Annual and large-scale variation of breeding output of Greylag geese (*Anser anser*) in Iceland

Helgi Guðjónsson

Faculty of Life and Environmental Sciences
University of Iceland
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Helgi Guðjónsson

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Advisors
Jón Einar Jónsson
Tómas Grétar Gunnarsson

External examiner
Arnór Þórir Sigfússon

Faculty of Life and Environmental Sciences
School of Engineering and Natural Sciences
University of Iceland
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Faculty of Life and Environmental Sciences
School of Engineering and Natural Sciences
University of Iceland
Askja, Sturlugötu 7
107, Reykjavik
Iceland

Telephone: 525 4000

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Abstract

In this study differences in the breeding output of greylag geese across Iceland were assessed over two years. The aim was to produce a large-scale comparison of parameters that relate to breeding output (timing of breeding, reproductive investment and brood sizes) and identify large-scale variation in these within Iceland and possibly between years. During the two years of sampling a total of 360 Greylag goose nests were visited across Iceland and factors relating to breeding output were measured. In addition 888 Greylag goose pairs were surveyed to estimated large-scale variation in brood sizes. Incubation phenology varied significantly between parts of the country and started on average on the 30^{th} of April in West- and South Iceland, but significantly later in North Iceland (10^{th} of May) and East Iceland (20^{th} of May). Clutch size did vary between research areas as East Iceland had a smaller clutch size than South and West Iceland. Little to no variation was found in clutch volume between areas and it was independent of year. East Iceland was found to have the smallest brood size on average while West and North Iceland had the largest brood sizes. Annual variation was relatively little and when annual means for the whole country were inspected the only significant difference found was in the mean number of goslings, where brood size was smaller in 2013. Regional variation in start of incubation is most likely related to mean temperatures as the south and west parts of the country have the most temperate climate. It is therefore likely that South and West Iceland, generally have more favourable breeding conditions. Further potential causes for differences in breeding output between regions in Iceland are discussed and what implications this has for a sustainable utilization of the Greylag goose population.

Útdráttur

Markmið verkefnisins var að afla gagna um breytileika í varpárangri (varptíma, fjölda eggja og fjölda uppkominna unga) grágæsa milli mismunandi landshluta og mögulega milli ára. Þessar upplýsingar gagnast fyrir nýtingu og verndun grágæsastofnsins. Á árunum 2012-2013 voru 360 grágæsahreiður rannsökuð og þættir sem hafa áhrif á varpárangur mældir. Að auki voru 888 grágæsafjölskyldur taldar til að rannsaka breytileika í ungafjölda milla landsvæða. Mikill munur var á upphafi varptíma milli landsvæða og byrjaði að meðaltali 30. apríl á Vesturlandi og Suðurlandi, en hófst mun síðar á Norðurlandi (10. maí) og seinast á austurlandi (20. maí). Urpt var nokkuð breytileg milli svæða og reyndist minni urpt á Austurlandi en á Vesturlandi og Suðurlandi. Breytileiki var lítill í rúmmáli urptar milli landshluta og var það óháð ári. Á Austurlandi voru að meðaltali fæstir unga á par en ungar á par voru flestir á Vesturlandi og Norðurlandi. Breytileiki í mældum þáttum var tiltölulega lítill milli ára en þegar heildarmeðaltöl voru skoðuð reyndist aðeins vera marktækur munur á meðalfjölda unga á par og reyndust þeir vera færri 2013. Líklegt er að munur milli landshluta og ára tengist hitastigi en skilyrði til varps virtust almennt hagstæðari á Suðurlandi og Vesturlandi. Breytileiki í æxlunarárangri grágæsa og nýting og vernd grágæsastofnsins er rædd.

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Introduction

The state of the Greylag goose population

Greylag geese are common breeding birds in most areas of the Palearctic but the Icelandic breeding population winters almost exclusively in Britain and Ireland (Madsen et al. 1999). There are two large breeding goose populations in Iceland, the Pink-footed goose (*Anser brachyrhynchus*) and the Greylag goose (*Anser anser*). The Greylag goose, greylag from now on, nests almost exclusively in lowland areas below 200 m above sea level in Iceland, the pink-footed goose has on the other hand a more aggregated distribution in the highlands (Mitchel et al. 1999). Since 1982, the trajectory of the two populations has diverged greatly, so that Pink-footed geese are now almost three times as numerous as greylags (Figure 1). Greylags have been regularly counted in autumn in Britain since the early 1950´s and they have increased from 20,000-30,000 birds in the 1950´s to c.a. 100,000 in the early 1990´s. In the later 1990´s both populations stopped increasing and the greylag population declined until 2000 when the population was estimated at 80,000 individuals, which is about 20% decrease in population size. It is not clear what caused this, although it is possible that a decrease in temperature is somewhat connected (Icelandic Meterological Office 2014). Since then both populations have rapidly increase again and today greylags are estimated at 105,000 while the Pink-footed goose is estimated at 350,000 individuals (Mitchell et al. 1999; Frederiksen et al. 2004a; WWT data 2014, Figure 1). Since 2000 there has been a considerable increase in cereal agriculture in Iceland, which coincides with the increase in both goose populations (Statistics Iceland 2014). It is therefore possible that this change in agricultural practices is connected to the growth of both goose species.

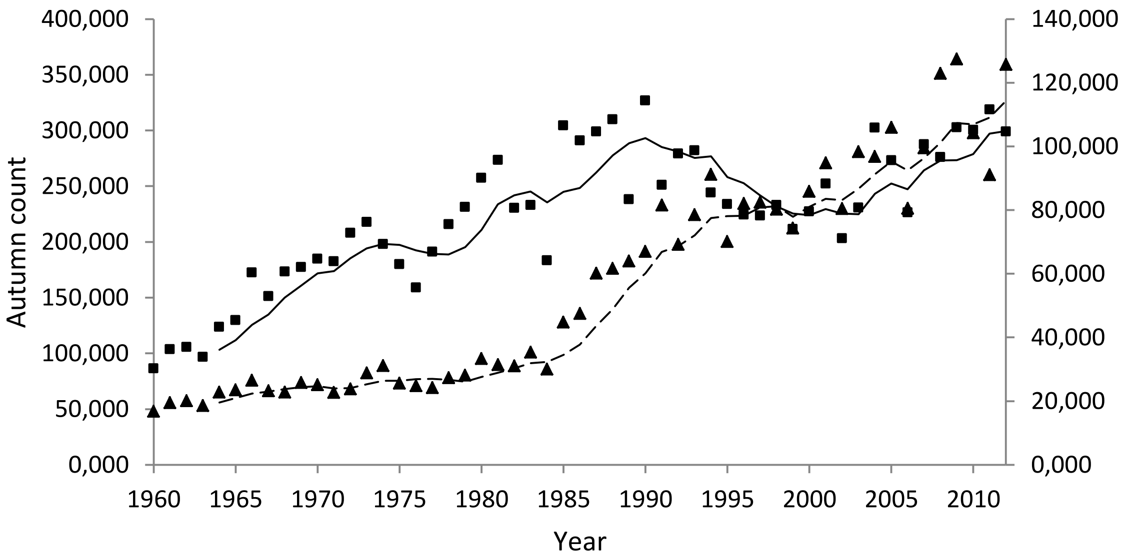

Figure 1. Autumn population size of greylag and pink-footed geese 1960–2012 in Britain, as recorded by the Wildfowl & Wetlands Trust goose survey. Annual total counts and 5-year running means are shown for greylag geese (squares and right y-axis) and pink-footed geese (triangles and left y-axis) (WWT data 2014).

Both goose populations are common quarry species in Iceland and bag statistics show that hunters in Iceland shot on average about 40 thousand greylags per year and about 15 thousand pink-footed geese, in the period 2000-2010 (The Environment Agency of Iceland 2014). The hunting season for greylags in Iceland is from 20th of August to 15th of March (The Environment Agency of Iceland 2014) and is timed so the geese should have finished moulting and the goslings are able to take flight. Despite of the extensive hunting the greylag population has been increasing and the Pink-footed goose has increased drastically in numbers (Mitchell 2013; Frederiksen et al. 2004a). Furthermore, it is estimated that in Great Britain about 15-20 thousand greylags are hunted every year (Hart & Harradine 2003). Frederiksen et al. (2004a) has suggested that the population size of greylags may be underestimated in the census in the winter grounds in Great Britain. It is also possible that strong density dependence is operating which allows the population to compensate for the high hunting pressure or that it would be growing in the absence of hunting (cf. Sutherland 2001). In many long-lived species such as geese, population changes have primarily been linked to a response to changes in survival rates, with fecundity playing a minor role (Sæther et al. 1996; Pistorius et al. 2004; Pistorius et al. 2006). The biggest factors causing this are changes in the bird's habitat or the development of their habitat (Sutherland 1996).

Recent changes in agricultural policy have led to extensive areas of largely uniform, intensely managed areas of grassland and cereals. This change has increased the carrying capacity of the European land mass for grazing birds and while the effect has been negative for many species the larger terrestrial herbivorous migratory waterbirds, such as swans and geese, have benefitted from the recent changes in abundance of farmland and have been increasing in population size the last few decades (Madsen et al 1999; Fox et al. 2005). Many goose populations have become increasingly reliant on cultivated land to feed upon, especially during the winter months, when geese utilize specially grown and bred high-quality crops. It is very likely that the conversion of natural habitats to agricultural land has been the dominant factor in the increase in goose numbers the last 50 years (Madsen et al. 1999). This increase in goose populations has led to increasing conflicts with farmers but has also resulted in increased information gathering relating to their abundance and population size over a long time (Fox et al. 2010). This conflict is not only present in Iceland, for example extensive research has been done in Scotland on the many methods used to mitigate damage by goose grazing. These methods are numerous but most commonly used are (culling, non-lethal scaring, compensation schemes for affected farmers and the creation of alternative feeding areas), the most effective way has been to utilize an integrated strategy with input from stakeholders at all levels. The strategy consists of a combination of top-down and bottom-up management whereby the government controls which management methods are to be used while groups on the local level ensure that the methods are tailored to each area (Cope et al. 2006; Tombre et al. 2013). Most of these methods are non-lethal as many populations are protected under the 1979 European Union Birds Directive (Directive 79/409/EEC).

In general, the management of goose-agricultural conflict has been dealt with mostly at the local level and there is a need for more concentrated effort to ensure success, both internationally and at the local level. In areas with no management schemes, farmers rely almost exclusively on scaring to defend their crops. Scaring, though, has been questioned on ethical grounds even though it is non-lethal and the birds in question are not endangered. Scaring is both time consuming for farmers and is often less than successful if not coordinated with neighbors (Eythórsson 2004). In some areas the establishment of a compensation scheme for farmers that are paid not utilize scare tactics has led to a condition which has benefitted both the agriculture in the region and the wintering goose population (Cope et al. 2003). This method is not though without its drawbacks as the question arises whether this means that all goose grazing in agricultural land should be compensated. This method is also often difficult to employ as few agree from which governmental budget the compensations come from, who are entitled to it, how much, and on what grounds. Furthermore, it is both complicated and expensive to accurately measure grazing damage (Tombre et al. 2013).

Links between habitat choice and fitness

In the arctic and northern temperate regions migratory geese are among the dominant herbivores (Smith & Odum 1981; Jasmin et al. 2008; Kerbes et al 2009) and geese interact strongly with anthropogenic interests as they are both an important quarry for hunters and their increasing utilization of agricultural farmland has led to increasing conflicts with the agricultural industry. Geese are among the most successful species in utilizing agricultural development and the increase of cultivated land (Abraham et al. 2005; Fox et al. 2005). Geese are able to take advantage of both cultivated land and natural wetlands but the highest food intake rate is usually on cultivated land (Fox et al. 2005; Jónsson & Afton 2006). In cultivated areas, energy density (KJ/g food) is higher and geese have to spend less time grazing as they would have to in natural habitats (Jónsson & Afton 2006). The ever constant pressure of creating better crops has successfully created plants with high protein and energy content as well as high digestibility. In addition, modern sowing techniques, growth regulators, fertilizers and pesticides have been further managed to ensure stable food production at ever increasing plant densities. This trend has also highly benefitted geese by enhancing food intake rate and availability (Fox et al. 2005). In many instances geese have become so highly dependent on the availability of farmland that they have changed their habitat preferences from natural wetlands to agricultural fields (Alerstam & Högsted 1982).

Greylag habitat choice is somewhat different between breeding-, wintering- and staging grounds. In wintering- and staging grounds greylags mostly take advantage of farmland and utilize sandbanks of estuaries, rivers, reservoirs and other large bodies of water for roosting (Owen et al 1986). During the breeding season breeding geese are mainly found in dwarf-birch bogs, marshes and river plains while non-breeding greylags are almost exclusively found on farmland (Gunnarsson et al. 2006). In addition greylags tend to favor areas that have a close proximity to lakes, rivers and wetlands (Gunnarsson et al. 2006). A few days after the goslings have hatched, greylag families tend to congregate into larger groups, which is about the same time as the adult become flightless (Madsen et al. 1999). During this time they are mostly found on farmland with convenient water sources as escape routes and on natural grasslands close to water. This journey from the main nesting site is most often performed when the goslings are only a few days old and the distance traveled can be over 30 km (Mainguy et al. 2006). The quality of the brood rearing habitat is very important as fledgling survival during autumn migration is often related to body mass (Owen & Black 2002). It is also very beneficial for the geese to nest close to high quality brood rearing areas as goslings that do not have to travel long distances have been found grow faster (Mainguy et al. 2006).

It is energetically expensive to produce eggs and raise goslings and the quantity of material that is required for egg production is high in relation to body weight (Reed 1973). Raising the goslings is also not without cost as gosling fitness has been linked to future adult reproductive value (Nikolai & Sedinger 2012). Goslings and adults have different nutritional requirements because of body size, as goslings require higher concentration of nutrients and energy in their diet while adults need a greater biomass (Sedinger 1997). If a brood rearing habitat is high in food quality but insufficient in biomass it may have an adverse effect on the energy intake of the adults. Raising of high quality broods may therefore have a carry-over effect on future adult reproductive value (Inger et al. 2010; Nikolai & Sedinger 2012).

As the highest quality areas are the most sought after they are subject to heavy grazing during the breeding season. An increased population size or density of individuals in feeding areas has been known to cause a decrease in food availability and, consequently, a decrease in fecundity and/or survival (Williams et al. 1993). As geese are philopatric to nesting areas and faithful to traditional feeding grounds, it is clear that as a population grows the grazing of high quality areas will intensify (Cooke et al. 1975; Cooke & Abraham 1980). The resulting environmental degradation then has an influence on the energy intake of grazers. As an environment degrades the geese need to feed more intensely, for a greater period of time and with an increasing rate of pace, still, net resulting in a declining energy intake rate (Vickery et al. 1995). In heavily grazed areas a correlation has been found between the degrading environment and declines in various fecundity and survival parameters, for instance mean clutch size (Cooch et al. 1989), gosling growth rate (Williams et al. 1993), and first-year (post-fledging) survival (Francis et al. 1992; Sedinger et al. 1995). In addition, Williams et al. (1993) showed that gosling survival was lower for those families that frequented heavily grazed areas while those that sought out alternate feeding areas had broods with higher survival. This density dependence effect is well known in many animal populations and regulates populations that are increasing in size. This effect is sometimes exploited in popular quarry species to keep fecundity high while the population is kept in a stable state with hunting (Sutherland 2001).

Conditions experienced in one season can have a drastic effect on fitness in subsequent seasons and is known as a carry-over effect, this is particularly evident among migratory species. As geese are migratory they spend different periods of the year in geographically distinct places and it is reasonable to assume that habitat occupancy and the resulting condition of individual birds is likely affected by events in the previous season. In addition, conditions of individuals and population density of the current season will influence individuals and populations in subsequent seasons (Norris & Marra 2007). Such seasonal interaction is not only limited to individuals as it can also interact at the population level. Interactions on the individual level occur when events and conditions in one season produce non-lethal, carry-over effects that influence individuals the subsequent season while interactions on the population level occur when a change in population size in one season influences recruitment rates the following season (Sutherland 1996; Norris & Marra 2007).

Nesting ecology & breeding success

Bird populations are very susceptible to environmental changes as breeding success depends both on food availability and timing of breeding to coincide with climax in food availability. Mortality rates of adult greylags on the winter grounds in Great Britain are mostly influenced by availability of convenient farmland (Gill et al. 1997; Swann et al. 2005). If the quality of the wintering grounds is sufficient then the energy reserves stored by geese during spring migration allows them to initiate nesting before food supplies become abundant (Raveling 1979). Usually geese have the highest body weight and maximum amount of fat reserves at the start of the breeding season in preparation for migration, territorial defense and egg production (Ryder 1970; Reed 1973; Raveling 1979). It has therefore been suggested that for many geese species fat reserves are attained mainly in the few weeks before migrating north, although their body condition throughout winter undoubtedly influences the rate at which they obtain fat reserves and their ability to carry it (Reed 1973). Migratory birds that breed in the high Arctic are limited by a short summer season. During this time they have to complete breeding, moult, raise young and prepare for the return journey before winter sets in. For them to succeed, nesting as early as the snow melts is highly beneficial (Raveling 1979; Madsen et al. 2007). Snow cover in breeding grounds has been found to heavily affect both timing and reproductive success in high Arctic breeding geese (Madsen et al. 2007). Despite of this, little connection has been found between precipitation and reproductive success. On the other hand, more correlation has been found between spring temperatures in breeding areas and start of incubation (Summers & Underhill 1987).

Start of incubation is very important to most birds as offspring that hatch sooner in the spring often have better life expectancy but this is also often connected to food availability and how mature the offspring are at the time of autumn migration (Poussart et al. 2000; Prop et al. 2003; Durant et al. 2004; Frederiksen et al. 2004b). It is therefore of great importance for birds to coincide the hatching of offspring with the climax in food availability. Geese are among birds that have precocial offspring that are relatively independent at hatching and the nest is therefore soon abandoned after the offspring have hatched. It is normal for birds with precocial offspring to hatch eggs synchronously even if incubation is initiated before the final egg of the clutch has been laid (Hanssen et al. 2002). One mechanism that birds may use to achieve this is by decreasing egg size after the start of incubation in an effort to either ensure synchronous hatching or to decrease fitness cost of late hatching eggs (Gladbach et al. 2010; Hanssen et al. 2002). Another mechanism proposed is that embryos in late eggs can be stimulated to accelerate development and hatch in a shorter time than earlier eggs (Hanssen et al., 2002). This decrease in incubation time of late laid eggs may lead those offspring to be less developed than their siblings, and offspring from small and late laid eggs have in addition a slower growth rate (Anderson & Alisauskas 2002; Hanssen et al. 2002).

An early start of incubation is known to be often positively related to fitness in birds as those individuals that first lay eggs are generally those that are in the best physical condition, lay the largest clutches and have the best nesting success (Erikstad et al. 1993; Bêty et al. 2004; Arnold et al. 2004). The number of eggs shows a correlation to the physical condition of geese and ducks (Ankney & MacInnes 1978; Erikstad et al. 1993; Öst et al. 2008; Gladbach et al. 2010). Nesting of geese is often synchronized, commonly up to 90% of nests are initiated within an 8 day period (Lepage, Gauthier & Menu 2000). Clutch size has been shown to decrease with a later start of nesting in many species of birds, and the life expectancy of offspring often shows a negative regression to date of hatching (Lepage et al. 2000; Arnold et.al 2004; Traylor & Alisauskas 2006). The relationship between the start of incubation and nesting success has in addition been found to be curvilinear as both early and late nests have a higher rate of failure than those that initiate nesting near the median (Lepage et al. 2000). Age has also been known to influence reproductive success in birds and a study by Black & Owen (1995) suggested that age at breeding can have a considerable effect reproductive success. Low reproductive success in the early years of breeding was attributed to females, which might be due to inexperience in food and feeding area selection. Low reproductive success in later years of breeding was on the other hand attributed to males, as their fighting ability declines with age which influences their ability to attain and defend suitable nesting sites (Black & Owen 1995). A few studies have also found a strong correlation between lemming abundance and breeding success of geese, which is consistent with the hypothesis that predators, such as Arctic Foxes, that usually prey on lemmings switch over to geese and other birds when lemming numbers are low (Summers & Underhill 1987; Nolet et al. 2013).

As previously discussed, reproductive success is influenced by many things and can even be influenced by conditions in previous seasons. Species with extended parental care, for instance geese, are also influenced by parental status as this can affect them later in life (Lepage et al. 2000; Inger et al. 2010). Goose families are dominant over individuals and are often able to monopolize the best quality resources, but it has been shown that later in the non-breeding season adults with families utilize resources of lower quality than non-breeders, this has been attributed to parents being constrained by the lowered foraging efficiency of the juveniles (Inger et al. 2010). Adult geese that recently raised juveniles have also been found to be less likely than expected to breed again in the next breeding season and it has been suggested that this may be caused by conditions during the non-breeding period that are carried over into the subsequent season (Inger et al. 2010).

The Icelandic Greylag goose

In Iceland the most likely threat to the greylag habitat are change in land-use patterns in lowland areas, for instance an increase in commercial afforestation, increasing pressure to bodies of water (for instance through building of summerhouses and fish farming), increased traffic due to recreation, and increased amount of farming in the species nesting habitat (Gunnarsson et al. 2006; Gunnarsson et al. 2008). It is also not foreseen what the effects of river regulation for electricity production will have in lowland areas of Iceland but it is well known that such changes can change the animal communities on and along rivers (Nilsson & Dynesius 1994). It is known that dams have a high impact on the ecosystems and biodiversity has been known to decrease when the flow of rivers is regulated (Kingsford & Johnson 1998; Kingsford 2000). It is therefore important to carry out research to better understand what effect increasing anthropogenic activities will have on the greylag population. More information is also needed about the nesting ecology of greylags in Iceland and the factors that influence productivity. The recent study by Gunnarsson et al. (2008) made a quantitative assessment on nesting habitat choice of greylags on a country-wide scale (Gunnarsson et.al. 2008). The connection between habitat choice and breeding success is still unknown but such information would allow prioritization of habitat conservation by importance to greylags.

To ensure a sustainable utilization of an animal population, the crucial factors that limit population size must be monitored and a good understanding on demographic rates must be obtained (Caughley & Sinclair 1994). Recent studies on greylags in Iceland have shed light on many factors influencing population changes and habitat choice of greylags in Iceland. What we lack are studies on variation in breeding success and output between parts of the country and an assessment on what areas are most important to the greylag population. In this study differences in the breeding output of greylag geese across Iceland were assessed over two years. The aim was to produce a large-scale comparison of parameters that relate to breeding output (timing of breeding, reproductive investment and brood sizes) and identify large-scale variation in these within Iceland and between years.

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Manuscript

Annual and large-scale variation in breeding output of Greylag geese (*Anser anser*) in Iceland

Helgi Guðjónsson[1], Jón Einar Jónsson[2], Halldór Walter Stefánsson[3], Aðalsteinn Örn Snæþórsson[4] & Tómas Grétar Gunnarsson[5]

[1]University of Iceland, Department of Life- and Environmental Sciences. Askja, IS-101, Reykjavík, Iceland

[2]University of Iceland,Snæfellsnes Research Center, Hafnargata 3, IS-340 Stykkishólmur, Iceland.

[3]East Iceland Natural History Institute, Mýrargata 10, IS-740 Neskaupstaður and Tjarnarbraut 39a, IS-700 Egilsstaðir, Iceland

[4]North East Iceland Nature Center, Hafnarstétt 3, IS-640 Húsavík, Iceland

[5]University of Iceland, South Iceland Research Center, Fjolheimar, Bankavegur, IS-800 Iceland.

Abstract

Capsule Large-scale variation in breeding output of Greylag geese (*Anser anser*) is relatively little but detectable variation is most likely linked to spring temperature.

Aims To ensure a sustainable utilization of animal populations, information on parameters that limit population size and on demographic rates must be obtained. Greylags are a favourite quarry species in Iceland but data on breeding demography are scarce. We made a large-scale comparison of parameters that relate to breeding output to identify spatial and annual variation.

Methods In 2012 and 2013, a total of 360 greylag nests were visited across Iceland and parameters relating to breeding output were measured (timing of breeding, reproductive investment and brood sizes). In addition, 888 greylag families were surveyed in the same period to estimate large-scale variation in brood sizes.

Results Incubation phenology varied significantly between parts of the country and started on average on the 30th of April in West- and South Iceland, but significantly later in cooler parts of Iceland, North Iceland (10th May) and East Iceland (20th May). In 2012 we found no difference in clutch size between areas but in 2013 East Iceland had a smaller clutch size than South and West Iceland. Overall, clutch size was around 4-6 eggs and was similar between years. We found little to no variation in clutch volume between areas and this was independent of year. Mean brood size varied from 3-5 between regions, where East Iceland was found to have the smallest brood size on average while West and North Iceland had the largest brood size. The parameter showing the largest difference between years was the brood size, where brood sizes were smaller in West and South Iceland in 2013.

Conclusion Regional variation in the start of incubation is most likely related to ambient temperatures as the South and West parts of the country have a relatively more temperate climate than the North and East. There are indications that conditions for breeding may be more favourable in South and West Iceland. We discuss further potential causes for differences in breeding output between regions in Iceland and what implications this has for a sustainable hunting of the greylag population.

Introduction

Agricultural changes have had a profound effect on many species of birds the last few decades. Recent changes in agricultural policy have led to extensive areas of largely uniform, intensely managed areas of grassland and cereals. This change has increased the carrying capacity of the European land mass for grazing birds and while the effect has been negative for many species the larger terrestrial herbivorous migratory waterbirds, such as swans and geese, have benefitted from the recent changes in abundance of farmland and have been increasing in population size the last few decades (Madsen et al 1999; Abraham et al. 2005; Fox et al. 2005). Geese take advantage of both cultivated land and natural wetlands but the highest food intake rates are usually on cultivated land (Fox et al. 2005; Jónsson & Afton 2006). It is very likely that the conversion of natural habitats to agricultural land has been the dominant factor in the increase in goose numbers the last 50 years (Madsen et.al 1999). This has led to increasing conflicts with farmers but has also resulted in increased data collection on their abundance and population size over long time scales (Fox et al. 2010). Many geese are also a common quarry species and considerable interests lie in the continuation and stability of populations. To ensure a sustainable utilization of an animal population, the crucial factors that limit population size must be monitored and a detailed understanding on demographic rates must be obtained (Caughley & Sinclair 1994; Sutherland 2001).

In many long-lived species such as geese, population changes have primarily been linked to a response to changes in adult survival rates, with fecundity generally playing a smaller role (Sæther et al. 1996; Pistorius et al. 2004; Pistorius et al. 2006). Important drivers of variation both in survival and productivity are changes in the bird's habitat or the development of their habitat (Sutherland 1996). Adult survival of geese on the wintering grounds is mostly influenced by availability of suitable farmland (Gill 1996; Swann et al. 2005). On the nesting grounds the limitation of breeding success is usually the most important driver of population changes (besides hunting) but it is mostly influenced by availability of suitable habitat and the spatial distribution of populations in relation to habitat.

Several common correlates to fitness can be useful for estimating variation in habitat quality and reproductive output. An early start of incubation is often positively related to fitness in birds as those individuals that first lay eggs are generally those that are in the best physical condition, lay the largest clutches and have the best nesting success (Erikstad et al. 1993; Arnold et al. 2004; Bêty et al. 2004). Offspring that hatch earlier in spring have often a better life expectancy but this is often connected to food availability and how mature the offspring are at the time of autumn migration (Poussartet al. 2000; Prop et al. 2003; Durant et al. 2004; Frederiksen et al. 2004a). The number of eggs shows a correlation to the physical condition of geese and ducks (Ankney & MacInnes 1978; Erikstad et al. 1993; Öst et al. 2008; Gladbach et al. 2010). Gladbach et al. (2010) also concluded that the mean egg volume and total clutch volume increased with female body condition and that hatching date is earlier for females in better body condition. Clutch volume and clutch size may therefore give a good indicator of physical condition of breeding geese. Clutch size decreases with later nesting in many species of birds (Arnold et.al 2004) and the life expectancy of offspring often show a negative regression to date of hatching among ducks (Traylor & Alisauskas 2006).

The Greylag goose (*Anser anser*), greylag from now on, is the most common breeding goose across the lowlands of Iceland, i.e., below 200 meters above sea-level in Iceland, where large-scale habitat selection and distribution have been assessed (Gunnarsson et al. 2008). The Icelandic population overwinters mostly in Great Britain and returns to the breeding grounds in Iceland early in the spring in March and April (Swann et al. 2005; Gunnarsson & Tómasson 2011). Variation in space and time, in parameters which relate to breeding output, are however unknown, but this information is needed for successful management and conservation. Bag statistics show that hunters in Iceland shoot on average about 40 thousand greylags per year, average of hunting statistics 2000-2010 (The Environment Agency of Iceland 2014). Despite of the extensive hunting the greylag population has been slowly increasing and is estimated at approx. 105 thousand individuals in late autumn after hunting in Iceland, 2012 census (Mitchell 2013). Furthermore, it is estimated that in Great Britain about 15-20 thousand greylags are hunted every year (Hart & Harradine 2003). Frederiksen et al. (2004b) suggested that the population size was underestimated in the census on the winter grounds in Great Britain which could explain how the population was doing well despite the intensive hunting. It is also possible that strong density dependence is operating which allows the population to compensate for the high hunting pressure or that it would be growing in the absence of hunting (cf. Sutherland 2001). In Iceland the most likely threat to the greylag habitat are changes in land-use patterns in lowland areas, for instance an increase in commercial afforestation, increasing pressure to bodies of water (for instance through building of summerhouses and fish farming), increased traffic due to recreation, and increased amount of farming in the species nesting habitats (Gunnarsson et al. 2006; Gunnarsson et al. 2008). It is also not foreseen what the effects of river regulation for electricity production will have in lowland areas of Iceland but it is well known that such changes can change the animal communities on and along rivers (Nilsson & Dynesius 1994). It is known that dams have a high impact on the ecosystem and biodiversity has been known to decrease when the flow of rivers is regulated (Kingsford & Johnson 1998; Kingsford 2000).

In this study we assessed differences in the breeding output of greylags across Iceland over two years. The aim was to produce a large-scale comparison of parameters that relate to breeding output (timing of breeding, reproductive investment and brood sizes) and identify large-scale variation in these parameters within Iceland and between years.

Materials & methods

Study areas

Fieldwork was conducted during the spring and summers of 2012-2013. Study areas were chosen across the country to capture possible large-scale variation in breeding parameters (Figure 1). Greylags nest almost exclusively in the lowlands of Iceland (under 200 meters above sea-level (Tómas Grétar Gunnarsson et al. 2008) and they are found around the whole country. The study was split into two phases: nest survey and gosling survey.

Nest survey

Each study area was visited in both years on a period from the first of May to the first of June. Sampling in each area took 2-3 days on average and the first area visited was West Iceland, then South and East and lastly the North. Major rivers and wetlands in each area were searched to locate breeding colonies and sample nests. Most nests were situated in small islands in rivers but in West Iceland nests were in islands in the Breiðafjörður bay (Figure 1). The search effort for nests differed between areas as the nest concentration and the supply of suitable nesting habitat varied between areas.

Gosling survey

Greylag flocks were surveyed during a three month period (June - August). Each area was covered at least once each month during the survey time. Brood surveys were conducted on a larger scale than the nest search since post-laying geese disperse, often over large areas. The search was conducted by driving parallel to major rivers and selected lakes in the catchment area, or along the coastline, as in the case of Breiðafjörður. Frequent stops were made and the area surveyed for geese with binoculars and spotting scopes.

The surveyed areas (Figure 1) in South Iceland ranged from the banks of Ölfusá to Eystri Rangá. The surveyed area for West Iceland was extended south and we included the area from Borgarfjörður to Kollafjörður. For North Iceland the surveyed area ranged from Vatndalsá and east to Víkingavatn. The East Iceland surveyed area ranged from the river Jökulsá á Brú to Lagarfljót lake.

Measures of productivity

Nest search

Greylag clutch size (eggs per nest), egg size (length & width), clutch volume (total volume of eggs per nest) and estimated start of incubation were measured for each nest. To minimize disturbance, risk of desertion and the effects of cooling of eggs, the time at each nest and colony was kept as short as possible. When measurements at each nest were completed, the eggs were covered with nest down to minimize the risk of predation and to reduce heat loss. Start of incubation was estimated by egg flotation (Westerskov 1950) and first day of incubation back-calculated by: Days from start of incubation = sampling date x 4.67 – 2.33 (Walter & Rusch 1997). We finally subtracted days from start of incubation from the sampling date and received estimated start of incubation, in ordinal days. To calculate egg volume we used the equation: Volume (cm^3) = 0.507 x length x width^2 (Westerskov 1950). Clutch volume was found by combining the total volume of eggs in each nest.

In 2012, measurements for North Iceland included only clutch size and timing of incubation and in 2013 only clutch size was recorded for East Iceland (Table 1). We included all nests that were visited in the analysis and did not differentiate between nests by clutch size. Since geese start incubation over a number of days, we could not accurately differentiate between nests where the goose had finished laying eggs or those that still had not finished, despite floating of eggs.

Gosling surveys

Brood sizes were estimated from the first week of June to the first week of September each year. Each time greylags were sighted the number of all greylags, with and without goslings, were recorded and the total number of geese at each location. From those measurements the average brood sizes could be compared between areas and years. Brood size was the number of goslings with each pair or individual adult greylag over the course of each sampling period, averaged over areas and years. We could not be sure whether we saw the same broods or new ones when we re-visited locations between months and hence we included all broods recorded in each area during the sampling period in the data.

Data analysis

Area and pooled annual variation in clutch size, egg size, clutch volume, start of incubation and mean brood size was assessed by ANOVA. We used Tukey's Honest Significant Difference as a post-ANOVA test to help distinguish differences between areas in the ANOVA. For an independent test for comparing difference between years within each area we used Welch two sample t-test. Year and area were explanatory variables. Statistical analyses were performed in R 2.15.2 (R Core Team, 2013).

The map of the research areas was made with ArcMap 10.1 using the ISN93 projection and based on the IS50V database.

Results

General variation in productivity

In the two years of sampling a total of 360 greylag nests and 888 greylag pairs with goslings were sampled across Iceland (Table 1). Overall, the average clutch size was 4.7 and ranged from 1 to 10 (Figure 2a). Length was on average 84.0 mm and ranged from 54.1 - 94.2mm. Average width was 57.7 mm and ranged from 49.3 – 62.1mm. The average clutch volume was 658 cm^3 and ranged from 123.4 cm^3 to 1369.0 cm^3. The average start of incubation was on day 124 (4^{th} of May) and ranged from 100 (10^{th} of April) to 157 (6^{th} of June). In the gosling surveys, overall average brood size was 3.6 and ranged from 1-12 goslings per pair.

Between area productivity

Greylag clutch size did vary between areas and was independent of year, as no interaction between Area*Year was found (Table 2). Both length and width of eggs varied between years but were dependent on area (Area*Year interaction significant) (Table 2). There was no variation in clutch volume between areas (Table 2). Start of incubation differed between areas independent of year (Table 2). Brood sizes differed greatly between areas, depending on year (Table 2).

Clutch size was smaller in East Iceland than both South and West Iceland and North Iceland was in between (Figure 2a). Start of incubation was almost the same between West- and South Iceland (Figure 2b). West- and South Iceland started incubation on average on day 119 (30^{th} of April), North Iceland started on average ten days later (10^{th} of May) and last came East Iceland on average ten days after that (20^{th} of May) (Figure 2b). There was very little variation in clutch volume between areas (Figure 2c). Mean brood size varied from 3-5 goslings between areas, and East Iceland had the smallest brood size on average (Figure 2d) while West and North Iceland had the largest brood size. West Iceland had the largest brood size in 2012 but in the following year that number declined and was similar to North Iceland (Figure 2d).

Annual variation in productivity

In the second year of sampling, fewer nests were found in South and West Iceland when re-visiting study areas from the previous year (Table 1). Annual clutch size, with all areas pooled, varied little between years and little difference was found in annual length and width between years (Table 2). Estimated start of incubation varied little and was consistent between years (Table 2). Brood size showed a positive interaction between years and an area-year interaction (Table 2). When inspecting annual means the only significant annual difference found was in the mean brood size, with smaller mean brood sizes in in 2013.

Clutch size within areas was found to increase slightly in West Iceland between years (Table 3). Length of eggs showed a slight increase in West Iceland between years but there was little difference in South Iceland (Table 3). Width of eggs differed slightly between years in South Iceland where it was smaller in 2013 but there was no significant change in West Iceland (Table 3). A slight increase in clutch volume between years was found in West Iceland while there was no noticeable difference in South Iceland (Table 3). Estimated start of incubation did not vary within areas between years (Table 3). Brood size was noticeably lower in West Iceland and slightly lower in South Iceland in 2013 while there was little variation in North and East Iceland between years (Table 3).

Discussion

During the two study years we found that there was some noticeable difference in all parameters either between years or areas except for in clutch volume. Out of six parameters that were measured we found a significant difference between areas in three (clutch size, start of incubation and brood size) and one between years (brood size). Clutch size differed between areas as East Iceland had fewer eggs than the South and West Iceland. In addition we found a variation in egg length and width where in 2013 West Iceland had both longer and wider eggs than the other areas. Start of incubation differed greatly between areas but not between years. We found that South and West Iceland were earliest and virtually identical in the start of incubation and then came the North and finally

East Iceland. The South and West study areas were almost identical in most measured parameters although West Iceland showed a bit more variation in most parameters between years than the South. North Iceland differed mostly from South and West by having a later start in incubation. East Iceland seemed to have consistently both smaller clutches and brood sizes than the other areas between years and the latest start of incubation. In general there was little annual difference in mean annual values except for brood size, which were smaller in 2013.

Clutch size average 4.7 eggs and was similar between years which, with the small differences in clutch volume, suggest that conditions for adults were sufficiently good for egg production in both years. In 2013 we found fewer nests in south- and west Iceland than in the previous year when we visited the same locations. It is well known for some ducks and other long lived species to skip breeding or abandoning the nest right after laying eggs if conditions are unfavorable and survival is potentially poor (Coulson 1984). We do not know if this was only an annual variation, a result of a colder spring in 2013 than in 2012 or a result of our sampling the previous year. It is though highly unlikely that the sampling had different effect in the south and west Iceland than in the north and east. A possible explanation for this is when conditions are not as favorable only the high-quality individuals lay eggs and those in poor condition skip breeding (Oro et al. 2013). We suggest that this explains why there were fewer nests in 2013 but little change in clutch size or clutch volume.

We saw a considerable difference in the start of incubation between parts of the country and this difference was independent of year. This difference could be linked to differences in temperature in the different parts of the country (Einarsson 1987). Spring temperature for the different areas shows a similar trend as the start of incubation (Figure 3). This may suggest that spring temperature influences breeding phenology, possibly through timing of vegetation growth and body condition of females (Summers & Underhill 1987; Gladbach et al. 2010). Brood sizes were lower in 2013 except for North Iceland, but the difference might be explained by the smaller sample size of 2012. The results from the gosling survey show also a significant difference on mean brood size between the research areas. Mean brood size was smaller in East Iceland than in the other areas. It might therefore be possible that the delay in the start of incubation is having an adverse effect on the life expectancy of the goslings (Lepage et al. 2000). There was a significant decrease in brood size in South- and West Iceland in 2013, and there might be a possible link between the decrease in gosling survival and the lower temperature. Temperature affects many factors, for instance length of growth season for plants (Walker et al. 2006), and it is possible that the delayed start of incubation and the shorter growth season are having a negative effect on the life expectancy of goslings. Lower brood size in East Iceland might be caused by a range of factors, including predation (Young 1972; Summers & Underhill 1987; Ebbinge 1989; Hersteinsson & Macdonald 1996), weather and temperature difference (Einarsson 1987; Summers & Underhill 1987; Sedinger 1992), and food availability (Mainguy et al. 2006) but the contribution of each is unknown.

The most notable difference between study areas is the start of incubation and the brood size. The earlier start in incubation in the South and West Iceland would give the goslings a considerable advantage as they have longer time to develop and grow. This coincides with a longer growth season in the South and West Iceland in a milder climate. We therefore suggest that South and West Iceland, generally have more favourable breeding conditions. South Iceland has the largest surface area dedicated to farmland in the country (National Land Survey of Iceland 2009) and is therefore highly important for breeding greylags as well as non-breeding. This study has mainly investigated the differences in breeding output between areas in Iceland. However, breeding greylags are more common per unit area in the East and Northeast, which is probably due to different availability of suitable habitat types around the country (Gunnarsson et al. 2008). So even though breeding conditions seem more favourable in the South and West, areas in the East and North are very important in the overall production of greylags across Iceland. Conversely, since these two years were highly different we suggest that these birds are robust regarding spring temperatures as we found little variation between years in clutch size and clutch volume. Furthermore, if the birds arrive in sufficient body condition, their success may be indifferent of spring conditions physical condition of the birds is sufficiently high when they arrive they are not as dependent on the conditions in breeding grounds (Reed 1973; Raveling 1979; Summers & Underhill 1987; Madsen et al. 2007).

This study is a significant step towards a better understanding of breeding output of Greylag geese in Iceland. For a sustainable hunting of the greylag population a more long term study is needed that would also account for long term changes in temperature and weather conditions during the spring. A large-scale marking program where the success of individual geese breeding in different habitats and across Iceland, followed over more years, would add significantly to our understanding of the large-scale demographic processes which are needed to develop a successful management strategy for this population.

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Figures

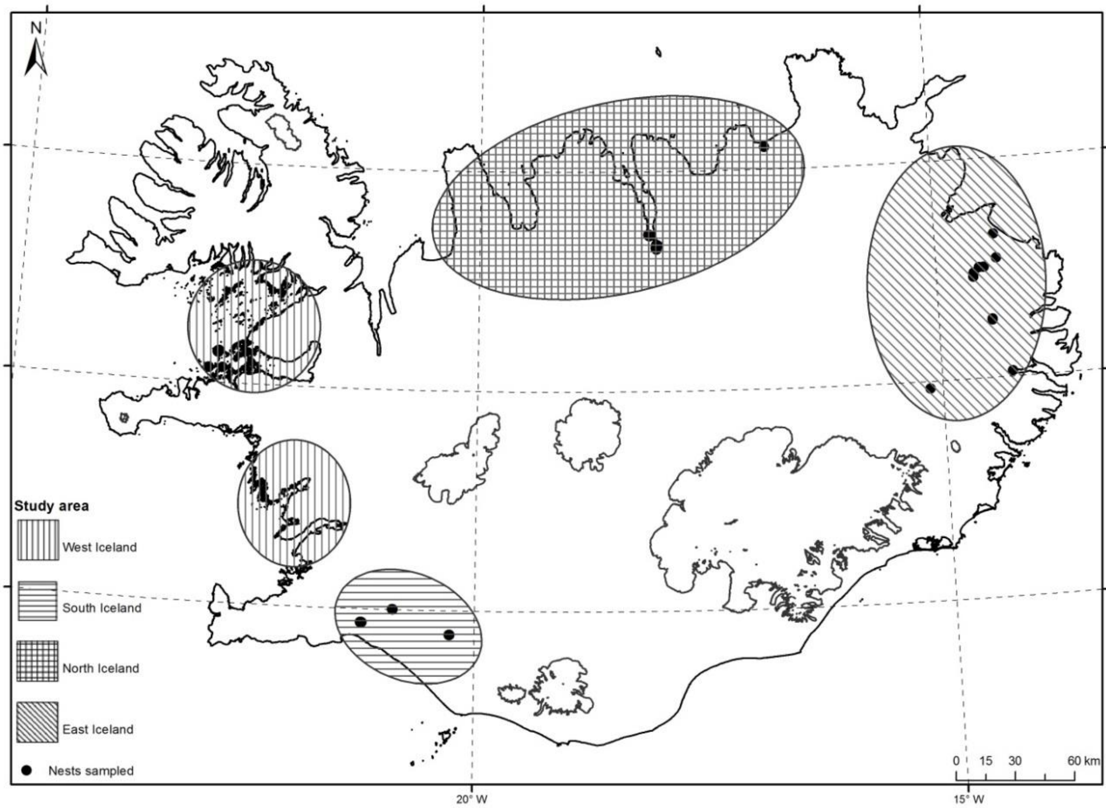

Figure 1. Location of study areas and nest sampling locations. The elypses show the areas where surveys of broods were performed. West Iceland (Vertical symbols), South Iceland (Horizontal symbols), North Iceland (Square hatching symbols) and East Iceland (Diagonal symbols).The large non sampled area in the southeast of Iceland is dominated by sparsely vegetated glacial sand plains. Locations of nests that were sampled are marked with circles.

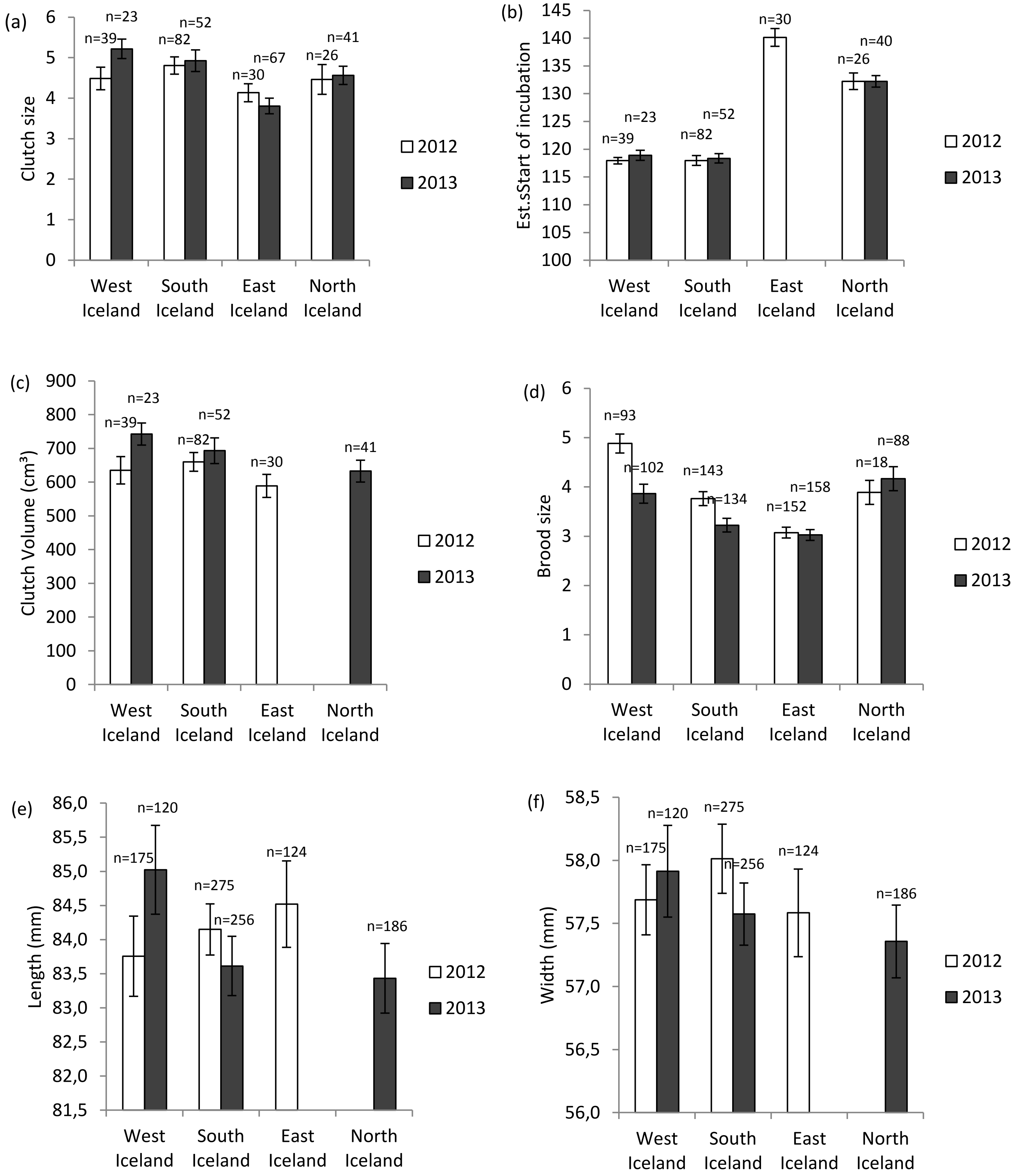

Figure 2. Annual and between area variation in mean (±se) (a) clutch size, (b) estimated start of incubation, (c) clutch volume, (d) brood size, (e) length of eggs and (f) width of eggs. White columns indicate values for 2012 and black columns indicate values for 2013. East Iceland lacks data in b,c,e and f for 2013 and was therefore not included. See Fig 1.for research area locations and details and Table 1 for n values.

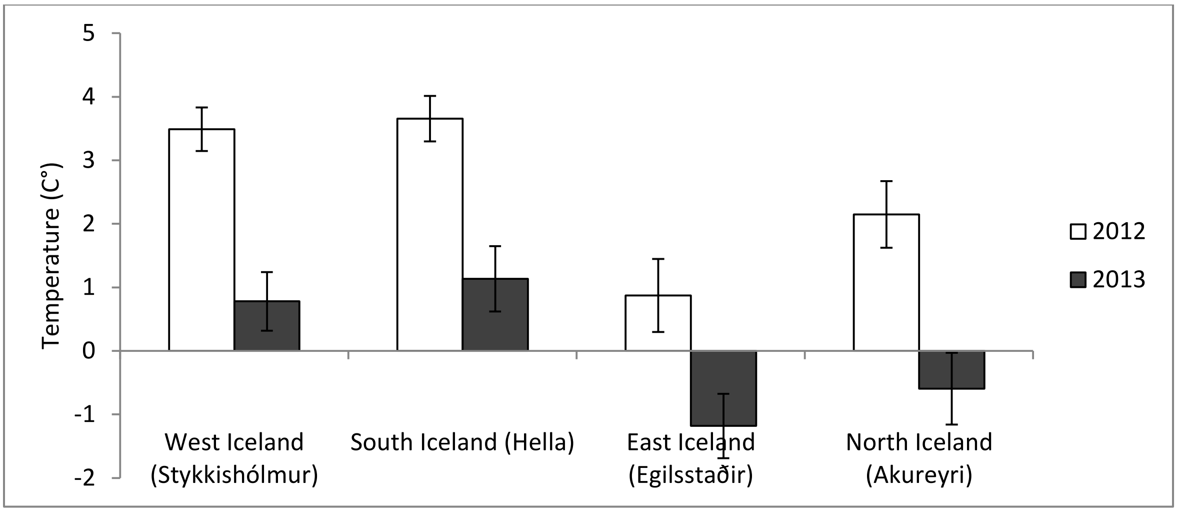

Figure 3. Annual and between area variation in mean temperature (±se) in april for the two sample years. Meteorological data from closest weather station to corresponding researh area (Icelandic Met Office, 2014). Names of the weather stations are given in parentheses.

Tables

Table 1. Numbers of Greylag goose nests, eggs, pairs with goslings and goslings monitored in each area in each year of the study.

	2012				2013			
Area	Nests	Eggs	Pairs w.goslings	Goslings	Nests	Eggs	Pairs w.goslings	Goslings
West Iceland	39	175	93	454	23	120	102	395
South Iceland	82	275	143	538	52	256	134	432
East Iceland	30	124	152	467	67	255	158	478
North Iceland	26	111	18	70	41	186	88	371

Note. In 2012 we only received number of eggs from North Iceland and in 2013 we only received data for number of eggs and estimated start of incubation from East Iceland.

Table 2. Results of ANOVA models of annual and between area variation in components of productivity of Greylag Geese in Iceland, between 2012 and 2013.

		Area	Year	Area*Year
Clutch size	F	6.127	0.119	1.135
	df	3	1	3
	p	<0.001	0.73	0.335
Length (mm)	F	3.570	1.630	13.429
	df	3	1	1
	p	0.0136	0.203	<0.001
Width (mm)	F	2.733	1.626	4.592
	df	3	1	1
	p	0.0426	0.203	0.0323
Clutch Volume	F	1.242	1.242	0.833
(cm^3)	df	3	3	1
	p	0.295	0.295	0.362
Est. Start of	F	133.600	0.247	0.26
incubation	df	3	1	2
	p	<0.001	0,62	0.771
Brood size	F	22.640	5.296	3.579
	df	3	1	3
	p	<0.001	0.0216	0.0136

Note. See Table 1 for details on sample sizes.

Table 3. Results of Welch two sample t-test exploring annual variation in components of productivity of Greylag Geese in Iceland, between 2012 and 2013, in study areas.

		West Iceland	South Iceland	East Iceland	North Iceland
Clutch size	t	-1,971	-0,345	1,106	-0,703
	df	58,96	109,42	71,37	40,84
	p	0,053	0,731	0,272	0,486
Length (mm)	t	-3,178	1,889		
	df	279,21	528,97		
	p	0,002	0,059		
Width (mm)	t	-1,094	2,210		
	df	254,22	517,27		
	p	0,275	0,028		
Clutch Volume (cm^3)	t	-2,010	-0,724		
	df	56,36	103,57		
	p	0,049	0,471		
Est. Start of incubation	t	-0,893	-0,319		0,412
	df	38,27	128,41		45,47
	p	0,378	0,750		0,682
Brood size	t	3,303	2,404	0,290	-0,569
	df	180,83	266,66	305,31	29,26
	p	0,001	0,017	0,772	0,574

Note. See Table 1 for details on sample sizes.

Apendix

Apendix 1. Locations of areas visited, measured components and number of nests sampled in 2012.

Area	Year	Location name	GPS location	# nests measured	Clutch size	Length (mm)	Width (mm)	Flotation test	date
West Iceland	2012	Elliðaey, Breiðafjörður	N65 08.715 W22 48.492	18	x	x	x	x	3.5.2012
West Iceland	2012	Þormóðsey, Breiðafjörður	N65 04.032 W22 54.393	18	x	x	x	x	4.5.2012
West Iceland	2012	Bænhúshólmi, Breiðafjörður	N65 04.220 W22 45.418	3	x	x	x	x	4.5.2012
South Iceland	2012	Auðsholt, Ölfusá	N63 56.382 W21 10.268	30	x	x	x	x	9.5.2012 & 21.5.2012
South Iceland	2012	Landeyjar, Hvítá	N64 00.166 W20 51.114	9	x	x	x	x	15.5.2012
South Iceland	2012	Bolholtsey, Ytri Rangá	N63 53.555 W20 15.529	36	x	x	x	x	16.5.2012
North Iceland	2012	Víkingavatn, Öxarfjörður	N66 06.081 W16 50.073	30	x			x	28.5.2012
East Iceland	2012	Hrafnabjörg/Hallgeirsstaðir, Hróarstunga	N65 28.860 W14 35.256	9	x	x	x	x	9.5.2012 & 17.5.2012
East Iceland	2012	Galtastaðir/Hrærekslækur, Hróarstunga	N65 39.281 W14 20.760	9	x	x	x	x	9.6.2012
East Iceland	2012	Litli Bakki, Hróarstunga	N65 30.337 W14 31.532	8	x	x	x	x	7.6.2012
East Iceland	2012	Dratthalastaðir, Hróarstunga	N65 32.603 W14 19.859	4	x	x	x	x	9.6.2012

Apendix 2. Locations of areas visited, measured components and number of nests sampled in 2013.

Area	Year	Location name	GPS location	# nests measured	Clutch size	Length (mm)	Width (mm)	Flotation test	date
West Iceland	2013	Elliðaey, Breiðafjörður	N65 08.715 W22 48.492	12	x	x	x	x	9.5.2013
West Iceland	2013	Þormóðsey, Breiðafjörður	N65 04.032 W22 54.393	8	x	x	x	x	9.5.2013
West Iceland	2013	Hjallsey, Breiðafjörður	N65 05.076 W22 44.273	1	x	x	x	x	15.5.2013
West Iceland	2013	Landey, Breiðafjörður	N65 04.676 W22 44.924	2	x	x	x	x	16.5.2013
South Iceland	2013	Auðsholt, Ölfusá	N63 56.382 W21 10.268	34	x	x	x	x	6.5.2013
South Iceland	2013	Bolholtsey, Ytri Rangá	N63 53.555 W20 15.529	18	x	x	x	x	14.5.2013
North Iceland	2013	Krossanesborgir, Eyjafjörður	N65 42.651 W18 08.179	16	x	x	x	x	28.5.2013
North Iceland	2013	Eyjafjarðarós, Eyjafjörður	N65 39.235 W18 03.706	25	x	x	x	x	29.5.2013
East Iceland	2013	Reyðafjörður area	N65 01.611 W14 14.283	4	x				
East Iceland	2013	Fljótsdalur area	N64 58.110 W15 08.146	16	x				
East Iceland	2013	Egilsstaðir area	N65 16.071 W14 25.006	9	x				
East Iceland	2013	Hrafnabjörg/Hallgeirsstaðir, Hróarstunga	N65 28.860 W14 35.256	16	x				
East Iceland	2013	Galtastaðir/Hrærekslækur, Hróarstunga	N65 39.281 W14 20.760	5	x				
East Iceland	2013	Litli Bakki, Hróarstunga	N65 30.337 W14 31.532	13	x				
East Iceland	2013	Hólmatunga/Torfastaðir, Hróarstunga	N65 39.281 W14 20.760	4	x				

Apendix 3. Locations and number of geese per site in gosling surveys of 2012-2013.

Area	Year	Location name	GPS location	Pairs with goslings	Total goslings	Total geese	Gosling/Adult	date
South Iceland	2013	Stokkseyri	N63 49.599 W20 59.579	0	0	9	0,000	13.6.2013
		Auðsholt (Ölfusá)	N63 56.512 W21 10.255	3	10	56	0,179	13.6.2013
		Tannastaðir (Ölfusá)	N63 58.734 W20 58.934	24	77	231	0,333	13.6.2013
		Vaðnes (Hvítá)	N64 00.225 W20 51.542	17	55	201	0,274	13.6.2013
		Auðsholt (Ölfusá)	N63 56.512 W21 10.255	10	34	74	0,459	9.7.2013
		Tannastaðir (Ölfusá)	N63 58.734 W20 58.934	17	56	418	0,134	9.7.2013
		Vaðnes (Hvítá)	N64 00.225 W20 51.542	30	110	279	0,394	9.7.2013
		Auðsholt (Ölfusá)	N63 56.512 W21 10.255	6	22	87	0,253	6.8.2013
		Tannastaðir (Ölfusá)	N63 58.734 W20 58.934	4	16	138	0,116	6.8.2013
		Vaðnes (Hvítá)	N64 00.225 W20 51.542	23	52	176	0,295	6.8.2013
West Iceland	2013	Vatn við Esjurætur (Kollafjörður)	N64 12.162 W21 42.479	6	32	88	0,364	20.6.2013
		Útkot (Hvalfjörður)	N64 17.196 W21 48.811	1	1	25	0,040	20.6.2013
		Laxárnes (Hvalfjörður)	N64 19.909 W21 37.909	1	3	11	0,273	20.6.2013
		Kalastaði (Hvalfjörður)	N64 23.867 W21 40.957	3	12	76	0,158	20.6.2013
		Lækjarnestangi (Grunnafjörður)	N64 23.823 W21 52.210	1	3	7	0,429	20.6.2013
		Hvítááreyrar (Borgarfjörður)	N64 31.886 W21 47.532	2	6	103	0,058	20.6.2013
		Grímstaðarvatn (Borgarfjörður)	N64 34.936 W21 42.986	2	9	21	0,429	20.6.2013
		Vík v.seinni tanga (Vigrafjörður)	N65 01.420 W22 44.463	0	0	59	0,000	20.6.2013
		Vogsbotn (v. Stykkishólm)	N65 03.228 W22 45.953	3	9	30	0,300	20.6.2013
		Berserkseyri (Hraunsfjörður)	N64 57.579 W23 04.139	7	18	48	0,375	20.6.2013
		Vestravík (Hvalfjörður)	N64 19.177 W21 53.006	2	6	16	0,375	20.6.2013
		Hraunsfjörður (Snæfellsnesi)	N64 57.096 W23 00.847	2	13	25	0,520	13.6.2013
		Brjánslækur (Vatnsfjörður) - Breiðafjörður	N65 31.786 W23 11.696	3	6	18	0,333	28.6.2013
		Vatnsfjörður (Breiðafjörður)	N65 34.104 W23 09.345	2	9	17	0,529	28.6.2013
		Fossá, nesið milli Vatnsfjarðar og Kjálkafjarðar	N65 32.367 W23 03.410	0	0	64	0,000	28.6.2013
		Tjörnin við Kolgrafarfj. Brúna (Kolgrafarfjörður)	N64 57.502 W23 05.467	0	1	3	0,333	1.7.2013

		Kolgrafir (Kolgrafarfjörður)	N64 57.502 W23 05.467	1	4	43	0,093	1.7.2013
		Berserkseyri (Hraunsfjörður)	N64 57.579 W23 04.139	0	0	23	0,000	1.7.2013
		Vogsbotn v. Stykkishólm (Vogsbotn)	N65 03.078 W22 45.581	2	5	9	0,556	3.7.2013
		Vatn við Esjurætur (Kollafjörður)	N64 12.162 W21 42.479	9	38	102	0,373	17.7.2013
		Útkot (Hvalfjörður)	N64 17.196 W21 48.811	0	0	7	0,000	17.7.2013
		Kalastaðir (Hvalfjörður)	N64 19.909 W21 37.909	0	0	16	0,000	17.7.2013
		Hvítáreyrar (Borgarfjörður)	N64 31.886 W21 47.532	3	11	228	0,048	17.7.2013
		Hólsvatn (Borgarfjörður)	N64 30.851 W22 07.074	0	0	400	0,000	17.7.2013
		Berserkseyri (Hraunsfjörður)	N64 57.579 W23 04.139	9	32	68	0,471	17.7.2013
		Kúludalsá II (Hvalfjörður)	N64 19.177 W21 53.006	7	21	127	0,165	17.7.2013
		Vatn við Esjurætur (Kollafjörður)	N64 12.162 W21 42.479	3	14	23	0,609	12.8.2013
		Pollur v. Esjuveg (lækur f.n. Ljárdal)	N64 13.388 W21 48.619	3	9	17	0,529	12.8.2013
		Útkot (Hvalfjörður)	N64 19.909 W21 37.909	2	4	18	0,222	12.8.2013
		Hjarðarland (Hvalfjörður)	N64 17.470 W21 49.522	3	13	95	0,137	12.8.2013
		Laxárnes (Hvalfjörður)	N64 20.059 W21 37.465	6	25	227	0,110	12.8.2013
		Láxá í Kjós, tún N megin (Hvalfjörður)	N64 20.613 W21 37.166	3	19	284	0,067	12.8.2013
		Miðsandur (Hvalfjörður)	N64 23.935 W21 27.982	0	0	19	0,000	12.8.2013
		Kalastaðir (Hvalfjörður)	N64 23.867 W21 40.957	1	6	8	0,750	12.8.2013
		Láxár ós (Grunnafjörður)	N64 23.287 W21 50.843	4	23	235	0,098	12.8.2013
		Lækjarnestangi (Grunnafjörður)	N64 23.700 W21 52.202	6	30	139	0,216	12.8.2013
		Eyrar í Hvítá (Borgarfjörður)	N64 31.881 W21 47.633	1	3	110	0,027	12.8.2013
		Vík v.seinni tanga (Vigrafjörður)	N65 01.420 W22 44.463	0	0	30	0,000	12.8.2013
		Vogsbotn (v. Stykkishólm)	N65 03.228 W22 45.953	0	0	19	0,000	12.8.2013
		Berserkseyrará (Hraunsfjörður)	N64 57.579 W23 04.139	2	10	22	0,455	12.8.2013
North Iceland	2013	Húseyjarkvísl (Varmahlíð)	N65 33.220 W19 26.081	1	5	8	0,625	27.6.2013
		Miklabær-Silfrastaðir (Héraðsvötn)	N65 33.037 W19 21.505	5	13	42	0,310	27.6.2013
		Stóra tjörn (Héraðsvötn)	N65 26.266 W19 12.818	1	5	9	0,556	28.6.2013
		Víkingavatn (Öxarfjörður)	N66 06.085 W16 50.069	8	22	102	0,216	28.6.2013
		Pollur v. N1 (Akureyri)	N65 39.993 W18 04.936	7	30	58	0,517	28.6.2013

		Pollur v. N1 (Akureyri)	N65 39.821 W18 04.885	4	15	31	0,484	30.6.2013
		Litli Garður v. Flugvöllinn (Eyjafjörður)	N65 39.500 W18 04.809	4	18	34	0,529	30.6.2013
		Hólmarnir (Eyjafjörður)	N65 39.090 W18 03.541	1	5	11	0,455	30.6.2013
		Brekkulækur (Eyjafjarðarós)	N65 39.721 W18 02.412	7	36	80	0,450	30.6.2013
		Fagranes (Blanda)	N65 35.265 W20 04.351	1	8	13	0,615	30.6.2013
		Blönduós (Blanda)	N65 39.467 W20 17.167	9	69	167	0,413	30.6.2013
		Blönduós (Blanda)	N65 39.467 W20 17.167	13	51	410	0,124	23.7.2013
		Pollur v. N1 (Akureyri)	N65 39.993 W18 04.936	6	19	45	0,422	23.7.2013
		Blönduós (Blanda)	N65 39.467 W20 17.167	22	75	350	0,214	26.7.2013
East Iceland	2013	Fljótsbotn (Hérað)	N65 04.465 W14 50.665	3	10			17.6.2013
		Stóra Steinsvað (Hérað)	N65 29.033 W14 21.115	1	5			20.6.2013
		Hesteyrar (Hérað)	N65 22.155 W14 22.949	1	4			20.6.2013
		Laxárós (Hérað)	N65 27.251 W14 38.414	4	13			30.6.2013
		Skipalækur (Hérað)	N65 16.789 W14 26.147	1	6			30.6.2013
		Fljótsbotn (Hérað)	N65 04.465 W14 50.665	11	32			12.7.2013
		Hrafnkelsstaðir (Hérað)	N65 03.070 W14 53.299	11	26			12.7.2013
		Skriðuklaustur (Hérað)	N65 02.421 W14 57.213	4	9			12.7.2013
		Múli í Fljótsdal (Hérað)	N64 57.711 W15 04.508	2	5			12.7.2013
		Arnheiðarstaðir (Hérað)	N65 07.682 W14 45.907	0	0			12.7.2013
		Vallanes (Hérað)	N65 12.700 W14 31.528	0	0			12.7.2013
		Fljótsbakki (Hérað)	N65 21.622 W14 23.541	1	3			12.7.2013
		Vífilsnes (Hérað)	N65 23.538 W14 24.411	17	49			12.7.2013
		Ekra (Hérað)	N65 31.353 W14 21.735	5	17			12.7.2013
		Torftjörn (Hérað)	N65 14.982 W14 23.958	1	1			12.7.2013
		Selfljót - Hjaltastaðablá (Hérað)	N65 34.705 W14 02.875	2	9			12.7.2013
		Grímsárlón-Lundur (Hérað)	N65 08.345 W14 32.232	3	10			13.7.2013
		Hvanná-Hofteigur (Hérað)	N65 22.057 W14 48.394	23	82			14.7.2013
		Eyrar (Hérað)	N65 17.513 W13 51.229	14	42			15.7.2013
		Litli Bakki (Hérað)	N65 30.337 W14 31.532	3	8			15.7.2013

		Hagholtsblá (Hérað)	N65 30.315 W14 31.823	1	4			23.7.2013
		Hagholt (Hérað)	N65 30.315 W14 31.823	6	15			23.7.2013
		Fossvallamóar (Hérað)	N65 29.913 W14 35.971	5	10			27.7.2013
South Iceland	2012	Sandvík (Ölfusá)	N63 55.969 W21 01.994	8	0	0	0,000	11.6.2012
		Tannastaðir (Ölfusá)	N63 58.530 W20 59.120	2	1	6	0,750	11.6.2012
		Stokkseyri	N63 49.609 W20 58.482	29	1	5	0,147	11.6.2012
		Auðsholt (Ölfusá)	N63 56.420 W21 10.379	96	11	42	0,304	13.6.2012
		Auðsholt (Ölfusá)	N63 56.420 W21 10.379	35	3	10	0,222	19.6.2012
		Vaðnes (Hvítá)	N64 00.273 W20 51.231	58	22	73	0,557	19.6.2012
		Tannastaðir (Ölfusá)	N63 58.740 W20 59.076	74	2	8	0,098	19.6.2012
		Stokkseyri	N63 49.609 W20 58.482	3	0	0	0,000	19.6.2012
		Stokkseyri	N63 49.609 W20 58.482	25	2	11	0,306	19.6.2012
		Bolholtsey (Ytri Rangá)	N63 53.496 W20 15.330	8	2	17	0,680	19.6.2012
		Auðsholt (Ölfusá)	N63 56.420 W21 10.379	9	2	8	0,471	4.7.2012
		Tannastaðir (Ölfusá)	N63 58.740 W20 59.076	115	7	31	0,212	4.7.2012
		Vaðnes (Hvítá)	N64 00.225 W20 51.542	74	26	96	0,565	4.7.2012
		Ofarlega í Þjórsá v. Hagaey	N64 03.222 W20 08.114	4	2	7	0,636	4.7.2012
		Rétt v. Hagaey alveg v. Veginn	N64 03.496 W20 07.358	6	2	17	0,739	4.7.2012
		Tannastaðir (Ölfusá)	N63 58.740 W20 59.076	147	4	22	0,130	11.7.2012
		Vaðnes (Hvítá)	N64 00.225 W20 51.542	52	26	65	0,556	11.7.2012
		Auðsholt (Ölfusá)	N63 56.420 W21 10.379	67	11	43	0,391	1.8.2012
		Tannastaðir (Ölfusá)	N63 58.740 W20 59.076	41	7	37	0,474	1.8.2012
		Vaðnes (Hvítá)	N64 00.273 W20 51.231	27	11	32	0,542	1.8.2012
		Stokkseyri	N63 49.609 W20 58.482	90	1	8	0,082	1.8.2012
West Iceland	2012	Berserkseyri (Hraunsfjörður)	N64 57.579 W23 04.139	12	3	15	0,556	4.6.2012
		Berserkseyri (Hraunsfjörður)	N64 57.659 W23 04.597	13	3	12	0,480	4.6.2012
		Ögursvatn (Stykkishólmur)	N65 02.541 W22 47.615	55	3	8	0,127	12.6.2012
		Auðshaugur (Barðaströnd)	N65 32.644 W23 00.133	18	1	4	0,182	18.6.2012
		Kjálkafjörður	N65 34.309 W22 54.791	36	3	15	0,294	18.6.2012

		Mjóafjörður	N65 36.988 W22 50.910	14	0	0	0,000	18.6.2012
		Kollafjörður	N64 12.162 W21 42.479	9	0	0	0,000	18.6.2012
		Reykhólar (tjörn við mastur)	N65 26.682 W22 12.820	2	1	6	0,750	18.6.2012
		Vatn við Esjurætur (Kollafjörður)	N64 12.108 W21 42.518	47	9	38	0,447	7.6.2012
		Hofsvík (Kjalarnes)	N64 13.572 W21 48.807	12	3	7	0,368	7.6.2012
		Vatn í botni hvalfjarðar	N64 23.086 W21 21.226	22	2	16	0,421	7.6.2012
		Vatn við Esjurætur (Kollafjörður)	N64 12.108 W21 42.518	27	6	32	0,542	27.6.2012
		Gröf (Hvalfjörður)	N64 19.927 W21 50.725	68	3	14	0,171	27.6.2012
		Galtarvík (Hvalfjörður)	N64 20.326 W21 49.157	18	9	53	0,746	27.6.2012
		Árdalur (Borgarfjörður)	N64 31.788 W21 48.512	395	0	0	0,000	27.6.2012
		Í mýri v. Árdal (Borgarfjörður)	N64 31.923 W21 47.116	11	3	16	0,593	27.6.2012
		Vatn við Esjurætur (Kollafjörður)	N64 12.108 W21 42.518	41	16	82	0,667	17.7.2012
		Botnsvogur (Hvalfjörður)	N64 22.348 W21 24.265	4	2	8	0,667	17.7.2012
		Botnsvogur N megin (Hvalfjörður)	N64 23.325 W21 23.916	6	3	13	0,684	17.7.2012
		Merkjalækur (Hvalfjörður)	N64 24.053 W21 40.403	162	15	75	0,316	17.7.2012
		Andakílsós (Borgarfjörður)	N64 31.881 W21 47.633	14	3	18	0,563	17.7.2012
		Galtarlækur (Hvalfjörður)	N64 20.651 W21 48.081	12	5	22	0,647	17.7.2012
North Iceland	2012	Grjótáreyri (Hrútafjörður)	N65 09.128 W21 03.725	0	0	62	0,000	8.8.2012
		Hvalshöfði (Hrútafjörður)	N65 10.815 W21 03.514	0	0	21	0,000	8.8.2012
		Oddstaðaeyri (Hrútafjörður)	N65 11.086 W21 03.870	1	6	22	0,273	8.8.2012
		Miðfjarðará ós (Miðfjörður)	N65 20.417 W20 53.849	0	0	90	0,000	8.8.2012
		Miðfjarðarvatn (Miðfjörður)	N65 21.043 W20 45.701	1	4	30	0,133	8.8.2012
		Flaga (Vatnsdalsá)	N65 26.480 W20 18.995	0	0	2	0,000	8.8.2012
		Blönduós (Blanda)	N65 39.485 W20 17.343	0	0	90	0,000	8.8.2012
		Grafarvatn (Blönduós)	N65 39.892 W20 13.895	0	0	29	0,000	8.8.2012
		Strjúgsstaðir (Blanda)	N65 34.537 W20 00.463	0	0	16	0,000	8.8.2012
		Auðólfsstaðir (Blanda)	N65 33.046 W19 56.154	3	21	205	0,102	8.8.2012
		Ytri Húsabakki (Héraðsvötn)	N65 36.634 W19 28.347	1	3	5	0,600	9.8.2012
		Ytri Húsabakki (Héraðsvötn)	N65 36.399 W19 27.503	1	6	8	0,750	9.8.2012

	Glaumbæjareyja (Héraðsvötn)	N65 36.835 W19 26.979	0	0	50	0,000	9.8.2012
	Borgarey (Héraðsvötn)	N65 37.211 W19 25.980	0	0	180	0,000	9.8.2012
	Hamraborg (Héraðsvötn)	N65 43.373 W19 31.837	0	0	22	0,000	9.8.2012
	Helluland 3 (Héraðsvötn)	N65 43.197 W19 31.790	0	0	3	0,000	9.8.2012
	Helluland 3 (Héraðsvötn)	N65 42.866 W19 31.865	0	0	25	0,000	9.8.2012
	Garðsvatn (Héraðsvötn)	N65 43.501 W19 27.191	0	0	116	0,000	9.8.2012
	Garðsvatn (Héraðsvötn)	N65 43.501 W19 27.191	0	0	72	0,000	9.8.2012
	Ytra Gil (Eyjafjarðará)	N65 37.448 W18 04.345	1	5	71	0,070	9.8.2012
	Teigur (Eyjafjarðará)	N65 36.493 W18 04.793	0	0	47	0,000	9.8.2012
	Botn (Eyjafjarðará)	N65 33.775 W18 05.605	0	0	49	0,000	9.8.2012
	Stokkahlaðir E megin (Eyjafjarðará)	N65 33.365 W18 05.881	0	0	10	0,000	9.8.2012
	Espigrund (Eyjafjarðará)	N65 32.771 W18 07.025	0	0	77	0,000	9.8.2012
	Rútstaðir (Eyjafjarðará)	N65 30.450 W18 08.452	0	0	19	0,000	9.8.2012
	Brekkulækur (Eyjafjarðarós)	N65 39.614 W18 02.715	9	21	193	0,109	9.8.2012
	Rifkelsstaðir (Eyjafjarðará)	N65 32.140 W18 06.525	1	4	145	0,028	9.8.2012

Note. We do not have locations of goose sightings in East Iceland in 2012.