Icelandic meadow breeding waders: status, threats and conservation challenges

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Abstract

Populations of many migratory wader species around the world are in serious decline, largely caused by anthropogenic activities. Throughout the developed world, agricultural expansion and intensification have been identified as among the main drivers of these declines. However, not everywhere have agricultural activities reached levels where noticeable negative impacts on breeding waders are apparent. Since settlement, Icelandic farmers have largely been self-sufficient in agricultural productivity, and substantial expansion of agricultural land only began after the 1940s'. Agricultural expansion has continued since then and today around 7% of area below 200 m a.s.l. (areas at higher altitudes are typically unsuitable) are used for cultivation. Large areas of natural or semi-natural habitats are therefore still common and widespread in Iceland, and the current mosaic-like landscape created by areas of agricultural land within these habitats may help to provide the resources needed by the very large populations of waders that breed in the country. Wader species have all been protected from hunting and egg-collecting by law since the 20th century. However, lowland landscapes in Iceland are changing quite rapidly, as a result of agricultural expansion, afforestation, shrub encroachment and widespread construction of summer cottages, and all of these developments pose potential threats to these species. Predictions of the potential impact of current and future land use changes on these species is hampered by limited information on population dynamics, and no specific conservation efforts are currently aimed at meadow breeding waders in Iceland.

Keywords
Shorebird conservation, sub-arctic habitats, lowland ecosystems, land use changes, agricultural expansion, breeding distribution.

Introduction
Migratory waders are declining in many parts of the world (International Wader Study Group 2003, Bart *et al.* 2007, Piersma *et al.* 2016) and evidence suggests that changing environmental conditions during the breeding season contribute to these declines in many cases (Zockler *et al.* 2003, Wilson *et al.* 2004). Agricultural developments are a major cause of these changing conditions, largely because the resulting landscape and vegetation structure fails to provide the necessary resources for breeding waders (Vickery *et al.* 2001, Smart *et al.* 2006). However, rates of agricultural development vary around the world.

Development and intensity of agriculture in Iceland
Icelandic agriculture is highly influenced by the country's geographic location, just south of the Arctic Circle (between 63° and 66° North). The interior of Iceland consists mostly of highland areas rising from 400 m elevation to more than 2000 m (57% of the area of Iceland is above 400 m a.s.l.; National Land Survey of Iceland 2013), and lowland areas are primarily along the coastline and river plains. Despite its high latitude, the temperature in Iceland is relatively mild in winter due to the Gulf Stream bringing warm sea currents from the south. Consequently the lowlands experience sub-arctic climates, while conditions in the highlands are closer to arctic climate (Arnalds 2015). Iceland was settled in the 9th century and since then Icelandic agriculture has been characterised by long periods of self-sufficiency and little cultivation, harsh weather and soil conditions and modest levels of foreign trade (Jóhannesson 2010). It was only at the beginning of 20th century that agriculture grew beyond subsistence, and cultivation developed alongside urbanization following the Second World War (Júlíusson & Ísberg 2005). In 1900, the most common land cover type in the lowlands of South Iceland was natural wetland (Wald 2012) and wetlands were also very common in other regions (Danish General Staff 1905). In the 1940s, the Icelandic government implemented a programme of subsidised drainage of wetlands encouraging farmers to increase both the area under cultivation and the grazing potential of their land. During the following four decades, extensive drainage took place in the lowlands, with 29,700 km of ditches being excavated (Gísladóttir *et al.* 2009). There were no legislative constraints on the extent of the drainage and many drained areas were never subsequently used for agriculture. During the 20th century, an estimated 55 to 75% of Icelandic wetlands were drained to some extent (Óskarsson 1998) and nearly 97% of the wetlands in South Iceland were disturbed by drainage (Þórhallsdóttir *et al.* 1998). In total 4200 km^2 of wetlands in Iceland were drained, of which only 570 km^2 are used for cultivation (Barkarson *et al.* 2016). In that century, the area of cultivated land in Iceland grew considerably, expanding from 400 km^2 in 1940 to 1650 km^2 in 1980 and has continued to increase to present levels of ~1750 km^2 (7% of the area below 200 m a.s.l.) (National Land Survey of Iceland 2013, Snorrason *et al.* 2015). These cultivated areas are constrained to the lowlands while the highlands, which are mostly sparsely vegetated or barren land, are used for grazing of sheep and horses. Cultivated areas in Iceland are mostly hayfields that are used for grazing or fodder production for livestock for meat and dairy production, as agriculture in the country is almost entirely animal based (pastoral). Arable production is small-scale and mostly comprises barley grown for fodder on the farm where it is grown, although most grain fodder is imported (Jóhannesson 2010).

Agriculture in Iceland is not as widespread and intense as in many other countries where agriculture dominates the rural landscape (Fig. 1). Large areas of semi-natural land, on which only low intensity grazing tends to occur, still remain in Iceland at present. The 7% of lowland area that is cultivated contrasts sharply with many other countries in Europe in which ~80% of land is either used for food production, settlement or infrastructure (European Environment Agency 2016). However, estimates suggest that >60% of the remaining semi-natural areas in Iceland could potentially be converted to cultivated land (The Farmers Association of Iceland 2010, The Farmland Database 2013). At present, Icelandic lowlands are characterised by a fine scale mosaic mixture of semi-natural habitats and agriculture (Fig. 1).

Legal status

Seven wader species breed in meadow-like habitats in lowland Iceland (as well as breeding in other habitats); Oystercatcher *Haematopus ostralegus ostralegus*, Golden Plover *Pluvialis apricaria altifrons*, Dunlin *Calidris alpina schinzii*, Common Snipe *Gallinago gallinago faeroeensis*, Whimbrel *Numenius phaeopus islandicus*, Black-tailed Godwit *Limosa limosa islandica* and Common Redshank *Tringa totanus robusta*. All these species, and their eggs, became protected by Icelandic law early in the 20th century, excluding Whimbrel which only became protected in 1954 (Fig. 2), but there is no evidence to suggest that hunting of these species was common before protection. Iceland is a member of several international agreements which confer protection status to waders and their habitats. Iceland ratified the Convention on Wetlands (Ramsar Convention) in 1977, the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) in 1993, the Convention on Biological Diversity in 1994 and became a member of the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) in 2013 (Schmalensee *et al.* 2013). Iceland is also part of the Arctic Council which has a biodiversity working group, the Conservation of Arctic Flora and Fauna (CAFF) which, among other current projects, is working specifically towards encouraging flyway-wide protection for migratory species breeding at Arctic latitudes. For the African-Eurasian Flyway, one of CAFF's priority conservation issues and proposed actions is to secure the breeding habitat of waders in Iceland by ensuring that national programmes of afforestation, and other land use policies and practices, are sustainable. CAFF aims to cooperate with Icelandic authorities to avoid changes in land use in the Icelandic lowlands that may impact breeding water birds, particularly regarding the national afforestation policy (CAFF 2016). Plans for large-scale state-subsidised afforestation of Icelandic lowlands have raised considerable concern for several years, especially because of the threats it poses to breeding waders, such as loss of breeding habitat and potential avoidance of areas close to forests (Wilson *et al.* 2014). The Standing Committee of the Bern Convention mandated an on-the-spot appraisal of the Icelandic afforestation situation in 2001 which confirmed the threat to migratory waders. The Standing Committee urged the Icelandic Government to undertake seven specific actions, including impact assessment, habitat protection and strategic planning. To date, limited progress has been made in response to these recommendations (BirdLife Iceland 2014).

Numbers, trends and distribution of meadow birds in Iceland

Breeding population sizes in Iceland of the seven meadow wader species range from 20,000 to 310,000 pairs, and the estimated proportions of the world population range from 3 to 34% (Fig. 2), highlighting Iceland's importance for these species (Guðmundsson 2002).

Trends

Unfortunately, systematic efforts to monitor breeding wader populations in Iceland have only recently started (first began in 2006), so no long-term population trends are currently available. Sufficient data should be available to track trends over the short-term in a few regions in the near future. **Population trends are known for the Icelandic Black-tailed Godwit population, as this overlaps little with other Black-tailed godwit subspecies on its wintering grounds in W-Europe (Alves *et al.* 2010), and so the long-term monitoring schemes from countries in which Icelandic godwits spend the non-breeding season can provide good annual estimates of the size of the Icelandic breeding population (Crowe *et al.* 2012, Frost *et al.* 2016).** Throughout the 20th century the Icelandic Black-tailed Godwit population has increased and the breeding range has expanded across lowland Iceland (Gunnarsson *et al.* 2005b). There is also some evidence to suggest that the population of oystercatchers may have increased in recent decades, since their range has expanded into more northerly parts of Iceland (Jóhannsson & Guðjónsdóttir 2009), **but no systematic survey data are available to confirm this suggestion**.

Demographic parameters

Demographic studies have only been conducted on a few meadow breeding species in Iceland. These have been short term and provide only snapshots of the variation in demographic rates. And although these provide some evidence for spatial and annual variation in current demographic rates, estimating longer term demographic changes require systematic long-term studies which are not in operation. Nesting success has been studied in Black-tailed Godwit, Common Snipe and Whimbrel, and can vary across habitats and between years. In a study of Black-tailed Godwits on 12 study sites in South Iceland in 2001–2003, between 50 and 75% of nests hatched each year (Mayfield adjusted success rate) and hatching success was generally higher in marshes than on dwarf-birch bog (Gill *et al.* 2007). Similarly, comparisons of nest survival of Whimbrels in South Iceland in 1997 and 1999 showed that, on a riverplain site, 61–100% (Mayfield-adjusted) of nests survived each year but only 1–19% of nests survived on a heathland site (Gunnarsson 2000). A later study of Whimbrel nesting success in 2009–2010 found 15–17% nest survival on a grassland site but 19–29% on a river plain site (Katrínardóttir *et al.* 2015). Finally, a recent study of Common Snipe nest success in different habitats in South Iceland in 2015 recorded Mayfield-adjusted nest survival rates of 3–18%, with survival being higher in marshes and a mosaic of lupin (*Lupinus nootkatensis*) and birch (*Betula pubescens*) habitat than in lupin fields (Wentworth 2015).

Less is known about fledging success of waders in Iceland but, on the 12 Black-tailed Godwit study sites mentioned previously, 20–80% of pairs which attempted to breed fledged one or more chicks with, on average, ~30% of pairs fledging one or more chicks on dwarf-birch bog sites and ~ 55% on marsh sites (Gunnarsson *et al.* 2005a). Variation in fledging success among habitats was also apparent in whimbrels in South Iceland between 1997 and 1999, where chick survival from hatching to fledging ranged from 50 to 55% on a river plain site (1.5–2.0 fledglings/pair) and from 36 to 40% (0.0–0.7 fledglings/pair) on a heathland site (Gunnarsson 2000). Similarly, whimbrel chick survival in 2009–2010 was 21% (0.36 fledglings/pair) on a river plain site and 32% (0.50 fledglings/pair) on a grassland site (Katrínardóttir *et al.* 2015).

Very little is known about survival rates of Iceland breeding waders but estimates of annual survival rates of Icelandic Black-tailed godwits from colour-ring resightings range from 87 to99% (Gill *et al.* 2007), while return rates of colour-ringed whimbrels to their breeding grounds (minimum survival) has ranged from 60 to 81% in two studies (Gunnarsson *et al.* 2005a, Katrínardóttir *et al.* 2015).

Distribution

All seven meadow-breeding wader species can be found in every region of Iceland (Fig. 3) and in all of the most common vegetated habitats (Gunnarsson *et al.* 2006), but their densities vary between habitats (Jóhannesdóttir *et al.* 2014). Oystercatchers and Common Redshanks are generally more frequently found in grasslands and on cultivated land, while Dunlin, Common Snipe, Whimbrel and Black-tailed Godwits are more often found on wetlands and semi-wetlands, and Golden Plover is most frequently found in the drier heath-habitats (Fig. 2). As all of these habitats are patchily distributed throughout the lowlands (Fig. 1), the species are generally widely distributed and not concentrated in specific areas. Although all seven species are most common in the lowlands, Golden Plover, Dunlin and Whimbrel also breed in the highlands (Guðmundsson 2002). The density of waders differs between regions in lowland Iceland, with up to three times more waders in the South than in the West (Gunnarsson *et al.* 2006). The divergent tectonic plate boundary that crosses Iceland along the North-Atlantic ridge, originates frequent volcanic eruptions (Arnalds 2015), and patterns of spatial variation in wader density are positively correlated with the amount of volcanic dust deposition. Deposition rates vary on a SW-NE axis through Iceland and regional variation in wader abundance is apparent along this axis, likely caused by the fertilizing effect of the dust input, particularly in wetlands (Gunnarsson *et al.* 2015, Jóhannesdóttir *et al.* 2018). Volcanic activity can have extreme effects on ecosystems as a whole, altering landscapes and even changing average temperatures. Short-term effects of volcanic activity have been shown to negatively affect breeding of Whimbrels in Iceland (Katrínardóttir *et al.* 2015), whereas long-term effects may be beneficial across broad geographical regions, as shown by the positive association between wader density and ash deposition rates across the country (Gunnarsson *et al.* 2015).

Threats and conservation

Land use changes are likely to be the most serious threat for meadow-breeding waders in Iceland (Sutherland *et al.* 2012), as a consequence of the resulting habitat loss, fragmentation and homogenisation. In the first decade of the 21th century, rapid land use changes occurred in Iceland, with conversion of natural landscapes into man-made surfaces (e.g. for settlement, infrastructure, recreation and agriculture) increasing by ~20% overall between 2000 and 2006, and by over 30% in South Iceland (Wald 2012), where the density of breeding waders is highest (Gunnarsson *et al.* 2006). The three most prominent land use changes in Iceland at present are commercial afforestation, the construction of new summer cottages and expansion of agricultural land (Wald 2012).

Afforestation

The Icelandic government plans to afforest 5% of the land below 400 m a.s.l. (Alþingi 2006), where waders are most common and where 2.7% of the area already has forest cover (The Farmland Database 2013). Afforestation poses a threat to waders through loss of breeding and foraging habitats. The resulting change in vegetation structure makes the habitat unsuitable as ground-nesting species typically prefer non-forested, open habitats which offer good visibility, probably to reduce the risk of predation (Stroud *et al.* 1990, Gunnarsson *et al.* 2006, Vliet *et al.* 2010).

Summer cottages

There are currently ~15,000 summer cottages in Iceland but the area over which permission for construction has been agreed could equate to up to 60,000 cottages (Skipulagsstofnun 2014). These are mostly concentrated in the lowland areas where waders are most abundant. In addition to the loss of habitat that results from the construction of buildings, the accompanying infrastructure, such as paths, roads, associated tree planting around houses and the presence of domestic cats in areas with breeding waders, can negatively impact the attractiveness of these areas to breeding waders and could increase levels of nest and chick predation (Loss *et al.* 2013, Wilson *et al.* 2014).

Agriculture

Agricultural expansion in Iceland is ongoing and, in a recent questionnaire study, the majority of Icelandic farmers surveyed reported that they are likely to expand their agricultural land within the next five years (Jóhannesdóttir *et al.* 2017). To what extent that proposed expansion will be carried out remains uncertain, but Icelandic farmers own the majority of land below 400 m a.s.l. (Kristófersson *et al.* 2007, Arnalds 2015), thus their land management decisions have the potential to greatly influence meadow breeding waders. Currently there are few regulations that restrict landowner action; this freedom to manage land independently means that farmers are the key decision-makers regarding wader conservation in Iceland. Expansion of agricultural land by means of conversion of natural or semi-natural land into areas that are cultivated or intensively grazed can lead to fragmentation and loss of wader breeding habitat. The land that is best suited for cultivation is in flat low-lying areas which are also preferred by waders, and important habitat types for breeding waders, such as partially drained wetlands are often targeted for agricultural expansion (Guðmundsson 2002, Gunnarsson *et al.* 2006, Jóhannesdóttir *et al.* 2014, Arnalds 2015, Jóhannesdóttir *et al.* 2019). Water level management is important in agriculture but the presence of pools and other wet features is very important for waders, as the invertebrate prey on which they forage are typically most abundant around these wet features (Eglington *et al.* 2010). Changes in water tables can thus seriously impact the suitability of habitats for breeding waders (Gunnarsson *et al.* 2005b, Smart *et al.* 2006, Eglington *et al.* 2008). Mowing of crops can destroy nests and kill both chicks and adults, so the frequency and timing of mowing activities within the breeding season are also important factors for waders (Schekkerman & Beintema 2007, Kleijn *et al.* 2010, Schroeder *et al.* 2012). The timing of hayfield mowing in Iceland has been advancing, mostly because of increased demand for good hay quality (Helgadóttir *et al.* 2013). However, with rising global temperatures, mowing time in Iceland could occur even earlier in the season, which is likely to increase the frequency with which mowing coincides with wader nesting and thus the destruction of eggs or young chicks may become more common. Icelandic agriculture is mostly livestock-based and livestock grazing is common throughout the lowlands and throughout the year as horses are kept outside all year around. Livestock grazing can impact ground-nesting birds directly through trampling and egg eating, and indirectly by changing vegetation structure such that areas are either unsuitable for nesting or more vulnerable to nest predators (Vickery *et al.* 2001, Tichit *et al.* 2005, Smart *et al.* 2006, Katrínardóttir *et al.* 2015, Laidlaw *et al.* 2015). Low levels of grazing can be beneficial for waders, for example by reducing encroachment of native bush species such as birch (*Betula spp.*) and willows (*Salix spp.*), but overgrazed habitats typically do not provide the necessary shelter for nests, chicks and adults, and shorter vegetation is likely to have lower prey abundance (Jóhannesdóttir *et al.* 2014).

Shrub encroachment

Rising temperature, as well as changes in agricultural practices and grazing by livestock, has caused shrub expansion in areas of high latitude (Myers-Smith *et al.*, 2011). Iceland is no exception to this but recent studies have shown that shrub encroachment is occurring quite rapidly in lowland areas. This can be linked to reduced intensity of sheep grazing but the number of sheep in Iceland has approximately halved since 1980, when numbers were highest (Statistics Iceland 2019), so there is less grazing pressure and an increase in the amount of land with no grazing (Alfreðsson 2018). Between 2001 and 2018, the frequency of areas where shrubs were visible increased by 96% for birch (*Betula pubescens* and *B. nana*) and by 56% for willows (*Salix* spp.) (Gunnarsson *et al.* 2006, Alfreðsson 2018). Most wader species, notably Oystercatcher, Golden Plover, Whimbrel, Black-tailed Godwit, Common Redshank and Dunlin occur in lower densities in areas with shrub cover, and Common Snipe is the only species that commonly breeds in these areas. If the warming trend and reduction in grazing pressure continues, large areas of currently prime wader breeding habitat may become unsuitable for most species of breeding waders in near future (Alfreðsson 2018).

Conservation measures and their effectiveness

There are no specific conservation measures aimed at meadow breeding waders in Iceland. About 9% of the land area in the country is protected, but most of these areas are in the highlands (The Environment Agency of Iceland 2016) and, as the largest proportion of meadow-breeding waders occurs on privately-owned land in the lowlands, this has little impact on them. National legislation is not well developed to deal with the cumulative impacts of the current rapid changes in land use on biodiversity, or with selective habitat protection at the scale of individual farms. Nevertheless, a recent study shows that farmers consider it important to have diverse birdlife on their land, and many report that they would be willing to participate in land management actions aimed at protecting and conserving birdlife (Jóhannesdóttir *et al.* 2017). One management action that is currently available to farmers is funding to restore wetlands, but its implementation has been slow (7 km^2 have been restored in the last two decades), although farmers have been increasingly interested in restoration options (Barkarson *et al.* 2016). Restoration of wetlands in lowland Iceland has the potential to be highly beneficial for breeding waders and with farmer willingness to participate in land management actions, given the right support this can potentially become an important conservation action in the future.

Future perspectives

Icelandic habitats sustain wader populations of international importance (Delany & Scott 2002, Thorup 2004) but land use changes offer an imminent threat to these populations. The loss and fragmentation of breeding habitats that is resulting from afforestation, construction of summer cottages and agricultural expansion, will erode the value of Icelandic landscapes for these species. It is hard to predict the speed and extent of these land use changes but they certainly have potential to seriously impact these internationally important populations. Unlike many other European countries, the landscape of Iceland has not yet been altered to such an extent that population declines are apparent, but lessons can clearly be learnt from other countries before irreversible damage occurs. Farmers play a key role in land management in the lowland areas of the country where most meadow breeding waders occur and their willingness to participate in conservation actions may be crucial for the preservation of these species.

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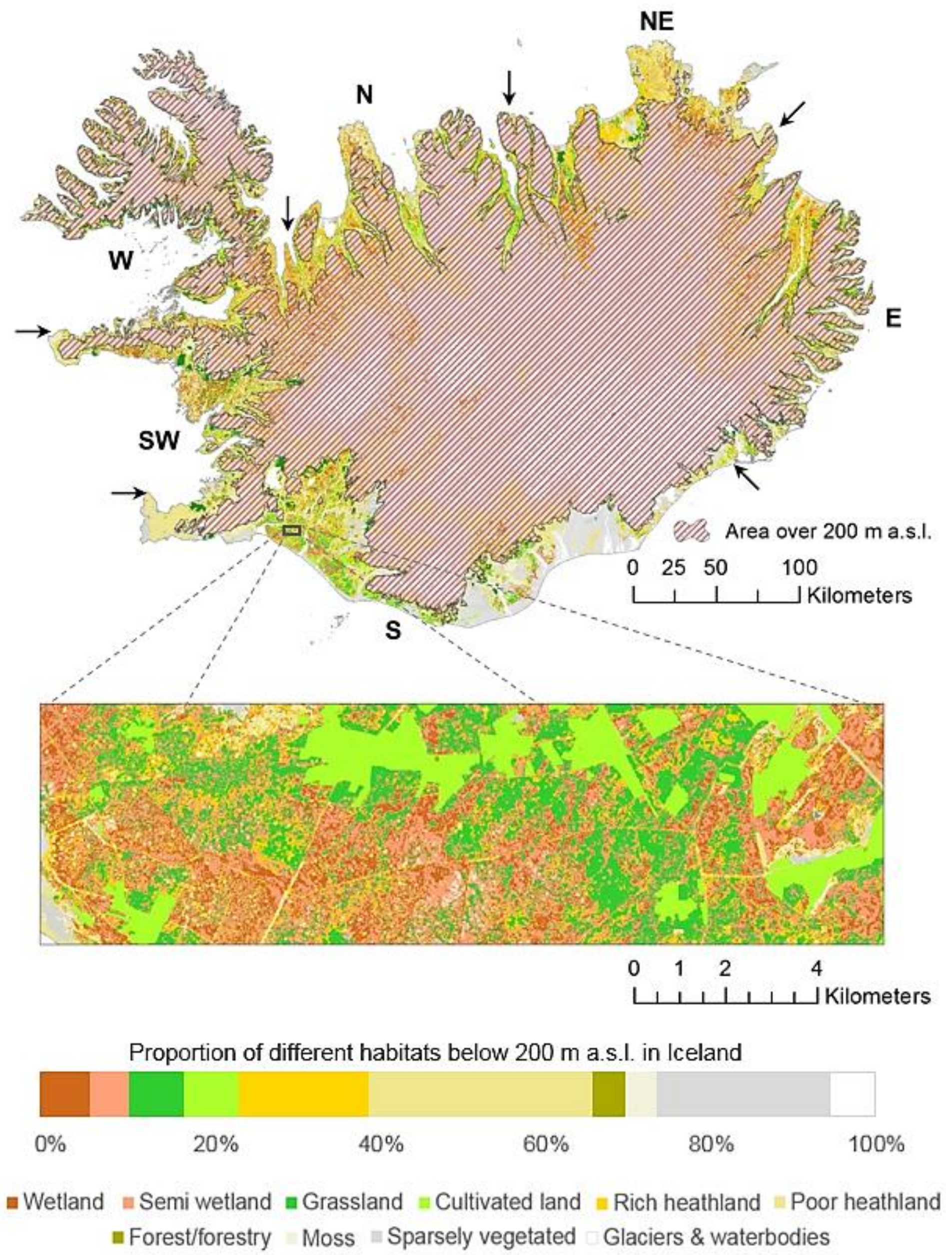

Fig. 1 -Composition and proportion of different habitats in Iceland below 200 m a.s.l. (striped areas are above that level). The central inset shows an example of the small scale mosaic of habitats typical of the agricultural areas in south Iceland. The arrows show borders between regions of the country.

Species	Subspecies	Population (pairs)	Data quality	Year of protection	Proportional distribution in different habitats
Oystercatcher	*(Haematopus ostralegus ostralegus)*	20 000	0	1914	
Golden Plover	*(Pluvialis apricaria altifrons)*	310 000	2	1914	
Dunlin	*(Calidris alpina schinzii)*	270 000	2	1914	
Common Snipe	*(Gallinago gallinago fareoensis)*	180 000	1	1914	
Whimbrel	*(Numenius phaeopus islandicus)*	250 000	2	1954	
Black-tailed Godwit	*(Limosa limosa islandica)*	25 000	2	1904	
Common Redshank	*(Tringa totanus robusta)*	140 000	2	1914	

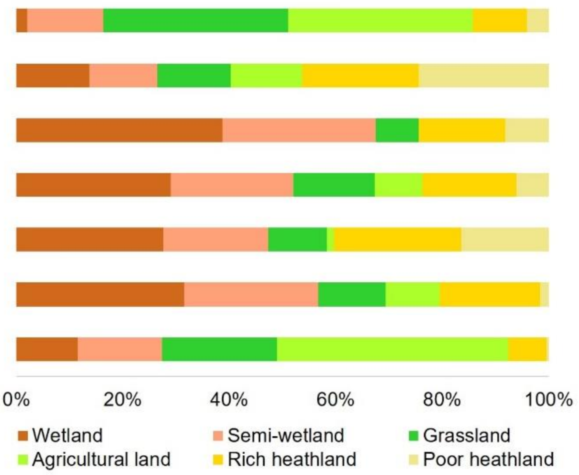

Fig. 2 - Population estimates of breeding wader species in lowland Iceland, and estimates of data quality (ranging from 0 (guesses) to 5 (full coverage);Thorup 2004); the percentage of the world population that breeds in Iceland (Delany & Scott 2002); the year each species was protected by Icelandic law (Schmalensee et al. 2013); and the proportional distribution of each species across the six main habitats they use in lowland Iceland (from Johannesdottir et al. 2014 - see Fig. 1 for habitat distribution).

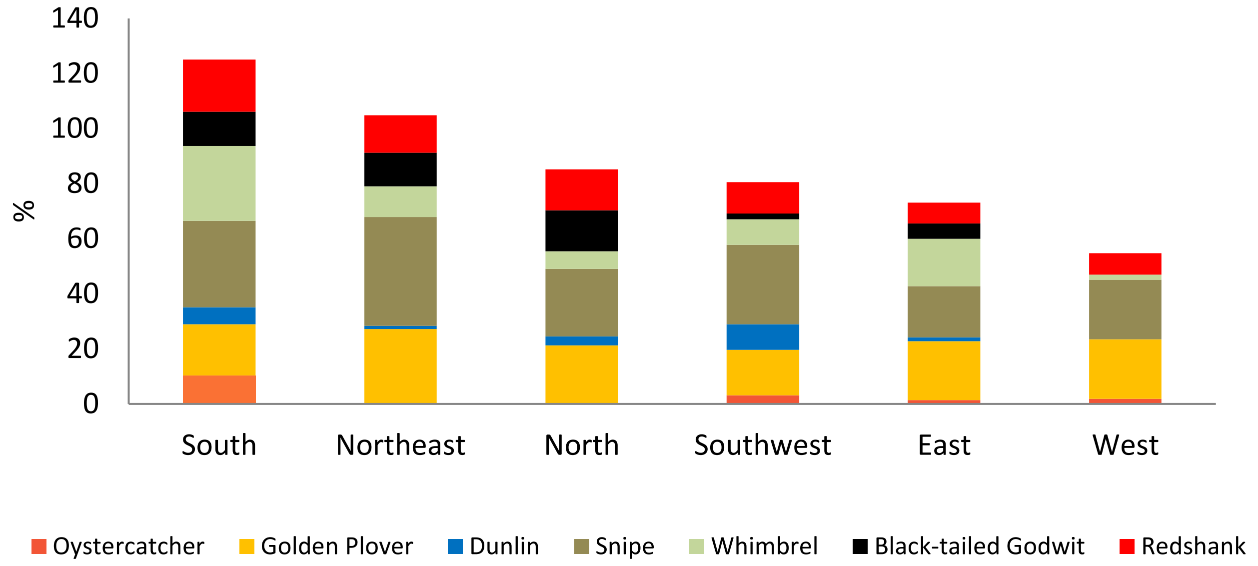

Fig. 3 – Regional variation in Icelandic meadow-breeding wader species throughout lowland Iceland, measured as percentage of survey points in each region at which each species was recorded (adapted from Gunnarsson et al, 2006). As each survey point can have more than one species, each region can total more than 100% (see Fig. 1 for regions).