# Natura 2000 Habitats Dominated by Ash and Elm, Invaded by Alien Invasive Fungi on the Gotland Island of Sweden: an Overview

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## *Abstract*

Natura 2000 sites in Gotland are unique and possess very high nature conservation values. Both ash and elm are the typical tree species in several key habitats of Natura 2000 sites and accommodate a high number of associated (red-listed) species. Recent invasion of Dutch elm disease and ash dieback pathogens threatens elm and ash existence, and threatens the integrity of Natura 2000 sites. Management measures undertaken are aimed primarily at sustaining ash and elm, and associated biodiversity, and thus aimed at sustaining high nature conservation values of Natura 2000 sites.

**Keywords:** nature conservation, *Fraxinus*, *Ulmus*, invasive pathogens, *Hymenoscyphus*, *Ophiostoma*

## Introduction

The Swedish island of Gotland is 2.994 km$^2$ in size and is fully encompassed by the Baltic Sea. The coast line is 770 km long. Gotland is located about 90 km east of the Swedish mainland and about 130 km west of Latvian coast. Gotland is made up of a sequence of sedimentary rocks of limestones and shales (Laufeld 1974). The highest elevation on the island is 82 m above sea level. Geographical position of the island, specific climate, which is maritime and therefore mild, and nutrient rich calcareous soils have given many valuable habitats and the establishment of many Natura 2000 areas unique in a European context. Natura 2000 is a network of valuable natural areas that have been built up within the European Union (EU). The aim with Natura 2000 areas is to protect birds, habitats and species. Natura 2000 areas were established across EU to address two directives: the Birds Directive (Directive 79/409/EEC), introduced in 1979, in order to protect the birds, and the Habitats Directive (Directive 92/43/EEC), introduced in 1992, to protect valuable habitats and species. Natura 2000 areas on Gotland include 129 sites based on Habitat Directive, and 30 sites based on Birds Directive (Figure 1A). The area of all these sites is of ca. 200.000 ha.

### *Importance of ash and elm to Natura 2000 sites*

Many Natura 2000 sites in Gotland are exceptionally rich in deciduous trees with elm (mainly *Ulmus minor*), ash (*Fraxinus excelsior*) and oak (*Quercus robur*) being most characteristic. Notably, there are at least one million elms in

Gotland, which is the largest wild population in northern Europe (Östbrant et al. 2009). Natura 2000 sites in Gotland include several key habitats of the Habitats Directive Annex I: 6530* - Fennoscandian wooded meadows, 9020* - Fennoscandian hemiboreal natural old broad-leaved deciduous forests, 9070 - Fennoscandian wooded pastures and 9010 - Western taiga.

Among these habitats 6530*, 9020*, 9010* are priority habitat types. Both ash and elm are the core species and pivotal constituents of the habitat types 6530*, 9020* and 9070. They constitute dominant elements comprising the whole landscape structure. Moreover, specifically under Gotland conditions ash and elm are the typical species featuring habitat type 9010*, which makes coniferous taiga stands of the island unique on the worldwide scale. Each of those four habitat types harbour wide range red-listed and vulnerable species directly associated with ash and elm including two species of birds, ten of bats, 37 of beetles, six of butterflies, 12 of fungi and 23 of lichens and mosses. Besides, elm and ash make up almost 70% of the old growth tree layer on Gotland and is significant even in a national context given that 17% of the Swedish population of old elms and 24% of the old ash are on Gotland (Skogsstyrelsen 2016).

From the cultural and historical perspective, Gotland represents the richest region of Sweden in terms of both pollard meadow landscape and noble hardwood dominated land where ash, elm and oak constitute a crucial component (Mebus 2006). During the last 1500 years they have been intensely used for pollarding, hay harvesting and pasture (Hultengren 2006). Consequently these tree species are of exceptional cultural and historical value. Prior to establishment of protected areas including Natura 2000 sites, the biodiversity associated with broadleaved woodlands, wooded pastures and wooded meadows has long been under serious threat from the intensification of agriculture, abandonment of grazing or conversion to conifer plantations (Jönsson et al. 2011). At present, all Natura 2000 sites in Gotland are protected with elaborated individual nature conservation plans (Lansstyrelsen Gotlands Län 2016). Nature conservation plans describe the natural values that should be preserved, the objectives of the conservation of the site and the measures needed to achieve them. The plan also describes the measures that may threaten the species or habitats that are protected under Natura 2000 conservation plan.

In the last few years, however, elm and ash populations in Gotland are threatened by the alien invasive fungi causing Dutch Elm Disease (DED) and Ash Dieback (ADB). DED and ADB result in loss of elm and ash trees and associated biodiversity especially in the habitats of the Habitat Directive Annex I 6530*, 9020*, 9070 and to a lesser extent in 9080, 6210, 6280, 9180 and 8210. The virulent form of DED was observed for the first time in Gotland in 2005 (Menkis et al. 2016b), while ADB invaded Sweden including Gotland in 2001 (Barklund 2007).

## Dutch elm disease in Gotland

DED is a lethal vascular wilt disease caused by the pathogenic *Ophiostoma* (Ascomycota) fungi, which during the last 100 years have destroyed billions of elm trees worldwide (Phillips and Burdekin 1982). In Gotland, DED is comprised of two distinct fungal pathogens, the less virulent *O. ulmi*, and the virulent *O. novo-ulmi.* Conidia of the DED pathogens are vectored by the elm bark beetles (*Scolytus* spp.) (Ploetz et al. 2013), and in Gotland, *Scolytus multistriatus* is the only known vector (Menkis et al. 2016a). Despite the fact that DED was present for decades in Europe including mainland Sweden, the elm population in Gotland remained unaffected. The geographical position of the island in the Baltic Sea has likely prevented natural dispersal of DED.

After introduction in 2005, the DED was observed for the first time in the north-eastern part of Gotland, and in the following years, it rapidly spread in all directions, generally following the major distribution of elms including a number of Natura 2000 sites (Menkis et al. 2016b). A rapid spread of DED was particularly notable during the first three years. Consequently, the area with DED-diseased trees in Gotland increased from 15.8 $km^2$ (0.5%) in 2005 to 1446.2 $km^2$ (48.3%) in 2008, and its diameter expanded from 5.5 to 85.6 km, respectively (Menkis et al. 2016b). During 2005–2008, 4278 DED-diseased elms were felled and destroyed. During the period between 2009 and 2013, the implementation of a new combat strategy resulted in the felling and destruction of 17903 DED-diseased and visually healthy elms growing in their vicinity. The use of the herbicide killed stumps and root systems of harvested elms. Implementation of this control strategy resulted in the number of DED-diseased trees and the area of Gotland infected by DED remaining similar each year (Menkis et al. 2016b).

The ongoing control measures resulted that incidents of DED have stabilised and spread to new areas was largely arrested. In 2009, both DED pathogens *O. ulmi* and *O. novo-ulmi* were present in Gotland. However, in 2012, occurrence of *O. ulmi* was found to be very occasional (Menkis et al. 2016a), suggesting that, as elsewhere, it is being replaced by *O. novo-ulmi* (Brasier et al. 2004). Moreover, *O. novo-ulmi* was found to be the second most common fungus vectored by *S. multistriatus* (Menkis et al. 2016a). Due to ongoing incidents of DED, all species of elms including *U. minor*, which is the major elm species in Gotland, are now red-listed in Sweden as critically endangered (CR) (ArtDatabanken 2016a). Besides, *U. minor* is generally more susceptible to DED than other *Ulmus* species.

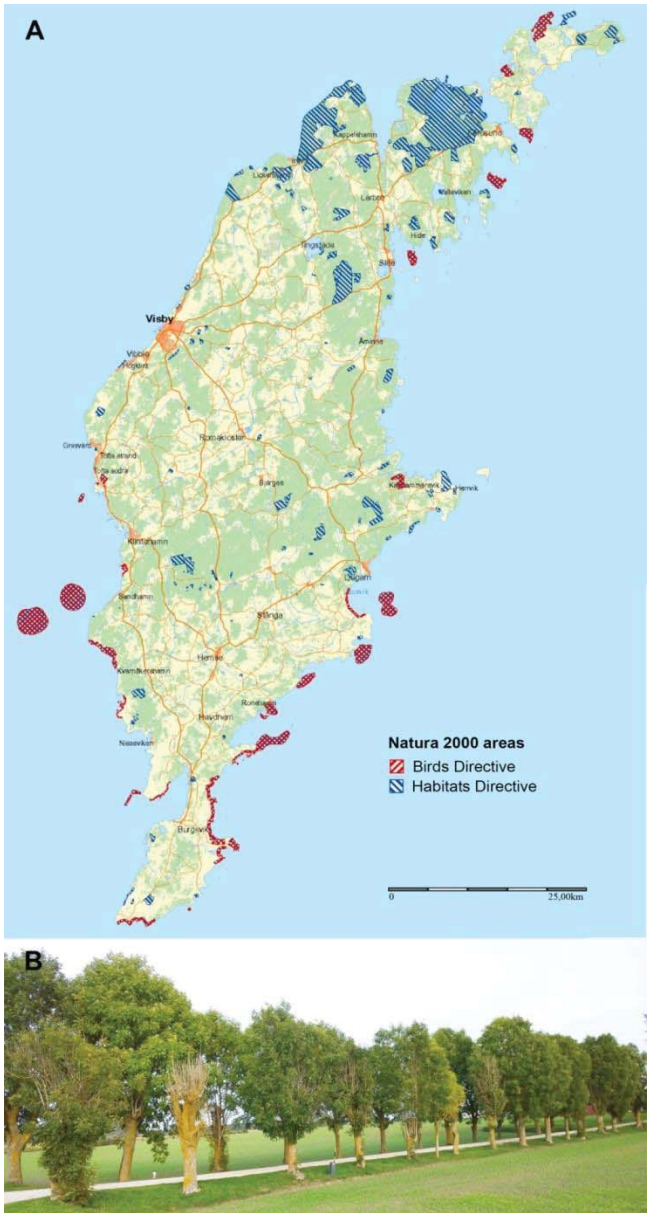


**Figure 1. A.** A map of Gotland showing Natura 2000 areas based on Birds Directive and Habitats Directive. **B.** Alley of *Fraxinus excelsior* in Gotland year 2015 showing variable degree of tolerance of individual trees to ash dieback pathogen *Hymenoscyphus fraxineus*

## Ash dieback in Gotland

ADB is caused by *Hymenoscyphus fraxineus* (Queloz et al. 2011), which is invasive in Europe (Husson et al. 2011), and which causes severe damage to *F. excelsior*, often resulting in mortality (Pautasso et al. 2013). Its origin is the Asian Far East (Zhao et al. 2012, Zheng and Zhuang 2014). It appears that the pathogen invaded Europe in early 1990s together with saplings of *Fraxinus mandshurica* imported to Poland and via airborne spores spread from there in all geographic directions (Bakys et al. 2009). ADB invaded Gotland approximately at the same time as mainland Sweden (2001-2002) leading to dieback and decline of many ash trees. Evaluation of ADB damage in Gotland showed that it largely resembles situation observed elsewhere in Europe with ca. 70% of susceptible or dead individuals in the population (Jonsson and Thor 2012). Only, a small fraction of the *F. excelsior* population can be expected to survive due to inheritable resistance (Pliūra et al. 2011) or specific phenological traits such as early leaf senescence (McKinney et al. 2011). Despite the damage, observations from Gotland demonstrate a variable degree of tolerance of individual trees to ADB, i.e. from dead to healthy-looking (Figure 1B), suggesting that breeding for resistance may be possible. As a result of ADB, since 2010 *F. excelsior* is red-listed in Sweden as strongly endangered (EN) (ArtDatabanken 2016b).

Besides the loss of elm and ash, the species diversity associated with these tree species in woodlands, wooded pastures and wooded meadows of Natura 2000 sites are threatened strongly by the DED and ADB. Many species linked to these trees and high conservation value is being lost when the old elm and ash trees die. Assessment of associated lichens in Gotland showed that dieback of ash trees results in loss of lichen community viability, with significant local reductions in species richness and shifts in lichen species composition (Jonsson and Thor 2012).

## Sustaining ash and elm in Natura 2000 sites

To address recent situation arising from invasion of DED and ADB in Gotland, various inventories, update of the conservation plans and concrete management measures are undertaken that favour elm or ash in Natura 2000 sites. To exemplify Natura 2000 sites on Gotland and measures implemented, the descriptions are provided below for Allekvie and Hörsne sites.

### *Allekvie wooded meadow*

Allekvie wooded meadow is 11.25 ha in size and includes four habitats of the Habitat Directive Annex I: 4.2 ha of 6530*, 3.2 ha of 6210, 3.1 ha of 9020* and 0.6 ha of 9070 (Figure 2A). Allekvie wooded meadow is rich in deciduous trees and lies in the area, which has been managed as a meadow for a long period, possible for more than two thousand years. Approximately one third of the area is managed traditionally where the leaves and twigs are collected in the spring and the hay is cut and removed in the summer. The other parts are grazed or have become deciduous woodland. Deciduous trees in the meadow consist primarily of *F. excelsior* (37 veteran ash trees), *U. minor* (32 veteran elms), *Q. robur* (13 veterans), *Malus sylvestris*,

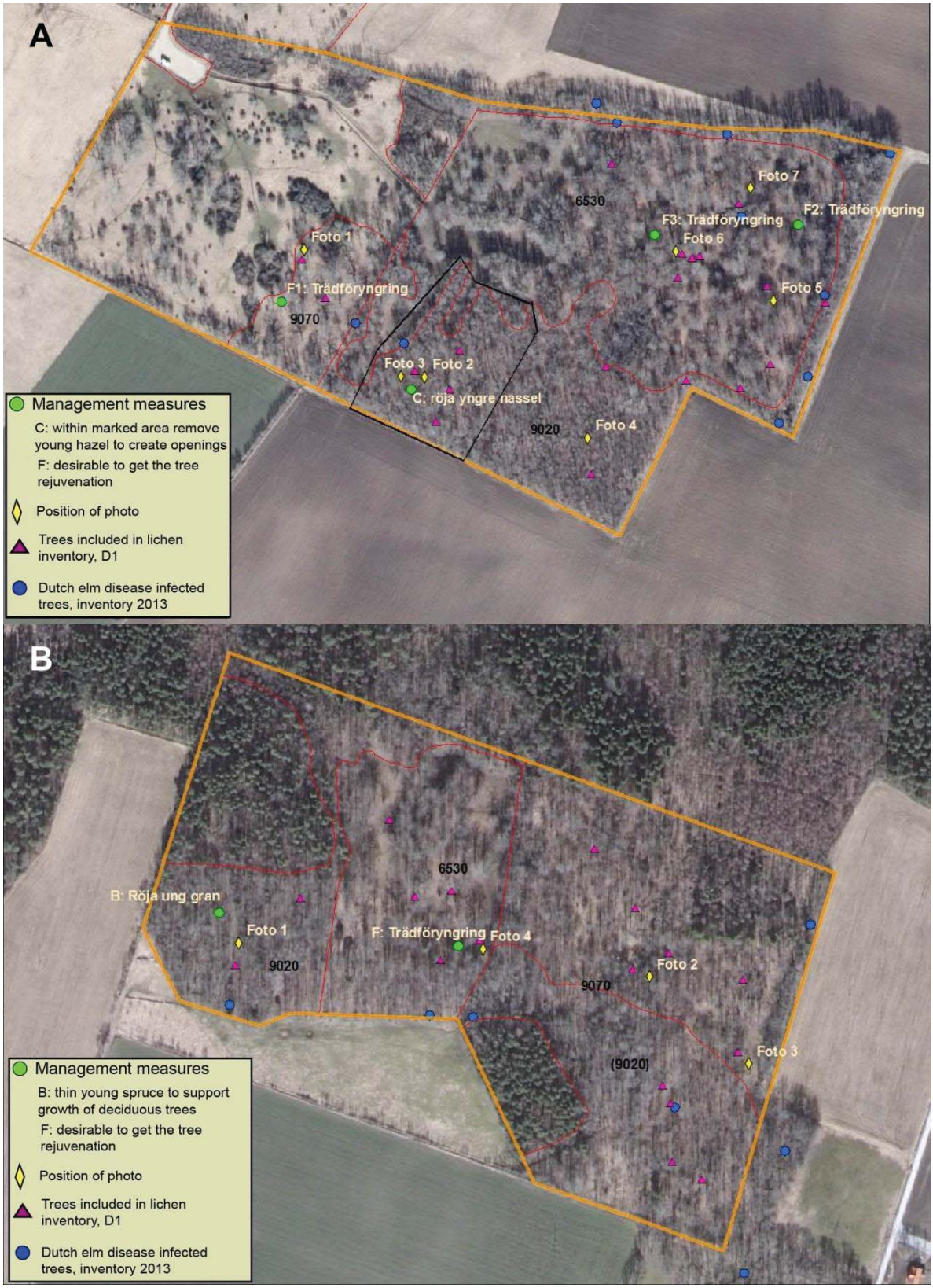


**Figure 2. A.** Allekvie wooded meadow and **B.** Hörnse wooded meadow in Gotland with planned management measures to sustain trees of ash and elm and associated biodiversity (maps are adapted from the restoration plans of Länsstyrelsen Gotlands Län)

*Sorbus aucuparia* and *Betula pendula*. Many of the ash and elm trees in the area look like old pollards. Ash and elm are two of the most important tree species in the meadow, which provide habitat for many species and give the site its character. Between the trees there are islands with *Corylus avellana* and other shrubs such as *Cornus sanguinea*, *Rhamnus cathartica*, *Rosa* spp., *Prunus spinosa* and *Crataegus* spp. The meadow has a rich plant and fungal flora. At least 27 species from the Swedish Red Data Book have been recorded.

Specifically, the wooded meadow of 6530* habitat is characterised by very high nature conservation values. In particular, many rare soil fungi, but also many species of lichens are present on the trees. The nature conservation values are linked to the old meadow trees of ash, elm and oak, and a continued hay meadow management and tree continuity. Lichens linked to ash and elm trees are rich in species. The broad-leaved forest of 9020* habitat was regrown with younger trees and hazel. The value lies mainly in the old-growth trees of ash, elm and oak. Lichens, mosses, wood-decay fungi and soil fungi are examples of species-groups that thrive here. Lichen flora associated with ash and elm is less species rich, probably due to inappropriate light conditions. Epiphytic lichen *Lobaria pulmonaria* is quite common and thrive on most trees, so for the sake of lichen alone the continuity of ash and elm are not necessary. However, there are other nature conservation values that would be lost if ash and elm disappear, and the goal is to maintain continuity of these tree species. The wooded pasture of 9070 habitat is characterized mainly by oak and ash trees. The value lies primarily in the rough oaks with high conservation values. A number of ash trees are declining.

Implemented concrete management measures to promote elm or ash are shown in Figure 2A. Management measures include: within the selected area in the south there is much of younger hazel growing next to the older hardwoods. To create more light in the area, and to get less sharp transition between the open meadow and hardwood forests and to open valuable hardwood trees, younger hazel should be cleared; in the meadow part on the north-east, it is desirable to have the tree rejuvenation of ash and elm. If healthy seedlings grow up, they should be fenced in order to become replacement trees in the future.

***Hörsne wooded meadow***

Hörsne wooded meadow is 9.68 ha in size and includes three habitats of the Habitat Directive Annex I i.e. 1.5 ha of 6530*, 5.8 ha of 9020* and 2.38 ha of 9070 (Figure 2B). The primary aim of the conservation plan for the Hörsne wooded meadow is to maintain favourable conservation status at a biogeographic level for the habitat types and species (according to the Habitat Directive and Bird Directive) included in the Natura 2000 site. Hörnse wooded meadow is a traditionally managed meadow. It is the remains of a once much larger wooded meadow area. Continuous management has taken place here for at least 2000 years. The meadow is criss-crossed by old boundary markers which can be seen today as lines of stones. The remains of a fossilised field can be seen here. The site has probably contained deciduous trees for at least 5000 years. The tree layer is dominated by *F. excelsior*, *U. minor* and *Q. robur*. The shrub layer is dominated by *Corylus avellana*. Many of the trees have been pollarded. The meadow is surrounded by woodland, which means that it has an even and humid micro-climate. The open parts of the meadow contain high biodiversity of plant communities. 1.5 hectares are managed as a meadow and 5.8 hectares have developed into deciduous forest. The meadow hosts species rich lichen and fungi flora and is also a good site for bats. At least 18 species from the Swedish Red Data Book have been recorded from the site.

On the site, both ash and elm are given as typical species for the habitats 6530* and 9020*. The ash and elm trees have been pollarded and have grown on poor soils, which means they are relatively small and have hollows and bark structure suitable for many epiphytic lichens and mosses. These hollows are important breeding sites for *Ficedula albicollis*, which is found here. It is also an important site for bats and *Eptesicus nilsonii* has been confirmed from this site. It is likely, however, that more protected species can be found if further study is undertaken. The species *Cossonus parallelepipedus* has been found in this site, which is a small weevil, which lives in hollow trees and especially in *Ulmus*. *U. minor* and *F. excelsior* are thus very important tree species on this site.

Specifically, the wooded meadow of 6530* habitat is characterised by many ash and elm trees several of which are veteran trees. Many species of lichens are attached to ash and elm, indicating desirable continuity of these tree species as well as continued and extended meadow management. 9020* habitat represent overgrown wooded meadow with elements of older trees. Dense lower layer of younger trees is composed of deciduous trees and of young spruce. Many species of lichens are attached to the ash and elm, making continuity of these species desirable. 9070 habitat is a wooded pasture with high nature conservation values, mainly linked to ash and elm, but also to oak and aspen. Many species of lichens are found on ash and elm, and their persistence dependent on the continuity of these tree species and continued grazing.

Implemented concrete management measures to promote elm and/or ash are shown in Figure 2B. Management measures include: in the western area of hardwood forest there are a lot of younger spruce trees, which should be cleared before it grows other and shadows the deciduous trees; in the meadow, it is desirable to get the tree rejuvenation that in the future can provide the natural conservation

values linked to the old-growth trees. If healthy seedlings appear, they should be saved and where appropriate fenced in order to become replacement trees in the future.

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