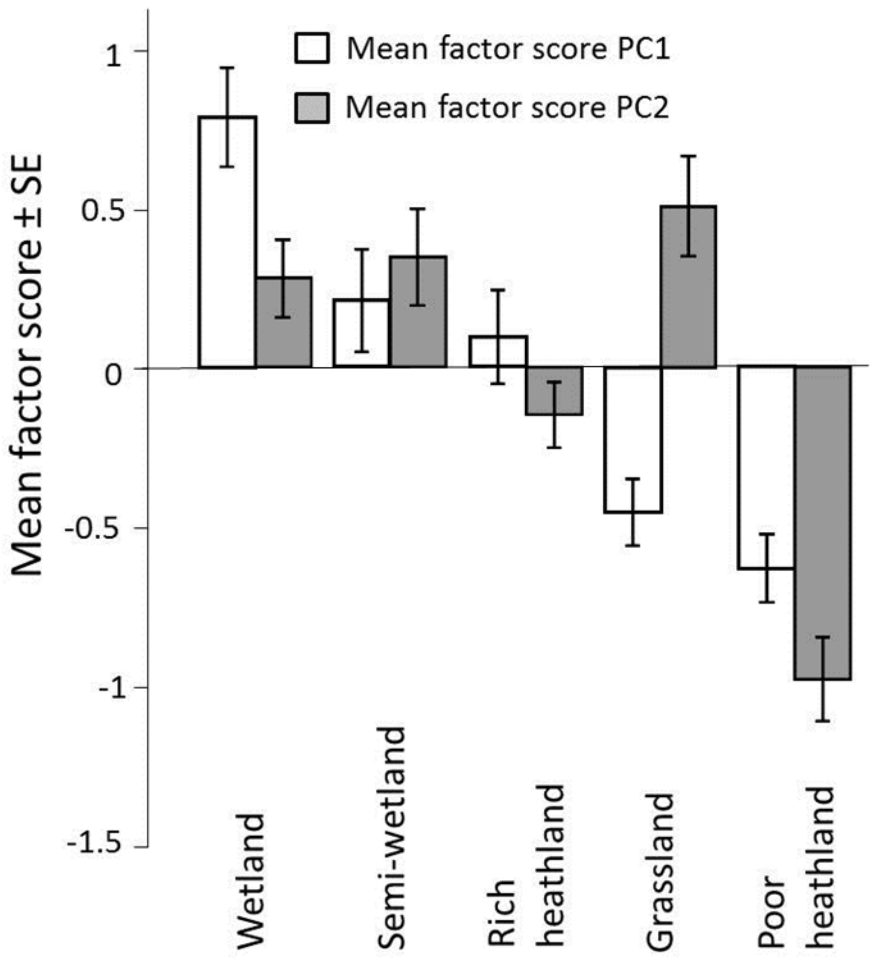

Figure 5. Mean (± SE) factor scores of the two factors from a principal components analysis of the habitat variables recorded visually at survey location (Table 8) for each of the five habitat types.

To assess the effects of within-habitat heterogeneity on bird abundance the PC scores of both factors were correlated with the density of the eight common species (Table 9). As the management focus of the study was at the habitat level, the PC scores were not entered into models of species abundance as a covariate. Half of the species showed a significant relationship with one or both of the two factors suggesting that there is considerable heterogeneity within the IFD habitats that contributes to variation in bird abundance. Only Whimbrel and Black-tailed Godwit did not show a relationship with either factor (Table 9).

Table 9. Relationship between the density of individual of the eight common species and indices (first two principal components) of heterogeneity within habitat types in 200 transects. Pearson correlation coefficients are given. Significant relationships at the 0.05 alpha level are shown in bold and relationships which were still significant after Bonferroni correction (alpha = 0.0031) are in italics.

Species	PC1	PC2
Oystercatcher	***-0.208***	0.111
Golden Plover	-0.138	**-0.155**
Dunlin	**0.148**	***0.196***
Snipe	***0.325***	0.035
Whimbrel	0.055	0.099
Black-tailed Godwit	0.085	0.124
Redshank	-0.076	***0.265***
Meadow Pipit	***0.380***	***0.249***

3.5. Bird diversity in different habitats

To assess variation in bird diversity between habitats, the total number of species, average number of species and the Shannon-Wiener index were computed (Table 10). Total number of species was generally similar ranging from 14 in wetland to 20 in grassland. This was in contrast with the mean number of species which was highest in wetlands, followed by *semi-wetland, rich heathland* and *grassland* had similar mean number of species per habitat and *poor heathland* the fewest. The Shannon-Wiener index ranged from 1.01 to 1.35; *wetland* had the highest score and *poor heathland* the lowest (ANOVA on Shannon-Wiener index; $F_{4,195} = 3.657$, $P = 0.007$).

Table 10. Difference in diversity between the five habitats surveyed.

Diversity	Wetland	Semi-wetland	Rich heathland	Grassland	Poor heathland
Total number of species recorded	14	18	15	20	15
Mean number of species per site (±SE)	5.65 (±0.25)	5.45 (±0.28)	4.925 (±0.28)	4.85 (±0.31)	3.65 (±0.23)
Shannon-Wiener index (±SE)	1.35 (±0.05)	1.23 (±0.06)	1.19 (±0.07)	1.16 (±0.08)	1.01 (±0.06)

3.6. Bird communities

To further estimate differences in avifauna which could be reflected by habitat, community structure was assessed by constructing a PCA of densities of the eight most common bird species. Three factors were identified which together explained 55% of the variation in the data (Table 11). Factor 1 was characterized by wetland-prone species such as Dunlin, Snipe and Black-tailed Godwit but also by the relatively non-habitat selective Meadow Pipit. Factor 2 was characterized by species most common on *grassland*; Oystercatcher and Redshank. Factor 3 was characterized by two species; Golden Plover, which prefers dry *heathland*, and Dunlin. The groupings of species which resulted from the PCA analysis were significantly related to habitat types (ANOVA on mean factor scores for birds; Factor 1: $F_{4,195} = 14.620$, $P < 0.0001$, Factor 2: $F_{4,195} = 3.739$, $P = 0.006$, Factor 3: $F_{4,195} = 4.240$, $P = 0.003$) (Figure 6).

Table 11. Component matrix from a principle components analysis of the eight most common bird species.

Variable	Factor 1	Factor 2	Factor 3
Oystercatcher	0.004	**0.757**	-0.152
Golden Plover	-0.077	-0.106	**0.757**
Dunlin	**0.554**	-0.129	**0.550**
Snipe	**0.631**	-0.340	-0.262
Whimbrel	0.374	0.295	0.444
Black-tailed Godwit	**0.543**	0.363	-0.208
Redshank	0.421	**0.525**	0.026
Meadow Mipit	**0.581**	-0.436	-0.249
% Variance explained	21	18	16

The loadings of each habitat variable on each factor is shown and all loadings >0.5 are shown in bold.

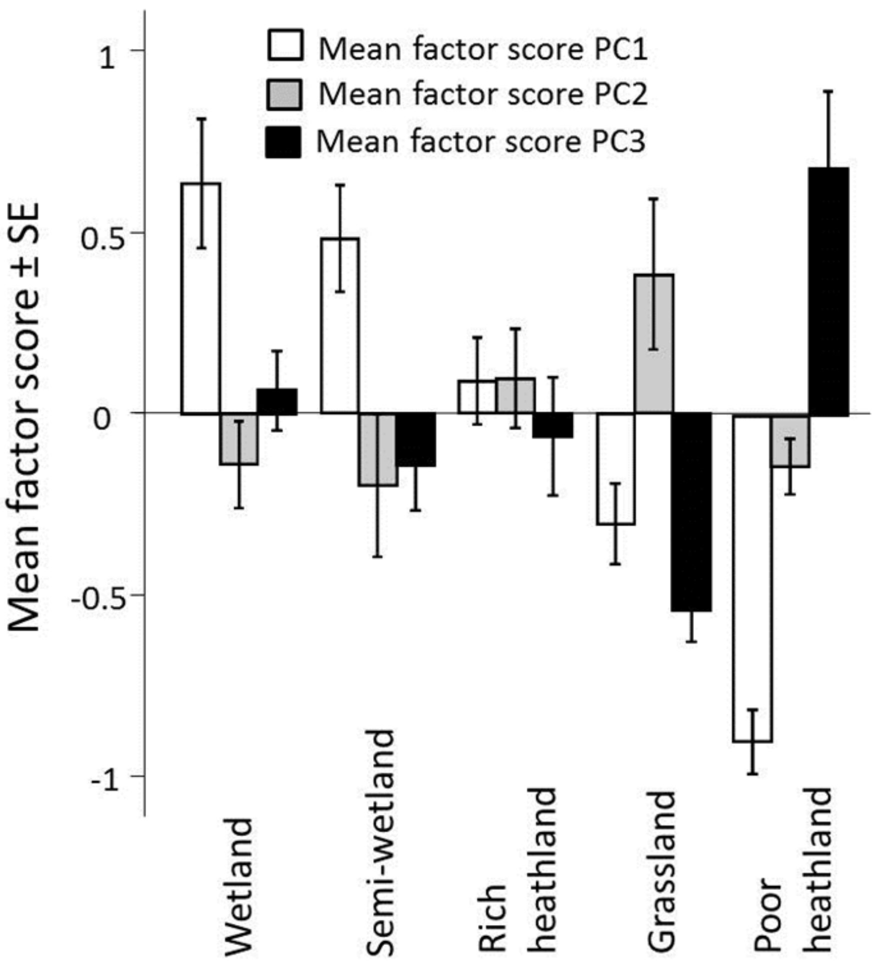

Figure 6. Mean (± SE) factor scores of the three factors from a principal components analysis of the eight most common bird species (Table 11) for each of the five habitat types.

3.7. Invertebrate abundance in different habitats

Invertebrate abundance was compared between habitats by sampling with a handnet on all sites in 2012. Comparison of invertebrate density between habitats showed an overall significant difference (Kruskal-Wallis: $H_4 = 14.961$, $P = 0.005$). Overall variation between habitats was similar ranging from 83 to 96 invertebrates on average per transect. Only *poor heathland* showed a significant difference in invertebrate abundance with only on average 35 invertebrates per transect (Figure 7).

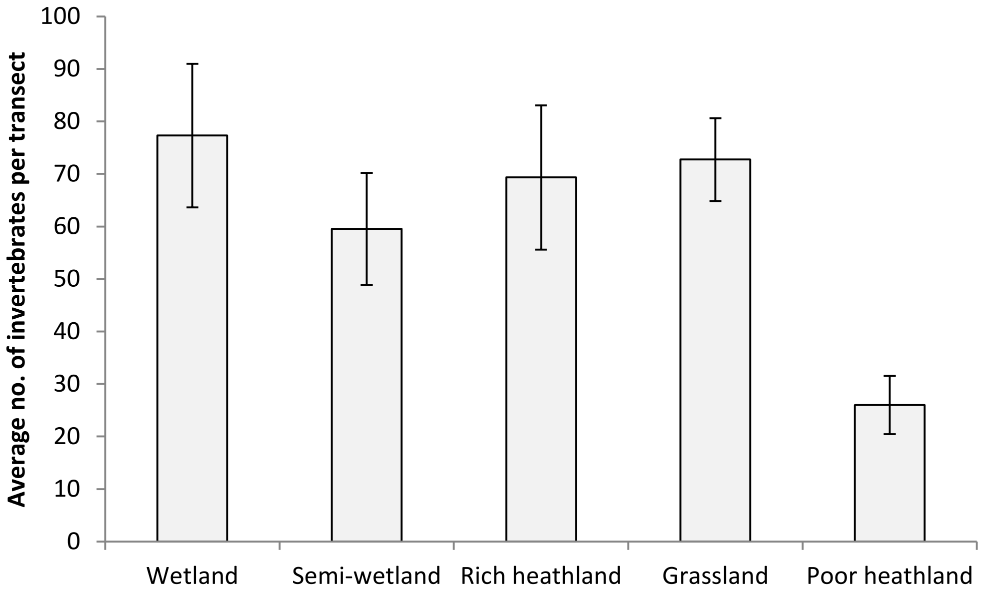

Figure 7. Comparison of invertebrate abundance between different habitats. The average (±SE) catch per habitat (sum of three random samples per transect) is given.

4. Discussion

This study assessed large scale patterns in bird density and diversity in South Iceland, an internationally important area for several open-habitat species (Gunnarsson et al., 2006) and where land-use changes are intense (Wald, 2012). There was therefore an urgent need a for rapid assessment of biodiversity in the area but organisms such as birds which are near the top of the food chain can be suitable indicators of biodiversity (Larsen et al., 2012, Doxa et al., 2010). The study focussed on the five most common, vegetated habitat types which further development and agricultural intensification are likely to impact. Several measures of the avifauna in these habitats, based on stratified random transect sampling at 200 locations, were developed: density, diversity, community structure and estimated population size. Rapid invertebrate surveys were also carried out on a subsample of the sampling locations.

4.1 Bird abundance

Overall, 22 species of birds were recorded in the five habitat types but only 8 of them comprised 95% of the recorded individuals. These were 7 species of waders and the Meadow Pipit and were used for most analysis except for the analysis of species diversity where the other species were also taken into account. Density of birds was different between habitat types with five species (Dunlin, Snipe, Whimbrel, Black-tailed Godwit, Meadow Pipit) occurring in highest densities in the wetter habitat types, *wetland* and *semi-wetland*, and dominating in the overall pattern of species density (Figure 8). Two species, Redshank and Oystercatcher, occurred in highest densities in the *grassland* but one species, Golden Plover was in highest density in the *heathland* habitats (Figure 9). This suggests that different IFD habitats are disproportionally important for birds and biodiversity and wetter habitats generally have higher densities of birds than the drier ones. These patterns of a general preference for wetter habitat types is in agreement with other studies on habitat preferences of waders and Meadow Pipit in Iceland (Gunnarsson et al., 2006, Gunnarsson et al., 2007) and other countries (e.g. Fuller et al., 2005, Smart et al., 2006). A few species did not accord to the general pattern. *Grassland* was significantly more favoured by two species, Oystercatcher and Redshank, and *heathland* habitats were preferred by Golden Plover (Figure 9). Redshank and Oystercatcher are usually associated with agricultural grasslands and the results presented here are supported by previous studies in Iceland and elsewhere (Gunnarsson et al., 2006, Smart et al., 2006). Golden Plover occurs most frequently on heathland throughout its range (Byrkjedal and Thompson, 1998) which was confirmed in this study.

The estimated regional population sizes suggest that the southern lowlands support very large populations of most of the common species despite the fact that several other habitat types (e.g. agriculture) were not surveyed. Three of the common species, Golden Plover, Dunlin and Whimbrel, are responsibility species and occur in internationally important numbers in Iceland (Einarsson et al., 2002) and the rest, Black-tailed Godwit, Redshank, Snipe and Oystercatcher, are all species facing a moderate or a large decline in their European breeding range, except for Meadow Pipit (Birdlife International, 2004). Previous studies comparing density of waders in wet habitat types across different parts of Iceland suggest that the average density of waders in South Iceland is generally higher (up to five fold higher than in West and East Iceland) than elsewhere (Gunnarsson, 2010). So it is likely that South Iceland supports a substantial part of the total Icelandic populations of many of the focal species.

To aid comparison with previous studies which have assessed the relationship between species occurrence and within-patch habitat variables (e.g. Gunnarsson et al., 2006) and to assess the relationship between the IFD classification and habitat trades, several visual habitat factors were recorded on each transect (Table 8, Table 9 and Figure 5). These factors were grouped with a PCA analysis which identified two factors which together were significantly different between the IFD classes. The relationships between birds and within-habitats heterogeneity corresponded well with the relationships shown between birds and habitats. Species which showed a significant relationship with PC1 (which was mostly associated with wet habitat types and characterised by high swards, bushes and hummocks) were hydrophilic species, Snipe and Dunlin, and the generalist Meadow Pipit. Factor 2 was characterised by wet features and grazing and was most strongly associated with *grassland* and *semi-wetland*. The species which showed a significant relationship with PC2 were Dunlin, Redshank and Meadow Pipit. These relationships between species density and habitat variables are in accordance with previous studies in Iceland which have linked species occurrence (presence/absence) to habitat variables (Gunnarsson et al., 2006). The present study did, however, link bird density directly to a composite measure

(PCA) of habitat variables whereas Gunnarsson et al. (2006) linked species occurrence to individual variables by a logistic model. The latter approach is better suited for detecting weaker species-habitat associations as modelling of presence/absence requires a much lower resolution than assessing the relationship between habitats and density like the present study. But modelling density is likely to give a more robust measure of species-habitat relationships.

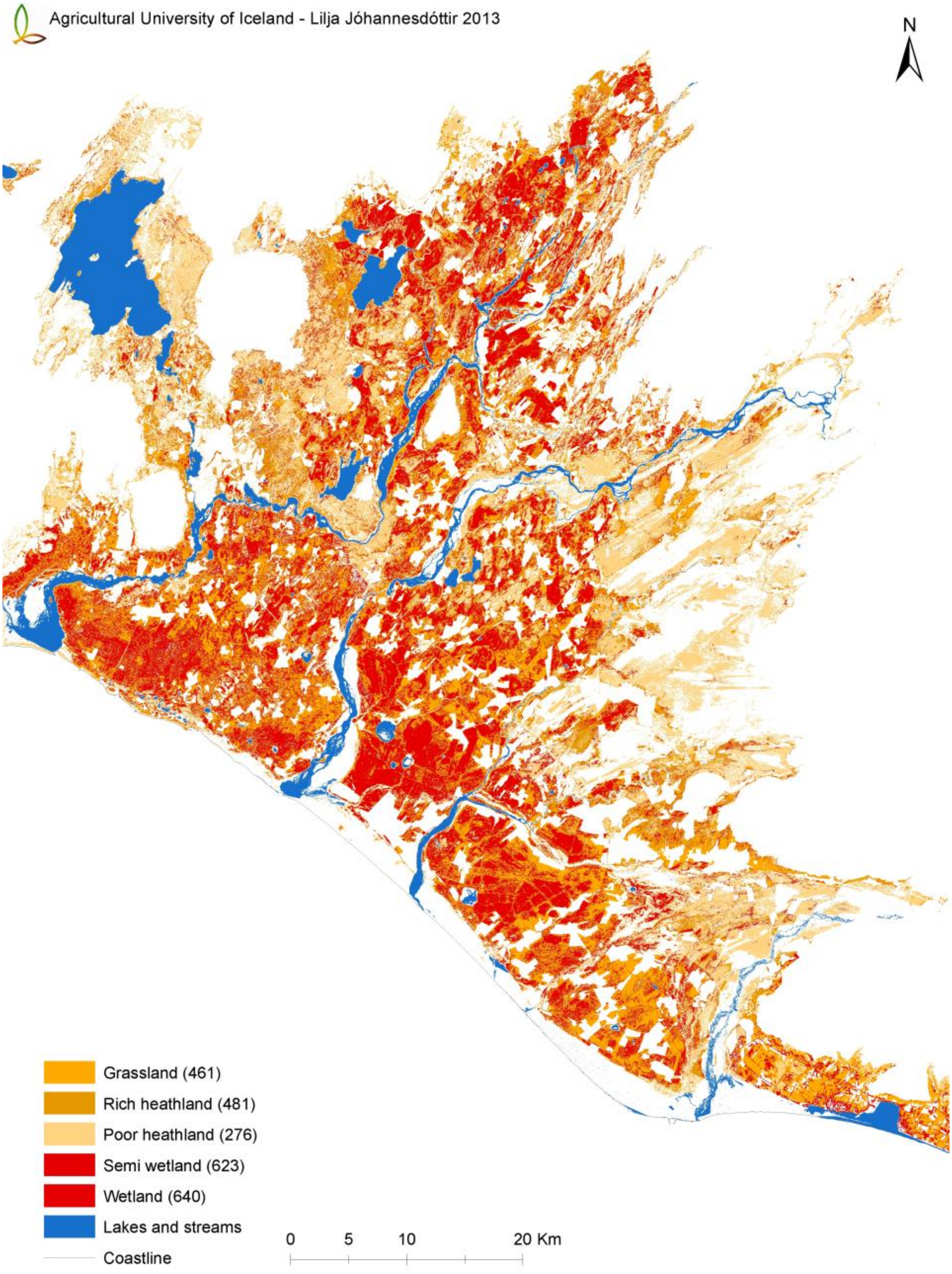

Figure 8. Distribution of the combined density of the eight most common bird species in the five habitats from the Icelandic Farmland Database below 200 m a.s.l. Total density (individuals/km^2) of the eight species per habitat is shown in parenthesis in the legend of the map. Five species occurred in identical or very similar relative densities across habitats as the overall pattern (see Figure 3).

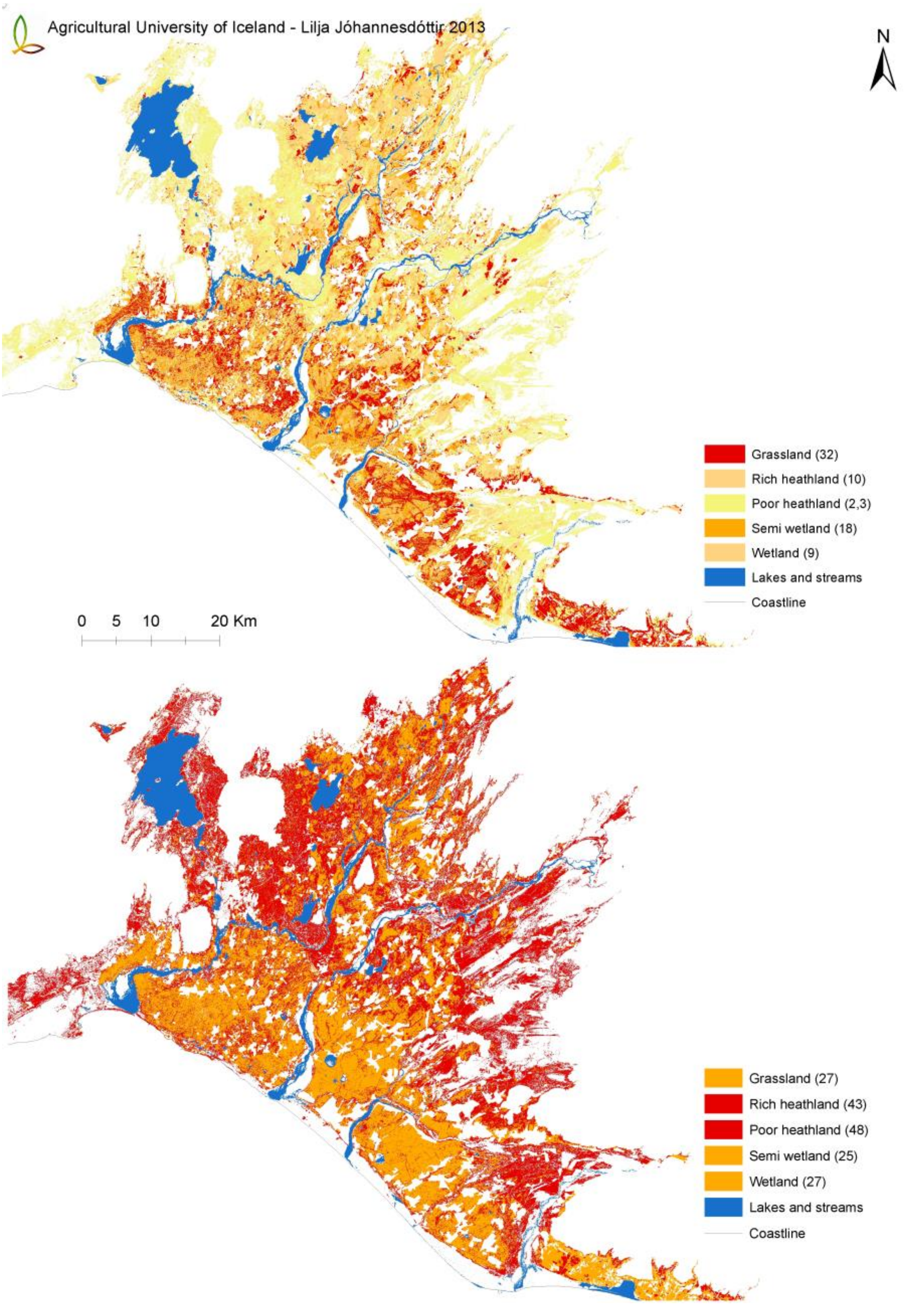

Figure 9. Distribution of the density (individuals/km^2) of the species which showed markedly different density patterns from most species (see Figure 3) in the five habitats below 200 m a.s.l. The upper image shows combined density of Oystercatcher and Redshank which occurred in highest densities on Grassland (and loaded most positively on factor 2 in Table 11). The lower image shows density of Golden Plover which was in highest density on heathland. Density per habitat is shown in parenthesis in the legend of the maps.

4.2. Bird diversity

Habitats did not only differ in density of species but also in diversity (Table 10). Considering species richness, there was a considerable difference between the habitats which had the highest and the lowest total numbers of species recorded per habitat or 30%. Most species were found in *grassland* but fewest in *wetland*. Measures of mean number of species per habitat and the Shannon-Wiener index ranked *wetland* at the top and *poor heathland* with the lowest diversity which is more in accordance with the preference of most species for *wetlands*. A possible explanation for the highest overall number of species occurring in *grassland* could be higher heterogeneity of the *grassland* habitat, due to more intensive drainage and higher variation in grazing but habitat heterogeneity is closely linked to species richness (Benton et al., 2003). As the different densities of individual species in different habitats would suggest, the birds group together in certain communities. The PCA of birds extracted three factors which represent roughly three different habitats. The first factor characterised a "wetland" community, the second one represents a "grassland" community and the third one was strongly related to heathland. This is the first attempt to detect communities of common bird species in lowland Iceland. That certain species group together is most likely a product of a similar habitat selection at the landscape scale rather than functional aggregation (Morin, 1999). The interactions of these common species are likely to be diverse and to have both positive and negative effects on fitness. For example, waders of different species can join in defence of the breeding habitat for predators (Jónsson and Gunnarsson, 2010) but the chicks of most have similar diet (surface arthropods) so some level of competition may operate.

4.3. Invertebrates

Rapid invertebrate surveys were carried out in the second year of the study by hand-netting on three random points on 58 transects in different habitat types. This survey technique yielded very similar invertebrate catches between habitats but only *poor heathland* was significantly different with lower catches on average. This was in accordance with bird densities which were also lowest on *poor heathland*. This approach of surveying invertebrates has the merit of being quick to implement in the field but is highly dependent on external conditions, e.g. temperature, wind and vegetation composition. If invertebrate surveys were to reflect variation in bird density better it is likely that more intensive sampling is required and possibly other methods as well. Conditions for invertebrates are likely to be highly variable and scale dependent. Pools and wet features are, for example, known to be a very important source of invertebrate food for waders (e.g. Eglington et al., 2008, Gunnarsson et al., 2005) but sampling this source may require different sampling schemes. Both surface and foliar arthropods are likely to be important for the common species but hand-netting captures mostly foliar ones. Pitfall traps have proven their worth in the studies of diet of waders (e.g. Tulp, 2007) and window traps capture temporary flushes of invertebrates well (Jonsson et al., 1986).

4.4. Survey issues

To capture habitat specific bird densities for management recommendations it was necessary to restrict the minimum size of the surveyed patches (to 20 ha) so they would represent one habitat and for reducing the effects of adjacent habitats. As birds often prefer diverse landscapes and use several habitat types together (Fahrig, 2003, Benton et al., 2003) the scale and type of the habitat mosaic can be important drivers of density. An attempt was made to assess the effects of adjacent habitats by comparing their ratio, within 1 km radius around the starting point of transects (extracted by GIS), to species density. No obvious relationship was found between species density and ratio of adjacent habitats. The relationships between adjacent habitats and species density are also affected by spatial autocorrelation and can say more about how habitats lay in the landscape than the relationship between habitat mosaic and bird density (Bahn et al., 2006). Such analyses are preferentially coupled with detailed measures of movements of individuals so their proportional use of the habitat matrix becomes evident. Along with grazing, the single most important habitat management intervention on the studied habitats is drainage. An attempt was made to rapidly assess the effects of drainage on the surveyed patches on bird density by measuring intensity of drainage (The Farmland Database, 2013) within 250 m radius of the transects. The intensity of drainage varied greatly between habitat types and species density responded inconclusively to drainage intensity. Drainage intensity at this level is probably a poor measure of local hydrology and habitat suitability as also suggested by Gunnarsson (2006). More detailed studies are probably needed to elucidate the relationships between drainage, hydrology and habitat suitability for common birds. Time since draining, and underlying habitat type are likely to be very important in this respect (Wald, 2012).

The IFD classification system correlated well with bird density and diversity in South Iceland and also with habitat variables recorded on site. The system seems well suited for the purpose of mapping and scaling up biodiversity patterns and can be a valuable aid in rapid and much needed biodiversity assessments in Iceland. Densities of the eight common bird species are generally higher in South Iceland than elsewhere (Gunnarsson, 2010) so basic measurements in other parts of the country are necessary before scaling up the results of the current study.

4.5. Management recommendations

The measures of avifauna in the five different IFD habitats lead to the conclusion that the wetter habitats are more important for bird biodiversity. *Wetland* and *semi-wetland* have higher densities than the other habitats, receive higher diversity index scores and host a higher mean number of species, and more of declining species. There have been major declines in wetlands, both in Iceland (Óskarsson, 1998, Thorhallsdottir et al., 1998) and worldwide (OECD and IUCN, 1996) so the scarcity of wetlands makes them relatively more important. *Wetlands* in the study area account for 16% of the total area of wetlands in Iceland (The Farmland Database, 2013). Due to the high biodiversity value and scarcity it is concluded that *wetland* and *semi-wetland* have the highest conservation value. But it is also important to consider that different habitats are important for different species and though wetter habitats are of relatively greater importance for more species, drier habitats can be important for some, notably the Golden Plover, one of Iceland responsibility species (Einarsson et al., 2002), so in all management it is important to consider different aspects of biodiversity, which can be measured by different means.

4.6. Future research

There is reason to focus future research on the habitats that were not included in this study, especially agricultural land for it might be a habitat that is important for at least some of the species common in this research and it counts for 12% of the study area (476 km^2). Since the area is of an international important it is crucial to establish knowledge of its value (Gunnarsson et al., 2006). Agriculture may also be important in mosaic with other habitats. A more detailed study of invertebrates in different habitats would increase the understanding of each habitat’s value for biodiversity. It also would be interesting to look at whether or how the mosaic in the landscape affects bird’s abundance and behaviour by considering different scales of the study as habitat heterogeneity can greatly affect birds and biodiversity (Fahrig et al., 2011, Pickett and Siriwardena, 2011). In relation to the impact of the mosaic in the landscape and habitat heterogeneity it would be useful to couple landscape level measurements with studies of the movement of individuals, either by radio tracking or other devices, to establish how they use the habitat mosaic available to them.

5. Conclusions

Different IFD habitats are disproportionally important for bird biodiversity. *Wetland* and *semi-wetland* have higher density of birds, higher mean number of species per transect and receive higher diversity index score than other habitats in the study. This suggests that wetter habitats are of greater importance for bird biodiversity than the drier ones, even though a few species occurred in highest density in other habitats. Massive decline in wetland area in Iceland (Óskarsson, 1998, Thorhallsdottir et al., 1998), and worldwide (OECD and IUCN, 1996), makes these habitats even more important in relation to biodiversity on an international scale. Vegetation in Iceland has been shaped by intensive grazing throughout the centuries creating a special cultural landscape characterized with open habitats such as heathland and wetlands (Arnalds, 1987). This landscape is of great importance for various wader species where a large portion of the world population breeds in Iceland (Thorup, 2004). Nearly all of these species are facing a global decline (Birdlife International, 2004) which further increases the importance of the Icelandic cultural landscape and of the study area.

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Appendix 1 Number of individuals of different bird species which were recorded on line transects at 200 random locations in five habitat types in South Iceland in 2011-2012

	Wetland	**Semi-wetland**	**Rich Heathland**	**Grassland**	**Poor heathland**	**Total**
Oystercatcher (*Haematopus ostralegus*)	3	21	15	52	7	**98**
Ringed Plover (*Charadrius hiaticula*)	0	0	0	0	1	**1**
Golden Plover (*Pluvialis apricaria*)	67	60	106	64	121	**418**
Dunlin (*Calidris alpina)*	171	126	72	35	37	**441**
Snipe (*Gallinago gallinago*)	168	130	103	88	35	**524**
Whimbrel (*Numenius phaeopus*)	166	119	145	66	101	**597**
Black-tailed Godwit (*Limosa limosa*)	84	65	48	33	6	**236**
Redshank (*Tringa totanus*)	23	32	15	41	1	**112**
Phalarope (*Phalarobus lobatus*)	5	1	3	6	0	**15**
Artic Skua (*Stercorarius parasiticus*)	0	10	0	2	4	**16**
Artic Tern (*Sterna paradisaea*)	5	7	3	33	2	**50**
Whooper Swan (*Cygnus cygnus*)	20	11	2	5	2	**40**
Greylag Goose (*Anser anser*)	8	16	5	25	0	**54**
Mallard (*Anas platyrhynchos*)	1	4	0	6	0	**11**
Widgeon (*Anas penelope*)	0	0	0	1	0	**1**
Teal (*Anas crecca*)	0	10	2	3	0	**15**
Eider duck (*Somateria mollissima*)	0	0	0	3	0	**3**
Rock Ptarmigan (*Lagopus mutus*)	0	0	0	0	6	**6**
Meadow Pipit (*Anthus pratensis*)	593	634	456	502	252	**2437**
Wagtail (*Motacilla alba*)	0	1	0	2	0	**3**
Wheatear (*Oenanthe oenanthe*)	0	3	2	3	12	**20**
Redwing (*Turdus iliacus*)	3	8	13	1	5	**30**
Total	**1317**	**1258**	**990**	**971**	**592**	**5128**
Total species	**14**	**18**	**15**	**20**	**15**	**22**