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– Comparing effects of the native tree species *Betula pubescens* and the non-native *Pinus contorta* in Iceland

Återbeskogning i norr

– En jämförelse av effekterna av den naturligt förekommande *Betula pubescens* och exoten *Pinus contorta* på Island

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Examensarbete i ämnet biologi
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Abstract

The use of non-native tree species in forestry is both praised and questioned. Foresters have often promoted their use, mainly because of higher growth rates, resilience to pests and diseases and improved survival under harsh conditions. Nevertheless, non-native tree species can also have negative impact on biodiversity and ecosystem functioning, especially when introduced to former treeless vegetation. In this master thesis, I have used data from the Icelandic Forest Inventory to compare the differences in understory vegetation, berry production, game potential and esthetical value between the non-native tree species *Pinus contorta* and the native tree species *Betula pubescens* in Iceland. Species included in the analyse were: *Empetrum nigrum, Carex vaginata, Geranium sylvaticum, Vaccinium uliginosum, Rubus saxatilis, Vaccinium myrtillus, Bistorta vivipara* in addition to vegetation cover of bryophytes, fungi, lichen, pteridophytes and herbs. Data was divided into three age classes; young forest, middle age forest and old forest. The inventory plots covered the whole Iceland. My result showed that bryophyte cover was significantly higher in old stands of *P. contorta* compared to *B. pubescens*. Arguably this is linked to the more acidic soils and humid forest floor that *P. contorta* are associated with. The presence of *Dryas octopetala, Vaccinium uliginosum* and *E. nigrum* were higher in *P. contorta* stands than *B. pubescens* in middle age forest. The presence of *D. octopetala* was higher in older stands compared to young stands, regardless tree species, which probably is connected with sheep grazing in Iceland. *D. octopetala* is a highly palatable plant and the high presence of sheep in Iceland is probably reducing its range. Due to the common practise of fencing around plantations this probably favoured *D. octopetala*. In other words it is likely that the fencing of the plantations was the main reason for higher abundance in older forest, not the forest *per se*. In the middle age class there were a significantly higher presence of *V. ulignosum* and *E. nigrum*. The denser structure of *P. contorta* was probably favourable to *V. ulignosum* and *E. nigrum* due to less wind, more acidic soils and higher moisture content at the forest floor than *B. pubescens*. Most variables did not show a significant difference between *P. contorta* and *B. pubescens*. One reason for this is that the cover data is collected in categories by the Icelandic Forest Inventory, which made it harder to detect small significant differences. My results indicates that plantation of *P. contorta* will result in a different understory than *B. pubescens*. Furthermore, a large difference could be seen between the different age classes indicating the importance of following stand development over time in order to fully understand the effects of establishment of the two tree species.

Keywords: Non-native tree species, Iceland, *Betula pubescens, Pinus contorta*

Sammanfattning

Användning av exoter inom skogsbruket har blivit hyllat såväl som ifrågasatt. Skogstjänstemän har ofta uppmuntrat användningen, framförallt på grund av högre tillväxt, motståndskraft mot sjukdomar och ökad överlevnad i karga förhållanden. Men exoter kan även ha en negativ påverkan på biodiversitet och ekosystem processer, speciellt då de blir etablerade på mark som tidigare saknat skog. I mitt examensarbete har jag använt mig av data från Icelandic Forest Research för att jämföra skillnader i undervegetation, bärproduktion, jaktmöjligheter samt estetiskt värde mellan exoten *Pinus contorta* och den naturligt förekommande *Betula pubescens* på Island. Följande arter är inkluderade i analysen: *Empetrum nigrum*, *Carex vaginata, Geranium sylvaticum, Vaccinium uliginosum, Rubus saxatilis, Vaccinium myrtillus, Bistorta vivipara* samt täckningsgrad av mossa, lavar, ormbunksväxter och lavar. Data delades in i tre åldersklasser; ung skog, mellan samt gammal skog. Inventeringspunkterna täckte hela Island. Mina resultat visade att mosstäckningsgraden var signifikant högre i äldre skogar av *P. contorta* jämfört med *B. pubescens*. Detta har förmodligen ett samband med de surare jordar och fuktigare markförhållanden, som är associerat med *P. contorta*. Förekomst av *Dryas octopetala* var högre i äldre skogar jämfört med yngre skogar, oavsett trädslag, vilket troligtvis är förknippat med förekomsten av får på Island. *D. octopetala* är högt betesbegärlig och det höga betestrycket av får har förmodligen reducerat dess antal. En vanlig åtgärd för att fåren inte ska orsaka betesskador är att stängsla in planteringar vilket förmodligen har gynnat den beteskänsliga *D. octopetala*. Med andra ord är det troligt att stängsling mot får är den största anledningen för större förekomst av *D. octopetala* och inte skogen i sig själv. Förekomsten av *E. nigrum* och *V. ulignosum* var signifikant högre i *P. contorta* bestånden jämfört med *B. pubescens* i den mellersta åldersklassen. Strukturen på bestånden av *P. contorta* är tätare vilket vanligen ger upphov till mindre vind, surare samt fuktigare jordar än *B. pubescens*, vilket gynnar förekomsten av *E. nigrum* och *V. ulignosum*. De allra flesta variablerna visade dock ingen signifikant skillnad mellan *B. pubescens* och *P. contorta*. En anledning till det är att täckningsgraden som Icelandic Forest Inventory samlar in är uppdelat i kategorier, vilket gör det svårare att upptäcka små statistiska skillnader. Mina resultat indikerar att plantering av *P. contorta* resulterar i en annan undervegetation än *B. pubescens*. Dessutom visar mina resultat på att det föreligger en stor skillnad mellan olika åldersklasser. Detta visar på vikten av att följa bestånd över tid för att förstå samtliga effekter när man planterar dessa två trädslag.

Nyckelord: exoter, Island, *Betula pubescens*, *Pinus contorta*

Table of contents

1 Introduction

The area of the world's forest cover continues to shrink as human population continues to grow and the demand for food and land increases (FAO, 2015). However, the rate of deforestation has slowed down during the past 25 years (FAO, 2015). One reason for the decrease is that in the temperate and boreal biomes, new forests are emerging, both by natural and assisted regenerations (FAO, 2015; (Chazdon, 2008). In the new forests, non-native species are increasingly being used (Chazdon, 2008). In this thesis I will study the effects of plantations of the non-native tree species lodge pole pine *Pinus contorta* compared to the native *Betula pubescens*, by using inventory data from the Icelandic Forest Research.

1.1 Non–native tree species

Non-native tree species in forestry are used globally, and this use is both praised and challenged. Foresters in have often promoted their use, mainly because of their higher growth rates, resilience to pests and diseases and improved survival under harsh conditions (Bragason, 1995; Richardson, 1998; Kjær *et al*., 2014). Other reasons for using non-native species include soil and water conservation and carbon sequestration (Bremer & Farley, 2010). Nevertheless, non-native tree species can also have great impact on biodiversity and ecosystem functioning, especially when introduced to former treeless vegetation (Richardson *et al.*, 2014).

Entire ecosystems can be altered by non-native species in many ways. Not only by consumption of and competing with native species, but also through alteration of the area they invade. For example, the non-native tree species *Melaleuca quinquenervia* has transformed entire landscapes in Florida, when replacing cypress, sawgrass and other native species (Schmitz *et al.*, 1997) *M. quinquenervia* also demands a lot of water which has changed the hydrology of the landscape which in turn has led to habitat degradation which affect native animals negatively (Mack *et al.*, 2000). Another example is the non-native tree *Myrica faya* that have been found to change the chemical composition in the soil in Hawaii because of its nitrogen-fixing ability (Vitousek *et al.*, 1987). When the soil becomes more fertile it becomes possible for other non-native trees to establish (Vitousek *et al.*, 1987).

As long as humans have travelled between and within continents, species have both intentionally and unintentionally been brought across their natural barriers (Mack *et al.*, 2000). Species have in this way been introduced to areas outside their native and historical range. But in the past century the rate of overall number of species brought outside the present range has increased (Vitousek *et al*., 1997; Richardson *et al*., 2014). Increased international trade, rapid movement of people and human population growth are all contributing to an increased number of non-native species (Pimentel *et al*., 2005; Lowe *et al*., 2000). For example, in Europe over 10 000 species of fungi, plants, vertebrates and invertebrates are thought to be non-native (Simberloff *et al.*, 2013).

A species that has evolved on site or has managed to colonize a location entirely without human activity is often called native (Webb, 1985). The term Vilà used to describe the opposite of native species are for example exotic, alien, non-indigenous, introduced, adventive and neophytes (Vilà *et al.*, 2010). Below I will use the term non-native to describe the opposite to these native species.

A distinction is often made between non-native species that have been introduced intentionally and those that have been introduced accidently (Mack *et al.*, 2000). Many plants have been introduced intentionally in the western countries and are today providing the majority of the food, such as corn, wheat and rice (Pimentel *et al.*, 2005). Plants have been mainly introduced for food, fibre and ornamental reasons. However, most introduced species do not manage to survive in their new environment without assistance from humans, and only a small fraction becomes naturalized (Mack *et al.*, 2000).

1.2 Iceland

Iceland is located in the North Sea (65° 00'N, 19° 00'W) and its remote location means that Icelandic ecosystems are isolated from other terrestrial ecosystems (Halldórsson *et al*., 2013). The total land area is 103000 km^2 (Óskarsson & Sigurgeirsson, 2001). The climate on Iceland is mostly humid with cold temperate in the lowlands and sub-arctic in the highlands. Summers are usually short and cool (Blöndal, 1987) and the winter is generally mild and windy with an average January temperature around 0°C in the low-elevation areas (Óskarsson & Sigurgeirsson, 2001). Iceland is strongly influenced by the Gulf Stream, giving it a mild climate relative to its northern location. Precipitation varies between 600 and 1500 mm per year in the lowland area, except from north-eastern Iceland which receive less than 600 mm per year (Arnalds, 2005; O. Arnaldsa, 2003). The growing season (i.e. the period with average daily temperatures exceeding 7.5°C) in the lowlands varies from 70 days in some regions of northern Iceland, to 120 days in the south coastal regions (Óskarsson & Sigurgeirsson, 2001).

1.2.1 Vegetation before human settlement

The geographical isolation of Iceland has led to a low number of native species, compared to the number found on less isolated locations with a similar climate (Blöndal, 1987). Through pollen analyses it is understood that birch species colonised Iceland soon after the latest glacial period, around 12 000 years ago. At the time when Iceland is believed to been settled (circa 873 A.D.) (McGovern *et al.*, 2007), large areas of the island was covered by downy birch *Betula pubescens* and to a lesser extent dwarf birch *Betula nana* (Dammert, 2001). Based on historical records, pollen analyses and soil remnants it is estimated that 65% of the island have been covered with vegetation, of which forest covered 25–40% (Arnalds, 1987). The dominating tree species was *B. pubescens*, which is the only native tree that form forest on Iceland (Bragason, 1995). *B. pubescens* is believed to have been relatively tall (up to 15 m) in areas protected from wind and towards the coast. Other native tree species were also present, such as *Populus tremula* (which is today only found at 6 locations on Iceland), *Sorbus aucuparia* and *Salix* species (especially *Salix phylicifolia*). *P. tremula, S. aucuparia* or *Salix* spp. did only occur fragmented within the birch forest, as they cannot form actual forest themselves on Iceland (Eysteinsson, 2013). The vegetation outside the forest was before human settlement more likely characterized by moss heathland dominated by *Racomitrium* moss and shrub heath (Arnalds & Barkarson, 2003).

1.2.2 The decline of the woodlands

Soon after Iceland was settled a decline of the forest cover begun. Based on the saga records, settlers used the birch forest for several purposes, including the use of building materials, firewood, livestock fodder and most importantly, charcoal (Dammert, 2001; Eysteinsson, 2013). Charcoal was needed in order to melt iron and make iron tools (Eysteinsson, 2013). Some of the forest were converted to grazing areas for sheep and horses that the settlers brought with them (Dammert, 2001). Grazing animals have been an important factor in determine the Icelandic landscape, including the forests (Arnalds, 2005). The highlands (situated 400-500 m.a.s.l.), which are mostly communal grazing areas (Arnalds & Barkarson, 2003), demonstrates the effect grazing animals can have on a larger scale. Plant composition in these areas are dominated by species tolerant to grazing, such as *Carex bigelowii, Empetrum* spp., *Kobresia myosuroides* and *Vaccinium* spp. (Arnalds & Barkarson, 2003). On the other hand, plants that sheep finds palatable are being grazed, which subsequently prevents the roots from establishment (Arnalds, 2001) and probably lower biomass and reduced reproduction. During the

14th century the climate became colder which made conditions for vegetation even harder (Dammert, 2001).

The soil of Iceland is formed from volcanic eruptions, creating a young, porous soil that is highly erodible (Dammert, 2001; Runolfsson, 1987). Most of the soil belongs to the Andosol soil order (Óskarsson & Sigurgeirsson, 2001). The combination of erodible soil and intensive grazing resulted in less vegetation and strong winds led to a widespread erosion after the tree cover disappeared (Dammert, 2001). The erosion led to decreased soil fertility and water retention and it is today viewed as one of the most important ecological problems on Iceland (Runolfsson, 1987). The forest cover is believed to have reached its minimum range at around 1950 when the forest cover was less than 1% of total land cover and perhaps even less than 0.5% (Eysteinsson, 2013).

1.2.3 Early afforestation

Iceland has a short history of commercial forestry. During the first half of the 20th century, efforts were mainly focusing on protecting the birch forest remnants, which resulted in the first forest law of 1907 and the founding of the Icelandic Forest Service (IFS) in 1908 (Halldorsson *et al*., 2008). Several areas with remnants of birch forest were acquired by IFS for this purpose (Halldorsson *et al*., 2008). These areas are today the background to the National Forest System (Halldorsson *et al*., 2008).

The Icelandic government became more involved in the 1950s, in forms of legislation, research and financial support (Halldorsson *et al*., 2008). Legislation became more strict and since 1955 clear cutting of native birch is not allowed without permission from IFS (Dammert, 2001). In the 1960's and part of 1970's a forest tax was added to cigarettes to support tree planting activities (Dammert, 2001). Planting increased greatly, and during 1960–1962 over 1.5 million seedlings where planted per year. However, in 1963 an extreme spring frost killed a large proportion of planted forest in south-western Iceland. This led to a negative impact of public interest and birch planting declined. Planting declined after 1963 and until 1989 remained around 500,000–1 million seedlings where planted annually (Halldorsson *et al*., 2008). Since 2005 6 millions seedlings were planted per year (Eysteinsson, 2009)

The land transformation from sheep pastures to forested areas has, however, not been conflict free. Due to heavily grazing in forest plantations, sheep have to be fenced out of the plantations, which has resulted in conflict with livestock farmers (Halldorsson *et al*., 2008). During the 20th century sheep farming became more intensive, but sheep numbers almost decreased by half during the 1980's which led to reduced grazing pressure in many areas (Halldorsson *et al*., 2008; (Aradóttir *et al.*, 2013) which might have dampened the conflict.

The government became increasingly involved in the afforestation during the 1980's and 1990's, with primarily erosion control and recreation as the main objectives (Dammert, 2001). The state budget for forestry increased during President Vigdís Finnbogadóttirs time at power (1980–1996) and she managed to make afforestation a popular concern (Halldorsson *et al*., 2008).

With the financial crisis in 2008, imported wood became more expensive and this provided unexpected opportunities for the national forestry. Icelanders use the same amount of forest per capita as other countries with similar living standards (Eysteinsson, 2013), and today the Icelandic forestry is considered small but profitable (Anon., 2009). Most of the Icelandic wood is being used for energy purposes (Anon., 2009) but other products are firewood, burnt in pizzeria ovens or fireplaces, fence posts, handicrafts and Christmas trees. In the year 2010 Elkem, an alloy factory in south-western Iceland, ran a trial using wood instead of charcoal. Since then a great demand of wood chips has emerged (Eysteinsson, 2013). The factory can, so far, not cover its demand solely from the Icelandic forest sector. In 2013 the Elkem factory used around 28 000 tons of wood chip, of which 1 000 tons came from the Icelandic forest (Jónsson, 2015).

1.2.4 Forest policy

In the latest forest legislation regarding local afforestation programmes (from 2006) the government on Iceland set a political goal to reforest at least 5 %, or 215 000 ha, of the lowland within the next four decades (Dammert, 2001). The government stated that the goals with the afforestation are multiple, including ecological (ecosystem processes, habitat, wildlife), economic (wood production, non-wood products), protective (soil and water conservation, shelter, sequestering carbon dioxide) as well as social aspects (recreation, spiritual) (Eysteinsson, 2009; Eysteinsson, 2013).

1.2.5 Non–native tree species in Iceland

Today 78% of the tree plantations in Iceland are composed of non-native species (Kjær *et al*., 2014). The first commercial plantations with exotic tree species took place at the "Pine Stand", Thingvellir, in 1899 with most surviving seedlings of *Pinus mugo* and *Pinus sibirica* (Halldórsson *et al*., 2013). Non-native tree species have since played an extensive role in the reforestation of Iceland (Blöndal, 1987). Nearly 100 tree species have been introduced (Blöndal, 1987). In the first years

(1900–1907) the results were poor, and most of the trees died (Bragason, 1995). Danish foresters later introduced a program called "Icelandic forest does matter" which is seen as a turning point for the Icelandic forestry (Blöndal & Gunnarsson, 1999). Trials were made with native *B. pubescens*, but were regarded as a disappointment. The native tree species were small, had poor stem quality and above all they were preferred by sheep. Instead trials were made with exotic conifer species, such as *Larix sibirica* and Sitka spruce *Picea sitchensis*, which ended up with higher survival rates. Today the foundation species of Icelandic forestry is sometimes described as "the big five", and is including; *B. pubescens*, *Pinus contorta*, *P. sitchensis*, *L. sibirica* and *Populus trichocarpa* (Jónsson, 2015). In my thesis I will focus on *B. pubescens* and *P. contorta*. *P. contorta* is a very commonly planted non-native tree species used in forestry, also outside of Iceland. For example in Sweden it is the most commonly planted non-native tree species and its introduction has not been conflict free. More research of its effect is therefore of great interest.

1.2.6 *Betula pubescens* in Iceland

Birch species, *Betula* spp. in different successional stages play an important role for biodiversity in coniferous forests in Europe, and a large number of functional groups are connected/linked to birch because they are the most common broad-leaved tree (Hynynen *et al*., 2009). Birch species are light-demanding pioneers that can survive on a wide range of soils, even though they do best on well-drained, slightly acidic soils. Birch can quickly establish in open areas and can grow both in pure and mixed stands (Hynynen *et al*., 2009). In Europe three birch species are recognized; *B. pubescens*, *Betula pendula* and dwarf birch *B. nana*. *B. pendula* is more common in the southern parts of Europe while *B. pubescens* is more spread in the northern and western Europe. *B. nana* is found in the alpine and artic regions of Europe. In Iceland *B. pubescens* and *B. nana* have coexisted since the early Holocene (Karlsdóttir *et al*., 2008).

Naturally distributed *B. pubescens* have a great variation in morphology on Iceland which reflects site conditions, genetics and climate (Oddsdóttir, 2010). On windy, exposed areas with oceanic climate *B. pubescens* tend to form 1–2 m high shrubs. Although, naturally distributed *B. pubescens* can reach 10–12 m at mature age in protected areas toward inland (Thórsson *et al.*, 2007). The majority (80%) of the stands in Iceland are, however, below 2 m (Jónsson, 2004), mostly due to the harsh conditions, e.g. strong winds. The stem quality differs and both single stem and multiple stems trees exist, but multiple stems trees are more common (Thórsson *et al*., 2007). The present upper-limit is 600 m.a.s.l. (Bragason, 1995).

For industrial use the stem quality is often too poor to use for timber production, but birch is used as pulpwood in Iceland. Sometimes *B. pubescens* is used in forestry as a shelter species. *B. pubescens* as well as *P. tremula, Salix* spp., *S. aucuparia*, are of big importance for recreational forests in Iceland (Alden *et al*., 1993).

The total planted forest of *B. pubescens* until 2011 was 7800 hectares, which is equal to 22% of the total plantation area (Snorrason, 2011) The plantation of native *B. pubescens* has varied from year to year – at the most birch has comprised 30% of the total planted seedlings (Eysteinsson & Sigurgeirsson, 2009). The area of native *B. pubescens* forest is also increasing through natural regeneration, most likely because of a reduction in sheep grazing (Anon., 2009).

Although the number of grazing livestock has declined the past decades, the presence of herbivores is still limiting regeneration of *B. pubescens* forests and today fencing of woodland areas is necessary to allow for afforestation due to uncontrolled summer grazing (Eysteinsson, 2013).

The effect of birch on site properties and vegetation differs from that of conifers in a number of ways. Firstly, birch leaves decompose more rapidly as compared to conifers, and the debris is less acidic. This lead to faster nutrient cycling (Hynynen *et al.*, 2009). Secondly, in birch stands more light reaches the ground floor, which promote the development of the ground vegetation (Hynynen *et al*., 2009). Species associated with *B. pubescens* on Iceland are the woody plants *Vaccinium uliginosum*, *Salix lanata* and *E. nigrum*, the non-woody plant *Rubus saxatilis* and the grasses *Deschampsia flexuosa* and *Agrostis capillaris* (Oddsdóttir, 2010).

1.2.7 *Pinus contorta* in Iceland

Lodge pole pine, *P. contorta* is a pioneer conifer tree species, that has adapted to grow on sites that is either marginal for other tree species or requires disturbance (Despain, 2001). *P. contorta* is a native species of the Rocky Mountains and the Pacific coast regions of North America, but has been introduced to countries well beyond its native range (Sykes, 2001). *P. contorta* has four subspecies and the subspecies *latifolia* is the most extensively used and the most economically important in North America (Despain, 2001). *P. contorta* have been introduced to various countries in both the northern and southern hemisphere, for example in Scotland, Denmark, New Zealand, Sweden, British Isles and Iceland (Elfving *et al.*, 2001). *P. contorta* is often planted with timber production as a primary goal, but also pulpwood can be extracted.

P. contorta has been used extensively in Iceland. In 2011 around 5000 hectares had so far been planted with *P. contorta,* which is equal to 14 % of all total planted forest (Snorrason, 2011). *P. contorta* was introduced into the Hallormsstadur forest 1940, and since then considerable changes have been recorded in the understory vegetation as compared to *B. pubescens*. Under the canopy of *P. contorta* there are few plants capable of growing and the forest floor was covered with a thick mat of needle litter (Vogt, 2007). *P. contorta* has been observed to regenerate naturally in Iceland (Bragason, 1995).

1.3 Chosen variables to compare *B. pubescens* and *P. contorta*

The following variables; understory vegetation, berry production and game production potential and esthetical value were included in my thesis in order to compare *B. pubescens* and *P. contorta*.

1.3.1 Understory vegetation

Tree species have a great impact on understory vegetation (Halldorsson *et al.*, 2008). The main effects tree species have on understory vegetation is through changed amounts of available light, water, soil nutrients and physical effects on litter (Barbier *et al.*, 2008). Light is often seen as a key factor of understory vegetation cover and richness (Halldorsson *et al.*, 2008). This is closely linked to the canopy structure of the dominating tree species. The canopy structure is also linked to air temperature and humidity (Barbier *et al.*, 2008). *P. contorta* tends to grow in dense stands which leads to low light intensity in a mature stand (Schoennagel *et al.*, 2004).

The amount of water available is another major factor for understory vegetation. Deciduous forests have a higher through fall (water dripping from the canopy), due to the ability that flat leaves have to collect water than coniferous forest (Barbier *et al.*, 2008; Stuart & Edwards, 2006).

Conifers are known to generally produce more acidic soils than broad-leaved trees which subsequently effect the understory vegetation (Barbier *et al.*, 2008). But most of the organic compounds of *P. contorta* is acidic (Yavitt & Fahey, 1986). Acidification of the soil may happen in rather young stands and Rigueiro-Rodríguez (2012) found that stands of *Pinus radiata* (which is similar to *P. contorta*) had increased the acidity of the soils after 11 years after establishment. Leaf litter of *B. pubescens* has a higher proportions of calcium which subsequently reduces calcium leaching, and hence a faster nutrient cycling than pine trees (Rigueiro□Rodríguez *et al.*, 2012).

Lastly, a thick layer of litter will have a physical effect on the forest floor through reduced light reaching the forest floor (Meers *et al.*, 2010; Barbier *et al.*, 2008). This is often associated with coniferous species (Meers *et al.*, 2010), and can prevent seed germination and seedling emergence (Meers *et al.*, 2010; Barbier *et al.*, 2008).

1.3.2 Game potential and berry production

Hunting is a common activity in Iceland. Out of the country's total population of over 330 000, more than 12 200 are registered hunters. Game species in Iceland are rock ptarmigan *Lagopus muta*, reindeer *Rangifer tarandus* and greylag goose *Anser anser* (Kettunen *et al.*, 2012). I will mainly focus on rock ptarmigan and the potential change in available food, such as berries, that a change of dominating tree species could mean.

The presence of birds in planted non-native coniferous stands has been poorly studied in Iceland. To my knowledge only one study have been published. Which found that the first ten years after plantation of conifers the avifauna showed no change in numbers compared to heath land (Halldorsson *et al.*, 2008). These results are similar to a study in Sweden comparing *P. sylvestris* and *P. contorta* and the presence of birds, where no difference could be found in young stands (Sjöberg & Danell, 2001). However, after the coniferous stands grew denser birds associated with open areas disappeared (Halldorsson *et al.*, 2008; Sjöberg & Danell, 2001). The structure of the forest has an impact on bird species composition, and bird species that are linked to open landscapes are disfavoured by denser stands, that *P. contorta* is associated with. Yet, even though this says something about what habitats the Icelandic birds preferred, it is helpful to understand how other factors connected to tree species, such as berry production, influences bird populations (Newton, 1998). I will therefore study amount of available food for rock ptarmigan. During the winter rock ptarmigan in Iceland feed primarily on dwarf birch catkin, foliar birch buds and *Salix* spp. However, when both birch and S*alix* spp. are present, S*alix* spp. are preferred (Bryant & Kuropat, 1980). No literature of game species in Iceland was found that indicated that they consume *P. contorta*. This, *per se*, might indicate that *B. pubesce*ns are more favourable to birds. Though, this can only be assumed during winter. In the late autumn and early spring the main food intake of rock ptarmigan are early spring berries (Pulliainen, 1970), shoots and leaves of *E. nigrum*, *V. myrtillus*, *Vaccinium vitis-idaea* and *V. uliginosum* (Pulliainen, 1970; Bell & Tallis, 1973a; Moss, 1975). Bulbils of *Bistorta vivipara* are also among the favourite food of rock ptarmigan in Iceland (Moss & Parkinson, 1975).

Regarding berry production, *E. nigrum*, *V. myrtillus* and *V. uliginosum*, have all also been used as human supplementary food since the settlement of Iceland (Svanberg & Egisson, 2012), and can therefore, arguably, be seen as an important non-timber forest product. The presence of berries has been poorly studied in Iceland, and to my knowledge there is no published study comparing berry production in Iceland between *P. contorta* and *B. pubescens*. However, relevant previous studies exist elsewhere, and investigated the differences between *P. contorta* and *P. sylvestris* (Miina *et al.*, 2009; Berg, 1986). The stand age is a key factor of estimating the coverage of *V. myrtillus* (Miina *et al.*, 2009). *V. myrtillus* usually increases with stand age until canopy closure (Miina, 2009). Usually *V. myrtillus* abundance is sparser in planted stands compared to naturally regenerated stands, due to more favourable light conditions (Miina *et al.*, 2009). Open pine woods are well known to provide favourable habitats *to V. myrtillus* (Ritchie, 1956). In addition, Miina *et al.* (2009) found that pine-dominating stands had a higher abundance of *V. myrtillus* than *B. pubescens* stands.

1.3.2 Esthetical value

Esthetical value is often experienced though visual observations and therefore the structure of the forest is a key factor for estimating how attractive the forest is perceived. (Olsson, 2014) showed that people are willing to travel longer distances to a forest that is valued as more attractive. Forests with a mixed structure, including different tree species of different age and size is often given a higher esthetical value compared to stands with more homogeneity (Olsson, 2014). In Iceland the deforestation has led to a forest cover of only 2% and hence people are used to the open landscape. During winter the exotic evergreen trees are easily seen from a long distance in absence of snow cover in a brown landscape, giving them a different appearance than the natural birch forest (Ritter, 2008). To act as protection from grazing sheep and horses, many plantations have been surrounded by fences which has resulted in a high number of rectangular plantations of *B. pubescens* (?) (Dammert, 2001). The perception of the esthetical value of *P. contorta* and *B. pubescens* is therefore likely to be different. In a survey from 2004 regarding afforestation in Iceland, 52% preferred birch and 23% of the people preferred pine when choosing tree species to be planted (Ritter, 2008).

1.4 Research questions

The implementation of non-native species in forestry is a common practice, both worldwide as well as in Iceland, but how this is affecting biodiversity and ecosystem services is not very well studied. Iceland pose a perfect study system as forests are surveyed every 5th year. The goal with my thesis is to examine how non-native and a native tree species affect understory vegetation species richness and ecosystem services. Specifically I investigated following:

(1) Understory vegetation – How does vegetation cover and the presence of different vegetation types differ between the non-native tree species *P. contorta* compared to the native tree species *B. pubescens*?
(2) Berry production and game potential – Are there any differences in the presence of berry producing species, and hence the amount of berries available for human and game species, between *P. contorta* and *B. pubescens*?
(3) Esthetical value – which of the two forest types are considered to be more attractive?

1.5 Hypothesis

Afforestation with *P. contorta* or *B. pubescens* is likely to have an impact on (1) understory vegetation (2) berry production and game production potential and (3) esthetical value. To guide my hypothesis I made a conceptual model (Fig. 1) of what internal driving factors that are likely to affect my chosen variables.

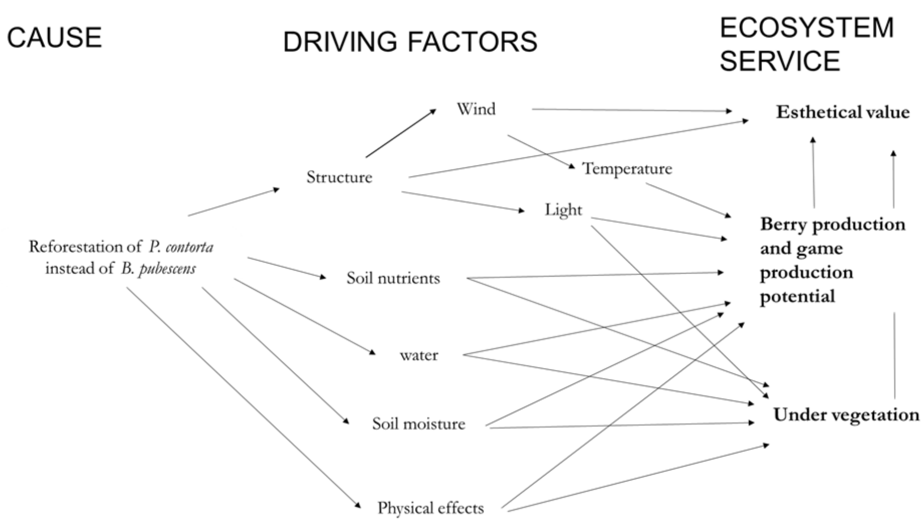

Fig. 1. Conceptual model for guide-lining hypothesis of potential effects that afforestation can have on responding chain effects.

1.5.1 Understory vegetation

The understory vegetation can be influenced by the dominating tree species in numerous ways (Fig. 1). Due to the differences in stand structure and effect on forest floor I expected to find a different composition in understory vegetation between *P. contorta* and *B. pubescens*. Shade intolerant groups are likely to be disfavoured by a denser canopy structure, which is more associated with *P. contorta*.

The characteristics of tree species often become more pronounced with age (Barbier *et al.*, 2008), and therefore it's less likely to find any differences in the youngest age group.

1.5.2 Game potential and berry production

Game production potential, and in particularly rock ptarmigan, were estimated by the amount of food that was found in *P. contorta* and *B. pubescens* stands. I assumed that a higher presence of *V. myrtillus, V. ulignosum*, *E. nigrum* as well as *B. vivipara* was equal to a higher berry production and should increase habitat quality for rock ptarmigan and hence also game potential. This allowed me to study the potentially different effect that *B. pubescens* and *P. contorta* have on game potential.

The factors that affects understory vegetation are also connected to berry production and game potential (Fig. 1). Shade intolerant species will likely be less in older stands of *P. contorta*. Plants associated with more acidic soils, for example *V. myrtillus* are likely to be favoured by *P. contorta* in the middle age class. At this stage the canopy cover is still probably not too dense and will allow enough light to the forest floor for *V. myrtillus*.

2. Methods

In Iceland a nationwide inventory has been conducted every fifth year since 2005 by the Icelandic Forest Research. The inventory is conducted using permanent plots in a grid system in planted forest, as well as naturally regenerated birch forest. In my thesis I only used data from inventories of plots in planted forest conducted between 2005 and 2014. Data was collected from the Icelandic Forest Inventory database during a study trip to Iceland in June 2015. Inventory plots were spread all over Iceland where it is possible for trees to grow (Fig. 2). The data contains cover estimates and height of understory vegetation, absence/presence of a few specific understory species and esthetical grading of the forest.

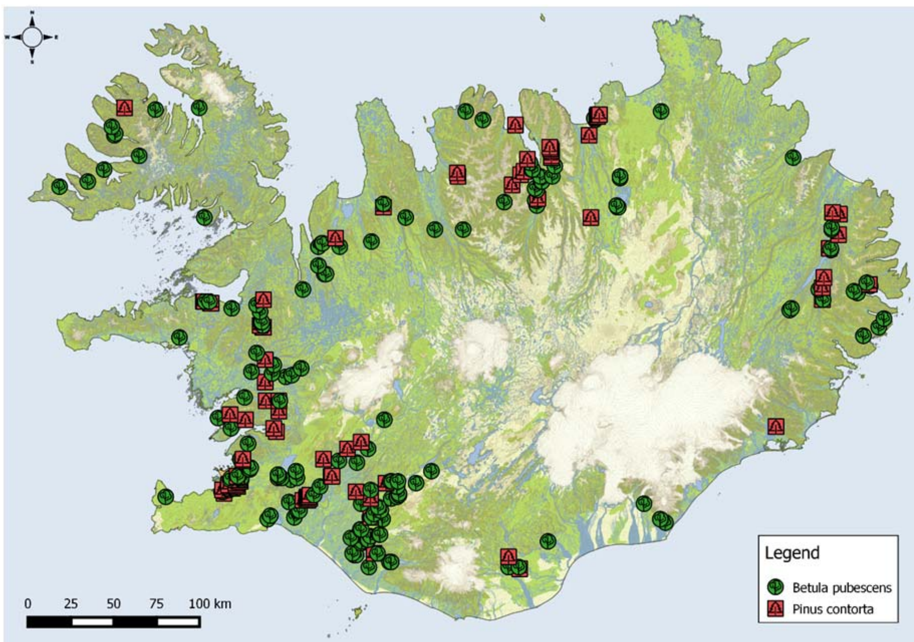

Fig. 2. Map showing locations of inventory plots divided by tree species: Betula pubescens *(green circles) and* Pinus contorta *(red squares).*

I used a total of 273 inventory plots. Inventory plots were selected after tree species, with the criteria that the dominating tree species constituted more than 70% of the total canopy cover. Due to this criteria of not using mixed stands many inventory plots could not be used. The different age classes were divided into three categories; young forest (0–10 years), middle age forest (11–25 years) and old forest (26–59 years) (KunskapDirekt, 2012).

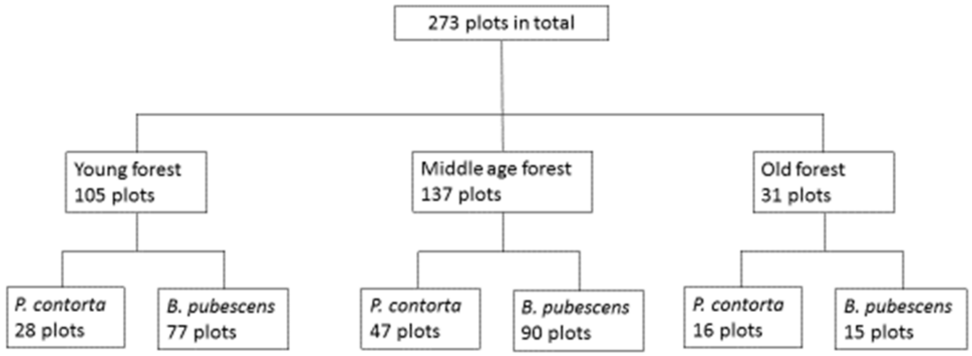

Fig. 3. Inventory plots divided in the three age classes and the two tree species. Young forest (0–10 years), middle age forest (11–25) and old forest (25–59 years).

2.1 Understory vegetation

Fig. 4. Photo of Dryas octopetala. By Lina Edgren

Moss, fungi, lichen, pteridophytes, grass and herb cover was analysed by using a Mann-Whitney U-test for independent samples (Table. 1 Overview of variables included in under vegetation and corresponding test using the software STATISTICA 10 (StatSoft, Inc Tulsa, OK, USA). Available data was divided in eight categories; absent, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100% and 100%, following the Braun-Blanquet scale. The presence of *D. octopetala* (Fig. 4), *B. vivipara*, *C. vaginata*, *G. sylvaticum* tested using Fisher's exact test in the software SPSS (IBM SPSS Statistics for Windows, 2011). Available data showed if the selected plant species were present or not in the inventory plot. Under vegetation height was tested with a t-test in SPSS (IBM SPSS Statistics for Windows, 2011). Below is a summarized table (Table. 1) of variables that were included in the analysis for understory vegetation.

Table. 1 Overview of variables included in under vegetation and corresponding test.

Tested with:	Variables included in understory vegetation :
Mann-Whitney U-test for independent samples	Moss cover
Mann-Whitney U-test for independent samples	Lichen cover
Mann-Whitney U-test for independent samples	Herb cover
Mann-Whitney U-test for independent samples	Fungi cover
t- test	Veg. Height
Fisher's exact test	*D. octopetala*
Fisher's exact test	*C. vaginata*
Fisher's exact test	*G. sylvaticum*

2.2 Game potential and berry production

The presence/absence of *R. saxatilis, V. myrtillus, E. nigrum, B. vivipara* and *V. uliginosum* was tested in SPSS (IBM INC. 2010) using a Fisher's exact test. Available data showed if the selected plant species were present or not in the inventory plot.

2.3 Esthetical value

Esthetical value was tested using a Mann-Whitney U-test for independent samples in the software STATISTICA 10 (StatSoft, Inc Tulsa, OK). Available data was divided in five categories; very ugly, ugly, passive, beautiful, very beautiful. Data were collected in the inventory, by trained foresters.

Nomenclature follows (Mossberg & Stenberg, 2003) for vascular plants, and (Svensson *et al.*, 2009) for birds.

3. Results

In the statistical analysis, four significant differences were found; moss cover in the age class old forest, *D. octopetala*, *and E. nigrum* and *V. uliginosum* in age class middle age forest. Most variables did not have a significant difference between *P. contorta* and *B. pubescens*.

3.1 Understory vegetation

Moss cover was significantly higher in old *P. contorta* stands, as compared to old *B. pubescens* stands (Mann-Whitney $U = 41$, $Np._{contorta}=15$, $Nb._{pubescens}=16$, $P<0.05$ two tailed). In age class 0-10 and 11-25, no significant differences of moss cover were found. No other cover estimates were significantly different for any of the three age classes (Fig. 5).

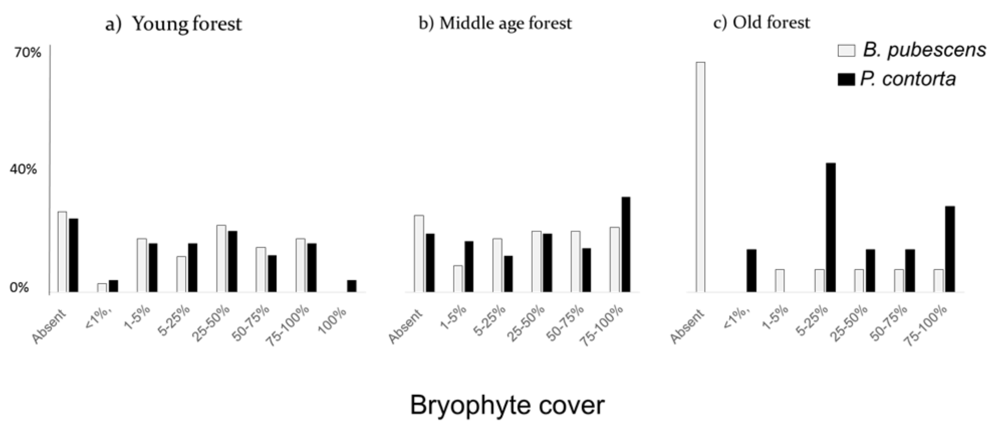

Fig. 5. Vegetation cover of bryophytes in the three age classes, divided in percentage of total sum. Black bars: P. contorta, *grey bars:* B. pubescens

In the middle age class *D. octopetala* was significantly more common in *P. contorta* (Fischer's exact test, p = 0.020), no *D. octopetala* was found in the old forest age class in any of the two species (Fig. 6).

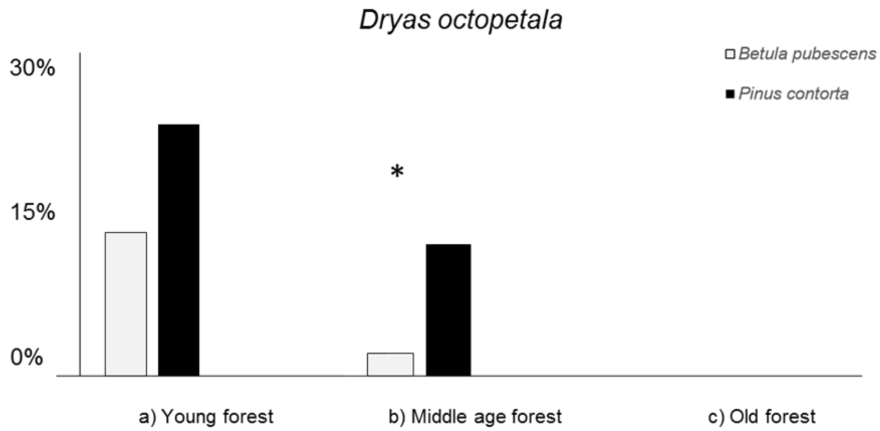

Fig. 6. Present or not present D. octopetala *in the three age classes, divided in percentage of total sum. Black bars:* P. contorta*, grey bars:* B. pubescens*. Differences where tested by using Fisher's exact test, significant results are presented: *: P ≤ 0.05, **: P ≤ 0.01, ***: P ≤ 0.001.*

3.2 Game potential and berry production

There was a significant difference between *B. pubescens* and *P. contorta* for *E. nigrum* in middle age forest (Fisher's exact test, p = 0.011) and *V. uliginosum* (Fisher's exact test, p = 0.008). Both *E. nigrum* (Fig. 7) and *V. uliginosum* (Fig. 8) were significantly more common in *P. contorta* forest in the middle age forest.

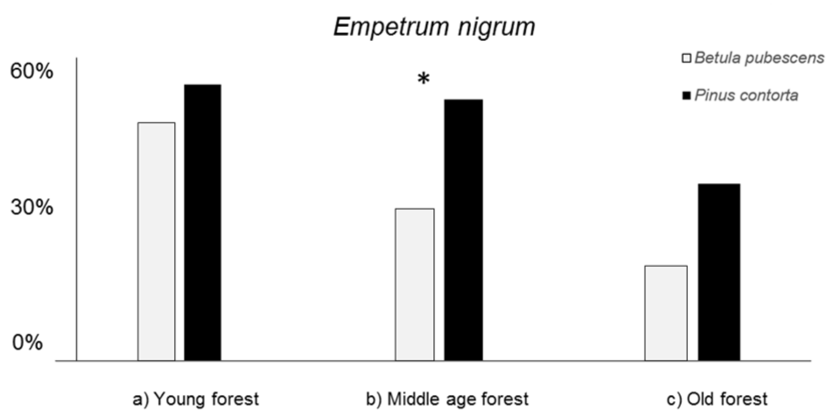

Fig. 7. Present or not present of E. nigrum *the three age classes, divided in percentage of total sum. Black bars:* P. contorta*, grey bars:* B. pubescens*. Differences where tested by using Fisher's exact test, significant results are presented: *: P ≤ 0.05, **: P ≤ 0.01, ***: P ≤ 0.001.*

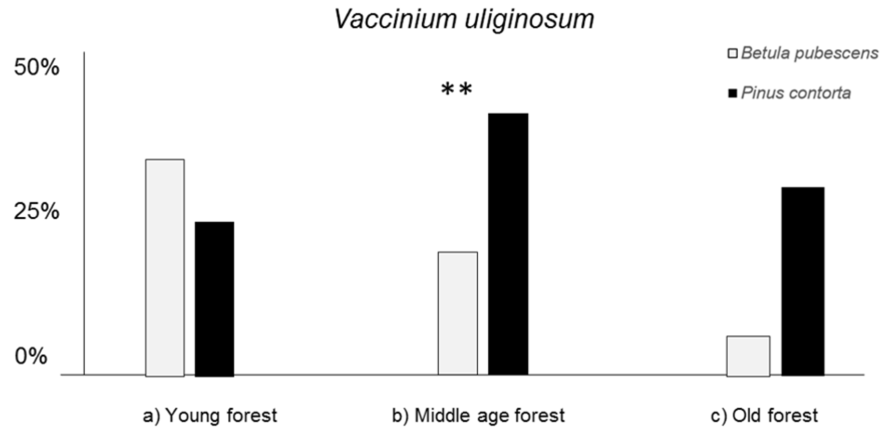

*Fig. 8. Present or not present of V. uliginosum in the three age classes, divided in percentage of total sum. Black bars: P. contorta, grey bars: B. pubescens. Differences where tested by using Fisher's exact test, significant results are presented: *: P ≤ 0.05, **: P ≤ 0.01, ***: P ≤ 0.001.*

3.3 Esthetical value

No differences was found between *P. contorta* and *B. pubescens* in esthetical value (Fig. 9).

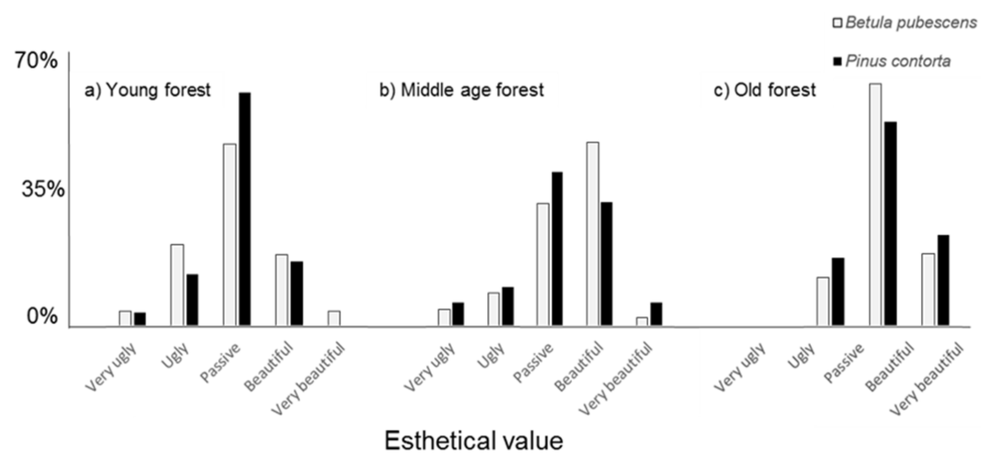

Fig. 9. Esthetical value of B. pubescens *and* P. contorta*, in the three age classes, divided in percentage of total sum. Black bars:* P. contorta*, grey bars:* B. pubescens*. No significant differences between* P. contorta *and* B. pubescens *within the age classes.*

5. Discussion

In managed forests the selection of tree species is one of the forester's most important choices (Barbier *et al.*, 2008). The selected tree species will have a great impact on understory vegetation and composition (Barbier *et al.*, 2008; Saetre *et al.*, 1997) and subsequently e.g. berry production. I have in this thesis examined how the Icelandic non-native *P. contorta* and the native *B. pubescens* affect understory plant species richness and ecosystem services, such as berry production and esthetical value. The main results indicate a difference in understory plant species richness and understory cover between the two tree species. Moreover, the data suggests that the effects increases with stand age.

5.1 Understory vegetation

Coniferous forest are thought to have less diversified understory than deciduous forest, however this is not always the case (Barbier *et al.*, 2008). My study showed that bryophyte cover was higher in stands of *P. contorta* than in *B. pubescens* in the oldest age class. Furthermore, a study in Iceland showed that *B. pubescens* forests were characterised by having a well-developed understory while *P. contorta* had very limited understory (Sigurðardóttir, 2000). Elmarsdottir & Magnusson (2007) reported a similar result when studying the effects on understory vegetation by *B. pubescens* as compared with coniferous species, including *P. contorta* in two study areas in Iceland. Even though the two study areas differed from each other geographically, the changes in understory vegetation were similar (Elmarsdottir & Magnusson, 2007). The result indicated a higher species richness, especially for moss cover, in the native birch forests than coniferous forest.

The reproduction and survival of bryophytes are positively influenced by higher air and soil moisture (Saetre *et al.*, 1997). The shaded microclimate may have decreased the risk of desiccation and in this way favoured bryophytes.

Bryophytes are also, in contrast to herbaceous species, benefiting from acidic soil conditions (Barbier *et al.*, 2008) which is often associated with *P. contorta*. Additionally, Saetre *et al* (1997) found that the cover of bryophytes were lower in coniferous stands mixed with birch, compared to unmixed coniferous, and the authors suggested that the presence of birch leaf litter was likely to be the most important factor for the differences in vegetation composition. Light is often regarded as a key factor for estimating understory vegetation cover and richness (Sigurdsson *et al.*, 2005) and the shading in *P. contorta* stands may be unsuitable for many species (Bäcklund *et al.*, 2015). In addition the litter of *P. contorta* has been suggested to favour bryophytes sensitive to physical effects (Barbier *et al.*, 2008).

A significant difference was also found for *D. octopetala* with a higher presence in *P. contorta* forests than *B. pubescens*. *D. octopetala* is a low growing shrub species that were chosen by the Icelandic forest inventory to "indicate drier and less productive forests or even of more open shrub to heathland vegetation" (Borgþór Magnússon, pers. comm.). Most *P. contorta* and *B. pubescens* are planted on less productive areas (Arnór Snorrason, pers. comm.), which is favourable to *D. octopetala*. But the presence of *D. octopetala* can be heavily reduced due to grazing by sheep. A study in Svalbard showed that high grazing pressure from reindeer had a considerable effect on the reproductive shoots of *D. octopetala* (Cooper & Wookey, 2003). The grazing pressure of reindeer is connected to the stand density (Helle *et al*., 1990). A study showed that young forest stands had a negative correlation with presence of *D. octopetala* as compared to older stands, which they explained by poor visibility in young stands which in turn reduced grazing (Helle *et al*., 1990). Grazing has, indeed, a great impact on the distribution of *D. octopetala*. For example, the majority of the populations of *D. octopetala* in Scotland were found in areas that were not exposed to grazing animals (Elkington, 1971). Furthermore, Elkington (1971) have also suggested that *D. octopetala* covered greater areas before the introduction of sheep to Scotland.

Arguably, due to the common practice of fencing almost all plantations (in order to protect trees from being grazed), the absence of sheep is likely the main cause of the relatively high proportion of *D. octopetala* in the youngest stands in my study. *D. octopetala* can manage to quickly establish in new areas, especially if the site-conditions are favourable (Elkington, 1971) which new plantations of *P. contorta* and *B. pubescens* often are. When sheep are removed from an area this allows *D. octopetala* to have a rapid regeneration. Thereby the choice to fencing an area might be of greater importance than the choice of tree species, for palatable species, such as *D. octopetala*. However, the proportional effects of establishment of forests in relation to the effect from fencing is not known and would need further research.

In the old stands *D. octopetala* is completely absent regardless of tree species, which is probably due to the fact that *D. octopetala* is a typical pioneer (Elkington, 1971) and is very light demanding. Even though *D. octopetala* had a higher presence in stands of *P. contorta* than *B. pubescens* in the middle age class there is nothing that indicates that *P. contorta* would be favourable in the long run. Instead the results indicates, even though not statistically tested, that the establishment of a forest has a negative impact on the light-demanding species *D. octopetala*. To explain this further research is needed.

5.2 Game potential and berry production

The abundance of berries is a vital component in the diet of many bird species, e.g. rock ptarmigan, but berries can also be linked to human consumption (e.g. *V. myrtillus*). My results showed significant positive correlations between the abundance of both *V. uliginosum* and *E. nigrum* and *P. contorta* in the middle age class.

V. uliginosum is a light demanding shrub that is considered to be a artic-montane species (Jacquemart, 1996; Bell & Tallis, 1973). *V. uliginosum* is very seldom found in dense woodland (Jacquemart, 1996), and therefore it might seem as a surprising result to find a positive correlation between *V. uliginosum* in *P. contorta* in the middle age class. In the youngest age class there were only a few percentage of the inventory plots that hosted any *V. uliginosum*, while in the middle and oldest age class around 40% of the inventory plots had *V. uliginosum* present in them. One explanation could be that *V. uliginosum* is generally found on moist soil types (Jacquemart, 1996), which is more associated with *P. contorta*. Additionally, *V. uliginosum* is linked to acidic soils, which usually is also more connected to *P. contorta* than *B. pubescens* (Jacquemart, 1996), which also supported my hypothesis. Finally, the increase of presence in both species could potentially be explained by the trees offering wind protection.

The presence of *E. nigrum* was significantly higher in *P. contorta* forests than *B. pubescens* in the middle age class. *E. nigrum* is less light demanding than *V. uliginosum* and even though it often is found in the same areas as *V. uliginosum* (Jacquemart, 1996), *E. nigrum* can also be found in open pine and birch woodlands (Bell & Tallis, 1973). When comparing the presence of *E. nigrum* in the youngest age class and in the oldest *E. nigrum* becomes less present. However, more research is needed to verify this.

Since both *E. nigrum* and *V. uliginosum* were higher in *P. contorta* stands in the middle age class this should in turn mean that there is a higher food availability for game species, e.g. rock ptarmigan, and human consumption. However, this is only true if berry production is positively linked to abundance of *E. nigrum* and *V. uliginosum.* The amount of higher vascular plant within stands of *P. contorta* stands was also found in a study in Sweden that compared the non-native *P. contorta* to the native *P. sylvestris* and *Picea abies* (Bäcklund *et al.*, 2015).

5.3 Esthetical value

It is clear that tree species choice is influencing people's preference for a forest (Gundersen & Frivold, 2008). My results showed, however, that people conducting the forest inventory did not rate the esthetical value of *P. contorta* or *B. pubescens* significantly different in respective age class. Though, the results does not say anything about how the Icelandic public value *P. contorta* or *B. pubescens*.

Trained foresters have been shown to respond differently to various silvicultural treatments, as compared to the public (Gundersen & Frivold, 2008). And people working in the forest often have another view of the esthetical values compared to the public. For example Gundersen & Frivold (2008) found that foresters were more positive to clear-cuts than the general public. In a similar study in Sweden, it was found that public forestry officials and employees preferred silviculture practices that promote production before biodiversity protection (Nordén *et al.*, 2015). For this reason it is important to remember that the results are the preferences of foresters and not the public. Nevertheless, this is valuable and unique information in itself. The tree species choice are generally decided by trained foresters (Barbier *et al.*, 2008), and not by the public. Therefore, information of preferences of what tree species that are considered to be "attractive" to trained foresters are of great value. Furthermore, this data also allows for future studies where people that are not trained foresters can visit the same inventory plots and give their value its esthetical value, and in this way investigate if a difference in the opinion of foresters and non-foresters in Iceland do exist.

The graphs over esthetical ratings of the forest stands (Fig. 9) indicated a difference between the three age classes, even though this was not tested statistically. Worth noting was that in the youngest age class the attractiveness of the forest was rather low, and most forests were considered "passive", i.e. neither "beautiful" nor "ugly". In the oldest age class the forests were generally considered "beautiful", which indicated that forest on Iceland are considered more beautiful with age by foresters. This indication is in line with many studies that show that older forests are generally considered more attractive than young forests (Nordén *et al.*, 2015; Olsson, 2014).

5.4 Non-significant results

Most of my statistical tests did not show a significant difference between *P. contorta* and *B. pubescens*. One reason for the absence of significant results might be due to the way the data was collected. When using the Braun-Blanquet scale in a Mann-Whitney U-test it is difficult to find small statistical differences. For example, some cover classes are including 25% of all collected data, but this class ranges from absent, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100% and 100 %. This is also the negative aspect of using data collected by others. If I had collected my own data I would probably have used a continuous scale with a 1% accuracy, which would have allowed for a greater variety of statistical tests. Another aspect is that some variables are strongly dependent of what time of the year the inventory is done, for example, most fungi species are only detectable in the autumn. On the other hand, not collecting my own data allowed me to study a greater number of samples over a vast area.

Another reason for not finding more significant result is probably due to the fact the forests have been established on previous tree-less land. Some of the new forests have a great distance between each other. So understory vegetation species that are typically connected to forests will have a long distance to travel to occupy new areas. It is important to remember that the forestry of Iceland is still a rather young practice. The oldest inventory plot in my data-set was 59 years old and therefore some structures, for example the bark of the trees will change in the next coming 20-30 years.

My study indicated that forest stand age, in addition to tree species, is an important factor for understory vegetation as well as for esthetical value. A potential future study of high interest could investigate this more thoroughly.

6. Acknowledgement

After an intense period of researching and writing the day finally arrived - the day when I’m finished!

I would first like to start by thanking both of my great thesis supervisors, Jörgen Rudolphi and Göran Thor. Jörgen Rudolphi for the faith and enthusiasm you had in this project since the very first time we met. Thank you for your patience and above all, the motivation and support you gave me before my oral presentation! Göran Thor, for the unfailing support, guidance and the many wise words of encouragements. My writing skills are improving with your great comments. I would also like to thank Hilda Edlund who were involved in helping me with the statistics with such a remarkable patience. Further, I would like to thank Arnór Snorrason, Bjorn Traustason and Bjarki Þór Kjartansson at the Icelandic Forest Research. Bjarki for the warm welcome you gave me and Mimmi when we first arrived to Iceland. Bjorn who was my supervisor at the inventory and the one who sparked my interest for *P. contorta* in Iceland. Thank you for stimulating conversations, and above all, that you inspired me to start reading Halldór Laxness. Arnór for believing in this project and the warm hospitality and answering all my questions I had about the data. My friends and family deserves the greatest of thanks for their wise council and encouragement but also for making this time more fun than I thought possible. Some that I would like to thank a bit extra are: Lina, Greger, Louise, Helena, Mimmi and Isabelle. Finally, but not the least, I would like to thank my boyfriend Linus for the invaluable support you gave me throughout writing this thesis. This accomplishment would not been possible without you.
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Författare: Sofie Kruse

2016:9 Immediate effects on the beetle community after intensive fertilization in young Norway spruce *(Picea abies)* stands
Författare: Martin Johansson

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Författare: Linda Vikström

2016:11 Artificial gap creation and the saproxylic beetle community: The effect of substrate properties on abundance and species richness
Författare: Nils Bodin

2016:12 Extended phenotypes in the canopies of Norway spruce
Författare: Christofer Johansson

2016:13 Comparison of three different indirect methods to evaluate ungulate population densities
Författare: Sabine Pfeffer

2016:14 Estimation of maximum densities of young of the year brown trout, *Salmo trutta*, with the use of environmental factors
Författare: Johanna Wärnsberg

2016:15 Analysis of the successfulness of wolverine (*Gulo gulo*) depredation control in Västerbotten County
Författare: Fredrika Vretling

2016:16 Increased public participation as a potential human – large carnivore conflict mitigation measure
Författare: Ruben Bloemsma

2016:17 Influence of temperature and predation risk on herbivore micro habitat choice in a South African savanna
Författare: Hanna Rogers

2016:18 Elephant utilisation of and impact on a locally threatened habitat, coastal scarp forest, in South Africa
Författare: Matilda Apelqvist

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