Integrating nature in urban areas

- How natural structures and features in urban spaces contribute to human health and well-being as well as biodiversity

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Abstract

Nature has shown to have many positive effects on our health and well-being as it benefits both our physical and mental health. Still, it has seldom been included in development processes in urban areas, which has led green spaces to become fragmented, resulting in decreasing the diversity of species. Urban biodiversity today, in contrast to the natural landscape, mainly consists of generalist species that are able to adapt to urban conditions and human disturbances. This makes it important to preserve biodiversity in urban areas, as it can benefit humans as well. This study has through the means of a literature study examined how nature can be integrated in urban areas and at the same time promote both human needs and biodiversity by looking at the natural landscape. It has further looked into how urban green spaces can help mitigate the negative effect on the climate.

The results suggest that the needs of biodiversity in urban areas can have many synergies with human needs, it can also raise conflicts affecting the relationship between humans and biodiversity. Further, it has also been shown that urbanization itself is often in conflict with both human needs and biodiversity, a conflict that can be solved through strategic designing. The structures and features found in the urban landscape do not help to mitigate the negative climate effects, but that the natural structures do help to mitigate them. The present study has also shown that to integrate nature in urban areas and still attend to human needs, urban inhabitants need to have knowledge of nature — how it works and its benefits. This is because the literature has shown that knowledge about nature changes humans preferences and attitude towards it. Because it is only when we understand the contributions nature provides us and our needs that we can fully integrate nature to further promote biodiversity in urban areas.

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INTRO DUC TION

Background

By the year 2050, 68% of the world's population will live in urban areas and a significant portion of humanity will not have daily access to nature, which is a reality for many people already (UNDP - Human Development Reports, n.d.). The World Health Organization (WHO) (Romanelli *et al.*, 2015) and United Nations Development Program (UNDP) (UNDP - Human Development Reports, n.d.) highlight that biodiversity contributes to human well-being. As the urbanization and human populations around the world increases urban areas grow larger and denser. Natural habitats are being fragmented due to urbanization which often leads to a biotic homogenization and a loss of specialist species (Bonthoux *et al.*, 2014). Urban green spaces and biodiversity are often neglected and threatened by the densification processes (Haaland and van den Bosch, 2015; Kirk *et al.*, 2021) and biodiversity is often not thought about until an urban development project is near completion (Kirk *et al.*, 2021). Conflicting interests for the development of urban areas in pursuit of profit (Gough, 2017) also often results in biodiversity being set aside (Miller and Hobbs, 2002; Qiu, Lindberg, and Nielsen, 2013; Wild, Henneberry and Gill, 2017). Consequently, urban green areas are lacking both in quantity, size, and quality, thereby also diminishing their contribution to human health and well-being (Ulrich, 1983; Grahn and Stigsdotter, 2003; Grahn, Stigsdotter and Berggren-Bärring, 2005; Hartig and Staats, 2006; Björk *et al.*, 2008; Commission, 2008; Jansson, 2008; Alvarsson, Wiens and Nilsson, 2010; Lucas and Dyment, 2010; Annerstedt *et al.*, 2013; Movium, 2013; Jansson *et al.*, 2014; Mavoa *et al.*, 2019; Giusti and Samuelsson, 2020; Ode Sang and Hedblom, 2021; Gramkow *et al.*, 2021). Therefore, the UNDP states that biodiversity needs protection for a sustainable development of our societies (UNDP - Human Development Reports, n.d.).

The United Nations Environment Program's (UNEP) sustainable development goal nr 15 "Life on land" (UNEP, n.d.) and one of Sweden's climate goals: "A rich plant and wildlife" (Sveriges miljömål, 2021) both states that the diversity of plants and animals should live in a mosaic of different environments, such as forms of cultivated land, forests, mountains, wetlands, streams, lakes, and seas. Although nature has been shown to have a positive effect on our health and well-being (Ulrich, 1983; Grahn and Stigsdotter, 2003; Grahn, Stigsdotter and Berggren-Bärring, 2005; Hartig and Staats, 2006; Sustainable Development Commission, 2008; Björk *et al.*, 2008; Jansson, 2008; Alvarsson, Wiens and Nilsson, 2010; Lucas and Dyment, 2010; Annerstedt *et al.*, 2013; Movium, 2013; Jansson *et al.*, 2014; Mavoa *et al.*, 2019; Giusti and Samuelsson, 2020; Ode Sang and Hedblom, 2021; Gramkow *et al.*, 2021), people who have less knowledge of nature often prefer formal parks (Hofmann *et al.*, 2012). Whereas people who grow up close to nature tend to show a preference to more natural areas and are generally more eager to embrace a pro-environmental stance (Hofmann *et al.*, 2012; Rosa, Profice, and Collado, 2018). Children without regular access to nature have shown less knowledge of nature (Samborski, 2010), less biophilic behaviors (Hand *et al.*, 2016), and greater fear (Bixler and Floyd, 1997)) of nature than children who have regular access. To achieve the environmental goals many habitats and species need to be protected as they are in risk of disappearing, and if they do, it will be harder to get them back (Sveriges miljömål, 2021).

Today's diversity in species has been created by both natural forces and human activity (Almstedt Jansson, De Jong, and Ebenhard, 2011). Around 6000 years ago humans started cultivating the land, which led to forests being cut down and used as building materials for housing and objects. This in turn has led to the creation of small fields, pastures, and meadows, for livestock to graze, and humans to plow and collect hay. The last ice age left rocks scattered over most parts of the northern hemisphere, which made it hard for farmers to plow. Rocks were collected and used to build piles of rocks or stone walls, which became important habitats for many species, and they are today protected biotopes as they hold high values for biodiversity. All this created a large variety in the landscape, a mosaic of smaller landscapes, which have allowed species to diversitize (Emanuelsson *et al.*, 2002).

However, Szaro and Johnston (1996) have stated that there is a conflict between the climate, our land use, and biodiversity as these factors either affect or compete with each other. The growth of our societies has caused many problems related to those factors, such as pollutants, CO_2 emissions (Grimmond, 2021), habitat loss (Borman, Balmori and Geballe, 2001) and land exploitation (Maxwell *et al.*, 2016; Persson *et al.*, 2020). This in turn has caused the climate crisis (UNFCCC, no date) and the threat of a sixth mass extinction (Ceballos, Ehrlich and Raven, 2020; European Parliament, 2020), which will greatly affect our lives and the welfare that we have created for ourselves. To cope with these difficulties, we must tackle new problems in new ways (Burgess, Harrison, and Limb, 1988; Bixler and Floyd, 1997; Dunnett and Hitchmough, 2004; Jorgensen, Hitchmough, and Dunnett, 2007).

Purpose and question

Purpose

The purpose of this paper is to investigate how the needs of humans and biodiversity can be brought together and optimized to create green, safe, and sustainable urban areas.

This is accomplished through the means of a literature study which serves to identify synergies and conflicts between biodiversity and human needs related to recreation in urban areas. The literature study is then used to produce a table listing criteria related to landscape design for the possible synergies between human needs and the need for improved biodiversity, or lack thereof, within certain design features that can be used in the designing of future urban green areas.

1. Identifying differences between urban biodiversity and biodiversity in the natural landscape.
2. To investigate how green areas can mitigate negative climate effects, and the basic human needs.
3. Identify synergies and conflicts between human needs and biodiversity in relation to urban areas.
4. To compare structures and features in the urban and natural landscape to identify what does/does not benefit humans and biodiversity to create a list of criteria.

Questions

Why is urban biodiversity different from biodiversity of natural landscapes?

How can urban green spaces mitigate the negative climatic effects?

Which synergies and conflicts are there between the needs of humans and biodiversity in urban green spaces?

How can urban areas incorporate the structures and features from the natural landscape while still attending to human needs, biodiversity, and the climatic effects?

Further, which criteria must be included and/or prioritized when designing for both humans and biodiversity in green urban areas?

Figure. 1 Lichen growing on a beech tree, Höör. Elin Fänge

Fulfillment and limitations

According to Boverket (2007) the definition of nature in an urban context is broad and includes the natural-cultural landscapes, green areas that are landscaped and managed, residential courtyards and parks. The definition also includes the greenery of vegetation, water, mountains, beach, and wildlife. Oxford Learner's Dictionary defines the word, Nature; "Nature [uncountable] all the plants, animals, and things that exist in the universe that are not made by people." and "Nature [uncountable] the way that things happen in the physical world when it is not controlled by people". (Nature, u.d.). As urban nature has such a broad definition this study has been limited to deal with green areas that are landscaped, managed, and used by humans, as well as more anthropogenic urban spaces, such as streets and courtyards where greenery may occur. As the study has had the purpose to investigate how to meet human needs in relation to biodiversity, it has also been limited to investigate what improves human health and well-being and how natural/forest-like green spaces in urban areas can play a vital role in that process. It also has had the purpose to investigate how to promote biodiversity in urban areas, since these spaces today are mainly prioritized for the purpose of humans. The subject of biodiversity has been limited to focus on indicator species in selected natural environments, which in turn are geographically limited to boreo-nemoral and nemoral conditions and that may occur in urban environments. Further, the study has excluded all habitats in water and marine environments, as well as species living in seas, lakes and in the beach zone. The study has also been limited to only investigate species that can be affected through the design of a site, and habitats similar to green urban spaces.

Outline

This thesis has been structured in five main sections: Introduction, Method, Literature study, Analysis and Discussion. In the introductory part, the context and theme of the problem has been described in a global perspective, which is followed by the purpose and issue of the paper that are presented along with fulfillment and limitations. The method presents the collection of material and compiles how the thesis has been described and motivated. This is followed by the literature study, which has been structured in four main headlines presented in the following order:

Human health in relation to urban areas and urban green spaces — describes and defines human health and well-being (HHWB) and how it benefits from nature.

Biodiversity in the natural landscape — presents the main habitats in the natural landscape, the diversity within those habitats and how it has been formed by both natural processes and human activity.

Urban biodiversity — describes how biodiversity in urban areas has evolved in relation to urbanization, densification processes and climate change. Further, what is needed to solve future climatic problems and how to integrate nature in a sufficient way to promote the needs of both humans and biodiversity have been presented here.

Mitigating effects in the urban landscape - describes how the urban landscape hightens the conditions of extreme weather and the levels of air pollution, and how these extremes can be mitigated with green spaces.

Human needs — describes the hierarchy of the basic human needs and how they are shaped by the urban landscape.

The literature study has later been compiled in the analysis where the biodiversity in both the natural and the urban landscape has been summarized and compiled to identify the main structures needed. This has later been set against human needs in the table of conflicts and synergies, which forms a list where the basis of criteria and how such conflicts have been solved in different urban green environments. Thereafter, the results have been discussed based on the background, purpose, and questions together with the literature study and the examples of solutions as well as the literature that has formed the base for the study. Based on the discussion, a conclusion has later been drawn. This is followed by a future outlook where a discussion has been made of how further research of the subject could continue on.

Method

The choice of method has been based on the purpose of the essay and the issues of the subject, furthermore the study has been based primarily on a literature study.

Literature study

A literature study is defined as a method where searches for literature studies weigh together results from several scientific studies and thus provide a new and more evidence-based knowledge of the subject (Forsberg and Wengström, 2016). The literature is then critically reviewed and evaluated on its scientific content. This literature study has been based on scientific articles, books and reports dealing with the perspective of health and wellbeing as well as human needs, e.g., security and accessibility. The literature has also dealt with what is needed to sustain biodiversity, e.g., habitats, processes etc. This has given a wide base of research where the key issues around the development of green urban areas have been examined, identified, and compiled. The results have been presented in relation to the questions and problems raised by this study. The focus of the study has primarily been Northern European cities, but the study has also included literature from other regions. The study has, in addition to various literature searches, consisted of selection and data processing, and the different parts of the method are presented in more detail in the following headings.

The choice of indicator species and species groups have been made through their possibility to affect their habitat through the design of a site.

Search for Literature

Literature and references were found through the university's library services, Google Scholar, and recommendations from teachers at SLU Alnarp. During the search of literature words such as biodiversity, urban biodiversity, public space, human needs, biodiversity AND needs, human health AND urban areas, human health, biodiversity, AND human health have been used. The words used have also been used in Swedish variants such as biologisk mångfald, biologisk mångfald i Sverige.

From a selection of articles and books found in the databases, more references have been found through manual searches in their provided lists of references.

Selection

The selection of literature has been based on articles, books, and reports with relevant content. The criteria for included material have been scientific articles, reports from governments and institutes written with either a qualitative or quantitative perspective. The literature must have been written from a global, urban, biological, human health perspective, relations, and problematics. The biological perspective includes both urban and natural environments, where natural environments have been selected, as mentioned above. Criteria for excluding literature have been literature with the perspective of urban areas other than urban green spaces, as well as human health separated from urban areas.

Data processing

The literature included in the literature study is in line with the purpose of the thesis and has been assessed to be scientific and credible. It has been processed through structuring, organizing, and advanced material has either been added, subtracted, or reorganized. Further, it has been compiled through categorizing and thematization, as the collected material has been divided in categories by its subject and further thematized in appropriate headlines. Headlines such as *Urban areas and urbanization affecting biodiversity and human health*, *Human needs*, and *Promoting biodiversity*. A result in line with the questions and purpose of the thesis have later been compiled.

LITERA-
TURE
REVIEW

Figure 2. Noise and air pollution in urban areas can lead to increased stress and other health problems, Malmö. Elin Fänge

Human health in relation to urban areas and urban green spaces

The rate of urbanization around the world is at a historical high point and continues to increase (Haaland and van den Bosch, 2015). In 2010 50% of the global population lived in urban areas and the number is expected to increase to two thirds by 2050. In Sweden 88% of the population lived in urban areas in 2020, where urban areas are defined as a densely populated area with 200 or more inhabitants and at most 200 m between houses (Sveriges Statistiska Centralbyrå, 2021). The continuing urbanization process will bring both challenges and opportunities for sustainable development in which promoting human health and biodiversity will be one of the most important goals (Grahn, Stigsdotter and Berggren-Bärring, 2005; Sustainable Development Commission, 2008). However, with the increased population growth and urbanization, the need for densification of cities and urban areas will continue to grow stronger (Haaland and van den Bosch, 2015). The densification aspects that come with urbanization, such as crowding, lower living quality (see Figure 2) and the removal of urban green spaces have all negative effects on both human health, biodiversity, and the city structures, and they will continue to increase with the increased urbanization.

Human health has been defined by the WHO as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization, 1948, page 1). Human well-being is a key concept in public health (Ode Sang and Hedblom, 2021) and is defined as "…how we are experiencing our health at any given moment and extends to include our satisfaction with life, having a sense of purpose or meaning. The population's health, especially in western societies, is improving in general, however some significant health problems remain, of which many are influenced directly or indirectly by the surrounding environment (Sustainable Development Commission, 2008).

People living in large, densely populated urban areas are at a greater risk of reduced mental health than people in smaller urban areas, and mental disorders are much higher in urban areas than in rural areas (Ode Sang and Hedblom, 2021). Dense urban settings with poor design and without accessible green spaces can increase exposure to environmental stress factors (Hartig *et al.*, 2014). Stress, depression, and aches are related to the most widespread illnesses in Sweden today, which often have a slow healing process (Grahn and Stigsdotter, 2003; Bengtsson and Grahn, 2014). This can lead to high expenditures on sick leave and rehabilitation which would then increase costs for society and increase the pressure on the welfare system (Grahn and Stigsdotter, 2003).

Nature, however, has shown to have a restorative effect on our brain and well-being, through lower stress-levels, reduced irritation and enhancing our ability to concentrate (Grahn and Stigsdotter, 2003; Bengtsson and Grahn, 2014). It has also been shown that nature has a positive effect on our will and ability to exercise (Hartig *et al.*, 2014). Further, it is not only the perception of nature that is restorative - healthy ecosystems with a rich biodiversity can also have a higher restorative effect (Giusti and Samuelsson, 2020). Harris (2018) found when asking people about the English landscape, suburban garden, open, and dense vegetation that the most preferred structure was English landscape and dense vegetation over the suburban gardens and lawns, as these contained woodier vegetation. Increasing the number of dense shrubs and structures that make up an English landscape in urban areas that have a natural structure benefit psychological wellness (Fuller *et al.*, 2007), which is also connected to the amount of plant and animal species richness that is found.

BIODIVERSITY IN THE NATURAL LANDSCAPE

Figure 3. Sunlit deadwood - a very important feature for biodiversity in the natural landscape, Klåveröd. Ulrika Ebelin

Biodiversity includes a variation of all living things that can range from the genetic variation in all organisms, species, and populations that exist in a complex web of communities and habitats (Persson and Smith, 2014). The fact that different species respond differently to disturbances, such as changes in the environment, pests, and diseases, is one of the fundamental rules in preserving ecological resilience and processes.

All living things, birds, mammals, insects, and plants have their place in the planet's ecosystems, where all play more or less important roles in the complex web of connections between different creatures and species (Weiss and Sjöberg, 2018). Although biodiversity is in constant change, preserving biodiversity is more about saving the actual diversity of species and creatures than just the species that exist today. In many cases, it can be too late for species that once lived in the habitat to return and build up their numbers again and that is why rebuilding a habitat is often not a solution (Niklasson and Nilsson, 2005). In some cases, the species may have gone extinct. Therefore, it is important to develop a diversity of creatures coexisting with humans to promote biodiversity in urban areas. To promote biodiversity, environments attracting a large variety of native species are needed to create a large web of connections between different creatures and species (see Figure 4).

For biodiversity to thrive, a variety of habitats in the landscape is required. Diamond (Diamond, 1988) suggests that it is not the size of the area itself that determines the amount of diversity found there, but the variety of habitats within the area. Different types of habitats harbor different species and therefore the greater the variety of habitats an area contains, the greater the diversity it harbors. Logically, the larger an area is the more habitats it can harbor, which is important as some species need several different habitats to survive.

Native species are better at supporting each other than exotic, as they have evolved in a supporting ecosystem (Corbet *et al.*, 2001; Burghardt *et al.*, 2010), e.g., native insects prefer native flowering species as they provide more pollen, and the flowers are often more customized/adapted to fit the size of the insects (Corbet *et al.*, 2001). It has also been shown that e.g., native species of insects have had difficulties extracting the pollen from exotic plants/species of vegetation, which have then benefited exotic insects instead (Burghardt, Tallamy and Shriver, 2008; Burghardt *et al.*, 2010). Birds, however, have not shown any preference of plants/vegetation in native and exotic species in relation to their capacity to provide berries and fruits (Daniels and Kirkpatrick, 2006). Although they are dependent on native species for the intake of larvae (specifically butterfly larvae) as they grow mainly in native plant species (Burghardt, Tallamy and Shriver, 2008; Burghardt *et al.*, 2010).

Figure 4. A nature reserve - Rinnebäcksravinen, which houses native plant species that benefit natural spaces, Lund. Elin Fänge

Succession

Recurring in all natural landscapes is natural succession (Nitare and Skogsstyrelsen, 2019) which is a term defined as the change in species composition in both time and space (Sjöman and Slagstedt, 2015). Succession describes how the vegetation changes from open and exposed land to a mature forest, and there are two types of succession: primary and secondary. The primary succession occurs after natural disasters, such as volcanic eruptions or after a period of inland ice. It is a process that can take thousands of years from that the disaster happens to a fully grown mature forest. The secondary succession however takes place in an already existing vegetated environment and is usually caused by human or natural disturbances, e.g., forest fires or when animals stop grazing. These disturbances expose the ground and give way for pioneer species to establish themselves — species favor areas that are exposed to the sun and with windy conditions (Nitare and Skogsstyrelsen, 2019). The primary succession includes mostly annual herb species and perennials specialized for extreme and exposed environments created by the disaster (Sjöman and Slagstedt, 2015). When tree species have the opportunity to colonize the area the succession stages are relatively the same in both the primary and the secondary succession.

The secondary succession is relevant for this study, and even though the pace in this type of succession is much faster than the primary, it can still extend over a long period of time - sometimes several hundreds of years (Sjöman and Slagstedt, 2015). How the vegetation systems will form and evolve from the most primary succession stages to the complex system (a mature forest) is hard to anticipate as the vegetation can develop in many different directions. Depending on the extent of the disturbance, species pool, and climatic conditions the vegetation systems develop in different ways. However, regardless of the difficulties to forecast which direction the succession will take it is possible to summarize and generalize which stages that it will go through from the pioneer species to the climax system. The first stages of development are: the annual stage, the grass stage, and the perennial stage, which are represented in this study as *Meadow*. After the perennial stage the stage of shrubs and young trees evolves and has been presented as the *Edge zone* and *Wooded meadow*. Later on, the young forest stage takes place followed by the stage of mature forest, which both have been presented as *Woodlands*.

Indicator species and structures

Indicators can be both living creatures (indicator species) and/or non-living things (structural indicators) that by their presence indicate high natural values, hidden factors and qualities in an area or a biotope (Jordbruksverket, 2003). High natural values are here defined as an environment rich in species and biotopes, and specifically threatened species. Structural indicators consist of landscape features and structures such as stone walls, hay meadows and calcareous soils. Indicator species are defined as species with strong connections to certain features in nature and/or special demands on its living environment, such as high humidity, soil chemistry, access to sunlight, water etc. However, the habitats presented in the relevant habitats below (meadow, wooded meadow, woodlands etc.) all have different indicator species groups. This is because certain species within the groups of lichen and mosses, mainly grow in e.g., woodlands whereas, meadows have plants, insects, mammals, and birds as they mainly benefit from a meadow.

Biotopes that share the same indicator species groups thrive when they have a mosaic where these different biotopes meet each other (Nitare and Skogsstyrelsen, 2019). It is important that they do not mix with each other, for example stands dominated by European beech (*Fagus sylvatica*) combined with stands dominated by Oak (*Quercus*) and Common hazel (*Corylus avellana*), as the beech will most definitely dominate and kill the oak in time. These different dominating stands have different conditions within the stands, and it is those differences species need in order to thrive.

Indicator species groups

Insects

Native woody species such as Hazel (*Corylus avellana*), Willow (*Salix*), Norway spruce (*Picea abies*) or Scot's pine (*Pinus sylvestris*) are important sources of food for many insects as they produce pollen during different times of the season (Weiss and Sjöberg, 2018). Different trees and shrubs are also important as they provide shelter for many insects in their bark and foliage. Different decomposer stages and species of deadwood provide shelter and food for many insect species and their larva. Standing deadwood in direct sunlight has some of the highest value for biodiversity as they provide warmth, shelter, and food for many species, as well as different types of cavities in different materials are also important sites for shelter. Herbaceous species can also provide shelter, resting places and mating spots for various insects.

All insects need water, but some insects are dependent on small waters, wetlands, and other types of natural wet areas for their survival and reproduction (Weiss and Sjöberg, 2018). Others are satisfied with dew and small portions of water found in vegetation. However, for many insects it can be a challenge to find water, food, and reproduction sites as many insects may have difficulties to move over larger areas without any place to rest. Bumblebees are one example of this as they can only be active in the air for about 40 min before they need to fill up their energy supply.

Our food production is dependent on insects, and especially on pollinators. A diversity among pollinators is necessary for both nature and agricultural production as many plant species need to be pollinated by different pollinating species to produce the food we eat (Borgström, 2018). Bees and bumblebees are the most effective pollinating species; however, many other species also contribute to the pollination process. Monocultural fields, such as rapeseed fields that are common in the southern parts of Sweden, can provide large amounts of pollen and nectar for insects to feed on, although only during a short period of time.

Birds

Birds are dependent on certain combinations of habitats and ecological conditions within the landscape matrix where they nest (Jordbruksverket, 2003). They are also a species that can easily remove themselves from a place if they find it for example threatening or poor in food sources (Egwumah, PO, and Edet, 2017), and slower moving species usually follow. This makes them good indicator species as changes in the population of some species, or groups of species can indicate changes on a large-scale level (Jordbruksverket, 2003). In addition to this, birds are also a well-known taxonomic group, both by experts and among laymen, which also make them important indicators of change in both ecosystems and the diversity of other species (Heyman, 2010).

Amphibians and reptiles

In Sweden 13 different species of amphibians and 6 species of reptiles can be found, all of which have a complex lifecycle and specific demands of their environment (Jordbruksverket, 2003). Amphibians and reptiles need multiple different habitats as well as sunlit places. For them to thrive certain aspects have to be fulfilled in the habitats, which makes them good indicators for certain types of qualities and conditions in an environment and therefore also indicator the existence of other types of species as well.

Mammals

There are 161 different mammal species in Sweden, of which 22 are exotic (SLU Artdatabanken, 2022), and they are most often not connected to certain habitats or substrates as they are relatively mobile (Jordbruksverket, 2003). However, most mammals have stationary shelters for overnighting, such as cavities in the ground or in live or dead trees, as well as for their reproduction they often utilize stationary sites for a longer period.

Lichen, mosses and fungi

Different woodland biotopes house different species, however, some of the indicator species groups in woodlands are lichen, mosses, and fungi (Nitare and Skogsstyrelsen, 2019). Some of these groups (lichen, mosses, and fungi) can be identified all year round and indicate conditions in the biotope such as certain soil conditions, a stable environment with sunlight and with old trees, shady conditions with high humidity, and/or different stages of deadwood. The differences in the bark's pH-levels are according to Niklasson and Nilsson (2005) the reason why different lichens grow on different trees, and it can explain why more lichen species are found on *Populus* spp. compared to *Fagus sylvatica* (beech). *Acer* spp., *Populus* spp., and *Ulmus glabra* (Wyche elm) are usually found with a high diversity of epiphyte species, and many endangered lichen species in the South of Sweden (Niklasson and Nilsson, 2005). Most lichens are limited to only growing on trees that are older than 150 years as the bark on those trees has a lot of texture.

Mycorrhiza are a symbiotic association between plant roots and fungi that help the trees take up nitrogen and phosphorus, which are vital for plant growth, and it is mainly found in deciduous tree species (Allen *et al.*, 2003). There are many different forms of mycorrhiza, and they aid vegetation in different ways e.g., by storing water so that the vegetation has a longer period of time to absorb the water. *Mycorrhiza* is not an indicator species group itself, however, the plant species of which mycorrhiza thrives on can be used as an identification that it is present, and therefore also indicate high biodiversity in biotopes. The following examples of species consist of different combinations in wooded stands to promote mycorrhiza (Bio-organics, n.d.): *Abies* spp., *Acer* spp., *Alnus* sp., *Aesculus* sp., Betula spp., *Carpinus betulus*, *Corylus avellana* (Common hazel), *Fagus* spp., *Malus* spp., *Morus* spp., *Pinus sylvestris* (Scots pine), *Populus* spp., *Quercus petraea* (Sessile oak), *Quercus robur* (English oak), *Salix* spp., *Tilia cordata* (small-leaved lime), and *Ulmus* sp. Bush species such as *Euonymus* spp., *Ilex* sp., *Juniperus* spp., *Rosa* spp., and *Rubus* spp. Other species such as bulbs (all), *Fragaria* × *ananassa* (Garden strawberry), *Geranium* spp., *Poaceae* spp. Herbs: *Pisum* spp., (pea family), and *Solanum* spp., (potato family) are also important.

Vascular plants and habitats

Vascular plants are the most well-known taxonomic group among plants as it consists of herbs, trees and shrubs, and the Swedish taxa consists of around 2200 species (Jordbruksverket, 2003). They form the foundation of the ecosystems and habitats that other creatures live in and feed off, and at the same time, vascular plants depend on other creatures such as pollinators and birds to drive their pollination process and spread their seeds.

Structural indicators

Structural diversity

Younger trees have very little structural diversity with their weak trunk, thin branches, and smooth and relatively thin bark. However, generalist species are usually found on younger trees, and since young trees are more usual there are more generalist species today (Niklasson and Nilsson, 2005). When a tree grows older it develops a more complex and diverse structure that many species, mainly insects but also birds, bats, mammals, fungi, lichens, and mosses can live off. As a tree grows, its structures change — it builds coarse branches, and the bark grows thicker. The structure of the old bark makes it possible for species like mosses, lichens, fungi, and vascular plants to inhabit the tree. An oak and beech tree can house up to 250 species of lichen, and trees such as pine often develop cracks between its bark flakes where insects can hide, insects such as night butterflies, and for beetles and spiders it can be an excellent sleeping place. However, its structures can also evolve through storms or from a branch breaking off exposing the inner wood. In time this exposure causes the wood to rot and makes it a perfect place for species living on rotting wood to thrive.

There are insect species that live their whole life cycle on the bark of a tree. Beetles such as *Nothorhina punctata* (in Swedish: reliktbock) and *Microbregma emarginata* (spruce bark beetle) live in older and sunlit pine and spruce bark that stand in an open and sparse forest (Niklasson and Nilsson, 2005). Older trees species and specifically the older version of *Populus tremula* (aspen) that are sunlit with exposed wood are important to the *Descarpentriesina variolosa* (marbled jewel beetle) species as it can only reproduce on a *Populus tremula* but it also needs other older deciduous tree species to survive. Deciduous trees produce sap when its bark is damaged, which many insects can feed on, and especially in the middle of the summer this is a hotspot for many insects, including predators. The leaves from the deciduous trees supply large amounts of humus to the ground and in turn create overwintering habitats and nesting materials for many species such as mammals, reptiles and amphibians, and insects (National Environmental Treasure, n.d.)

Damage

When a tree is damaged it starts a healing process causing the tree to sap or resin (Niklasson and Nilsson, 2005). The sap/resin makes it habitable to other species as it creates a microhabitat for species that need exposed wood to thrive (Niklasson and Nilsson, 2005). Pine and spruce tree species have the ability to quickly produce resin that makes it more resistant to mushroom and insects. Deciduous trees have the same function, but a large number of insects are drawn to it as it is a good source of food for them. This process can attract a whole forest of insects in the middle of the summer followed by predators and is considered to be very important to many insect species.

As trees grow older, they sustain many damages which expose the inner parts of the tree (Nitare and Skogsstyrelsen, 2019). In hardwood tree species the wood decomposes slowly, and the tree can both be alive, rotting and dead all at once over a long period of time, which is unique for these trees. Bats and beetles are two examples of species that are dependent on these tree species. The main component which is seen as a shortage today is the mulm that these old trees create. Mulm is the loose material that accumulates inside hollow trees. It consists mainly of loose, rotten wood. Excrement from wood-dwelling insects, birds and bats, old bird nests and remains of dead animals can also be found in it.

Deadwood

Deadwood is an important component to biodiversity that many species rely on, as it provides a range of different resources, such as a breeding ground and a food supply for insects, which in turn are eaten by mammals and birds (Nitare and Skogsstyrelsen, 2019). Cavities and hollows in deadwood can also be used for nesting and shelter by mammals and birds. It is the variety of deadwood that is important as it favors different species, varieties such as dry, moist, shaded, or sunlit deadwood (See Figure 3, p 19) can harbor different kinds of species (See Figure 5). However, the most important type of deadwood to preserve is older deadwood as it is more scarcer in today's landscape.

Leaves

Leaves are great at storing carbon and improving the topsoil layer, because when the leaves are left on the ground during the winter and spring, worms have a source of food and with that help bring oxygen, carbon, and humus into the topsoil (National environmental treasure, n.d). The leaf piles even prevent moisture from leaving the ground and early growing vegetation from growing up and that competes with later growing vegetation, thereby creating a variety of plant species and the species that live off those plants. It is important that the topsoil is not compacted as it makes it hard for worms to dig in these hard soils (Ashman and Puri, 2002).

Fires

Fires in woodlands were once a natural sitting in the south of Sweden, and it did not only open up the woodland, but the continuous fires also exposed the soil and allowed the sun to reach the woodland floor where ground flora such as pea plants and other early succession species could thrive (Nitare and Skogsstyrelsen, 2019). This kind of environment combined with different types of deadwood and trees damaged by fires also created a rich fauna of insects.

Figure 5. A mushroom that is dependent on deadwood to survive. It is also included in the indicator species group of mosses, lichen, and fungi, Höör. Elin Fänge


Figure 6. A continuously maintained meadow benefits a large diversity of species, Kågeröd. Ulrika Ebelin

Habitats

Open habitat

Meadow

The amount of area consisting of meadows and pastures in Sweden have decreased dramatically since the 19th century and are now threatened by extinction (Jordbruksverket, 2003). Intensified farming and decreased numbers of grazing animals have left only fragments of this once vast landscape. However, meadows and pastures have long been an important part of the agricultural landscape. Grazing by muzzles, the trampling of hooves and mowing by humans have all contributed to creating specific conditions where a rich diversity can thrive (see Figure 6).

The plants and animals living in meadows benefit from the process occurring by domestic animals grazing and/or humans mowing, and thereby affect the succession and keep it in check (see Figure 7, p 26; Jordbruksverket, 2003). However, the species composition in meadows managed either through grazing animals or mowing differs. Meadows managed through mowing are in general richer in flowers as vascular plants are allowed to bloom. The highest number of species prefer meadows that are cut in late summer, July to August, after which grazing animals take over. As mentioned, the plants in the meadow have had time to bloom before the grass is cut and when it is left to dry the seeds fall off. Later on, when a high pressure of grazing animals comes in, the wear and tear that occurs by their grazing and trampling creates stains of bare warm clay and sandy soils where many digging insects can thrive as well as the seeds of the flowering plants can grow.

Most vascular plant species found in meadows and pastures clearly favor different types of management (grazing or mowing), moisture and pH level in the ground (Jordbruksverket, 2003). The composition of vascular plant species is determined through which time during the season the different types of management regimes are implemented, and to which intensity, and in turn also determine the composition and survival of other types of species. For the vascular plants to survive the populations need 1) Growth - individual plants that can survive and grow to a size to which they can reproduce, 2) Reproduce - individual plants can produce seeds, and 3) Germinate - the seeds have the chance to grow into new plants. The fallen seeds become new plants after the winter and the removal of hay keeps the soil nutrient poor, which can stop invasive species from taking over the meadow as they often thrive on nutrient rich soils (Almstedt Jansson, De Jong and Ebenhard, 2011). The plants' ability to produce seeds decrease with increased pressure of grazing, on the other hand the establishment of new plants decrease with decreased grazing. Nonetheless, some species favor early mowing, others by intense and constant grazing, e.g., small mammals and birds can forage and live in cavities among the high grasses and herbs where they are protected and hidden from predators. When the meadow is later cut the small creatures become exposed and easily found by predators (Niklasson and Nilsson, 2005). Indicator species can guide us to find the right amount, and type, of management to use to achieve the desired composition of plant and species.

Figure 7. Goats are a great example to be used for grazing as they are not picky eaters, Karlskrona. Ulrika Ebelin

Indicator species/group of species

Insects

Some species of butterflies are excellent indicator species as they often respond to changes in the habitat very quickly and it is often obvious even to the naked eye (Jordbruksverket, 2003). Most butterflies in Sweden are very dependent on warmth and sunlight, which make meadows and open areas very important habitats. It is only during extreme heat and dry summers that half-shaded environments are used by the butterflies, however, their larvae are in need of more humid conditions for a successful development.

Almost all butterflies need living plants, herbs, shrubs, and trees to survive and many of the species connected to meadows and pastures are bound to unique flowers that only occurs in these landscapes for their larva, and in turn many of the butterflies are hosts to other parasitic insects that are specialized on one specie, just as the butterfly itself (see Figure 8, p 27; Jordbruksverket, 2003; Bernes, 2011). However, many species are, in addition to a suitable host plant, also in need of a suitable habitat with access to a variety of flowers with nectar to survive (Jordbruksverket, 2003). Open meadows are a very important habitat for butterflies, they have however quite particular demands as the land cannot be cultivated too much or too little. If there is too much pressure on the meadow from grazing animals, or if the haymaking is too early many species will disappear. If it is left unmanaged the habitat will be overgrown and the butterflies will once again disappear.

Mammals

Meadows and pastures are important for many mammal species, however, not all can be used as indicator species for this landscape (Jordbruksverket, 2003). Nevertheless, meadows and pastures are frequently used by bats as most of them avoid large open areas and instead prefer smaller glades and edge habitats. Insects are the most important source of food for bats (*Chiroptera* spp.), which makes bats good indicators for environments with high densities of insects and may also indicate a high number of insect species. Therefore, a small open pasture or meadow can be favorable, and a wooden pasture is among the best habitats for a bat. Dead and old trees with cavities are very valuable to bats as a shelter and wintering place, and the meadows most valuable to bats are often connected to ponds, lakes, or other types of water – places where insects often thrive.

Birds

Many bird species benefit from the structures and materials in natural meadows and pastures, such as dense shrubs and groves, old trees with cavities, stones and cairns, and bumps of grass (Jordbruksverket, 2003). As mentioned before, many bird species need combinations of habitats to survive, e.g., dense woody areas for nesting in combination with open sunlit meadows with insects to feed on. Stones and cairns are important for some birds, such as *Oenanthe oenanthe* (Northern wheatear) and *Linaria cannabina* (Common linnet), as they are often used by the birds for overlooking an area for mouses or small birds to catch as prey.

A list of these important structures and features has been summarized in Table 1

Figure 8. Butterflies depend on meadows that are in close vicinity to other plants, herbs, shrubs, and trees, Lund. Elin Fänge

Table 1. Describes structures and features important for biodiversity in meadows as well as describing which climatic conditions it should include. It also describes species and surrounding landscapes linked to these habitats.

	Indicator structures and features	Ground conditions	Climatic conditions and areas	Linked species	Surrounding landscapes/ connectivity
Meadows	Bumps of grass **Trees** -old -dying Cavities Deadwood **Shrubs** - dense - thorny Stones Cairns	**Management** Grazing - trampling hooves - grazing Mowing - human scything - regularly mown herbaceous layer **Soils** - bare warm clay - sand	**Climatic conditions** - warmth - humid conditions **Type of areas** - open - sun exposed - half-shaded - small-scale agriculture - groves	Deciduous species Plants Herbs Seeds and pollen plants Insects	*Meadow* *Wooded meadow* *Wooded pasture* *Edge zone* *Wetland*

Semi-open habitat

Wooded meadow

A wooded meadow consists of a half-open habitat with a mixture of free-standing trees and/or coppicing and pollarding trees (Nitare and Skogsstyrelsen, 2019). One difference between the wooded meadow and the wooded pasture is that the trees in the wooded pasture usually have a higher trunk as it was meant to keep the animals off annual shoots that were used for weaving. The wooded meadow is defined as landscapes where humans mow and livestock graze among scattered woody vegetation — a landscape type often more heterogeneous than other managed ecosystems such as closed forests or treeless farmlands (Hartel, Plieninger, and Varga, 2015; Plieninger *et al.*, 2015). (see Figure 9)

Wooded meadows are often covered by native vegetation where the heterogeneous structures, succession stages as well as density and age of the tree communities creates a diverse ecosystem (Nitare and Skogsstyrelsen, 2019). A wooded meadow can consist of e.g., deciduous trees with sparse natural stands and a regularly mown herbaceous layer. Deciduous species such as *Corylus avellana, Tilia cordata*, among others that build a half open mosaic environment with various areas of sun and shaded areas.

In wooded pastures the history is cultivated in many ways, such as preserving animal breeds and genetic resources (both animals and vegetation), but many wooded pastures also bear legacies from historical land uses (Nitare and Skogsstyrelsen, 2019). Such land uses can involve features such as terraces and stone walls but also management approaches such as coppicing and pollarding which are of high value for biodiversity as these are important habitats for many species (Harmer, 2004; Hartel, Plieninger, and Varga, 2015; Plieninger *et al.*, 2015). A wooded pasture can have deciduous trees and branchy trees, and an abundance of shrub species like *Crataegus* spp., *Prunus spinosa* (blackthorn), *Rosa* sp., *Malus sylvestris* (European crab apple), and *Pyrus pyraster* (European wild pear), as well as other fruit and berry bearing species.

Structural indicators

Large old trees with sun-exposed stems are a common feature in wood-pastures and a key structure and habitat for many species, such as beetles and other insects (Bernes, 2011; Hartel, Plieninger, and Varga, 2015). Further, indicator species groups of lichen, mosses and fungi need old deciduous trees, old broad-leaf forest, solitary trees, woodland trees with shaded trunks, exposed roots, stumps, fallen trees, as well as soft and rotten wood that is constantly damp (Nitare and Skogsstyrelsen, 2019). The management practices are also of great importance for the structure, e.g., pollarding can promote hollow trees which can be a habitat or shelter for bees, woodpeckers, tits, and owls. Bushes are also an important part of the structure as they can host a rich fauna (Bernes, 2011). Thorny shrubs are of great importance as they create local sanctuaries for smaller birds and some plants, such as bluebells and wild strawberries, that otherwise would have been grazed away. Areas that are favored by indicator species groups of lichen, mosses and fungi need a microclimate that is different from the surrounding landscape, high abundance of boulders, south facing edges, wooded pastures or wooded meadows are important features for this indicator species groups (Nitare and Skogsstyrelsen, 2019). The soil should either be moist and rich in humus, open and exposed, have thin layers, or be warm and exposed to the sun.

A list of these important structures and features has been summarized in Table 2

Figure 9. A wooded meadow consists of a half-open habitat with a mixture of free-standing trees, Lund. Ulrika Ebelin

Table 2. Describes structures and features important for biodiversity in woodland meadows and pastures as well as describing which climatic conditions it should include. It also describes species and surrounding landscapes linked to these habitats.

<table>
<tr><th></th><th></th><th>Indicator structures and features</th><th>Ground conditions</th><th>Climatic conditions and areas</th><th colspan="2">Linked species</th><th>Surrounding landscapes/ connectivity</th></tr>
<tr><td rowspan="2">Woodland meadow</td><td>Wooded meadow</td><td rowspan="2">Strucutres
- heterogeneous
- complex
- half open mosaic environment
- succession stages
- ten percent canopy coverage
- diverse

Trees
- a variation in density and age of the tree communities
- deciduous
- large
- old
- ancient Quercus and Fagus trees
- damaged by fires
- Thick brak
- coarse branches
- stems exposed to the sun

Damage
- sap
- resin
- exposed wood
- rotting wood
- broken off branches</td><td rowspan="2">Management
- coppicing
- pollarding
Grazing
- trampling hooves
- grazing
Mowing
- human scything
- regularly mown herbaceous layer</td><td rowspan="2">Climatic conditions
- many different types

Type of areas
- grazed forest
- stone walls
- terraces</td><td rowspan="2">Native
Wooded
Shrubs
Trees
Corylus avellana
Tilia cordata
Bluebells
Wild strawberrie
Smaller birds</td><td></td><td rowspan="2">Meadow
Pasture
Pond
Lakes
other types of water</td></tr>
<tr><td>Wooded pasture</td><td>Surrounding the pasture
- Abundance of shrub species
- Crataegus
- Prunus spinosa
- Rosa sp.

In the pasture
- Malus sylvestris
- Pyrus pyraster
- fruit and berry bearing species
- Deciduous trees</td></tr>
</table>

Figure 10 Ancient oak - It takes up 80-100 years before it can house a large diversity of species, Nora. Ulrika Ebelin

Ancient oak and beech trees (Quercus and Fagus)

Ancient Oak and Beech trees, which are noble trees, can reflect very long periods of time and they can form habitats important for many bark and wood living species (See Figure 10; Nitare and Skogsstyrelsen, 2019). These trees have a century old biological cultural heritage and can be compared to "living ancient monuments" with high natural and cultural values. It is the mulm that is probably the most valuable source that these trees can offer. Unfortunately, because of decreased grazing these are currently decreasing. However, this group of woodland only grows in Boreo-Nemoral and Nemoral conditions making it an important biotope.

The oak tree is one of the first species to move into an open and exposed area as it likes little competition and a lot of sunlight (Nitare and Skogsstyrelsen, 2019). As a solitary tree it can become up to 1000 years old and grow in both dry and humid conditions but prefers mostly drier conditions. The oak has been used in cultivated wooded pastures and has long been a very valuable tree with both highly cultural and economic values. For oak to be the dominating tree species in a woodland that houses other tree species such as *Pinus*, *Betula*, and *Sorbus aucuparia* it needs nutrient poor and dry conditions with sandy or rocky soils.

The beech tree is a shade tolerant species as young, but as it matures it dominates over other existing trees it changes to needing sun (Nitare and Skogsstyrelsen, 2019). As a solitary tree it can live to around 400 years and it preferably wants to grow in a humid atmosphere, well-drained and moderately fertile soils, and/or calcified or slightly acidic soils. Both the oak and the beech develop broad crowns, cavities, and a lot of branches as solitary trees — qualities important for a rich diversity of species.

Indicator species groups

Lichen, mosses, and fungi need complete accessibility to sunlight or half shaded areas (See Figure 11, p 31; Nitare and Skogsstyrelsen, 2019). In addition to this they need old trees, deep cracks in bark, and broken treetops as well as, damaged trunks, damaged branches, and roots. Trees filled with mulm, different stages of decaying and sunlit laying wood/deadwood/bark, rot damaged and sun exposed wood, large and pollarded trees with large holes in them, dry and sun-exposed heartwood, sap, and cavities are also important features. They also favor areas such as moist or dry conditions, exposed areas, poor sandy soils, glades, slopes, and/or rocky grounds.

A list of these important structures and features has been summarized in Table 3

Figure 11. Sunlit oak trees are a very valuable element for biodiversity. Nora. Ulrika Ebelin

Table 3. Describes structures and features important for biodiversity in habitats dominated by ancient oak and beech trees as well as describing which climatic conditions it should include. It also describes species and surrounding landscapes linked to these habitats.

		Indicator structures and features		Ground conditions	Climatic conditions and areas	Linked species		Surrounding landscapes/ connectivity
Ancient oak and beech trees	Quercus	Trees - leaves from the deciduous trees - old trees - aged solitary - broad crowns - coarse - rich in branches - large and pollarded trees with large holes in them Damage - trunks - branches - roots - both alive, rotting and dead all at once - filled with mulm - cavities - saw - broken treetops - deep cracks in bark - rotting wood	Deadwood - laying - sunlit - fallen trees in different angles - stages of decaying - aging of deadwood (age of tree wh Sunlit - bark - wood - heartwood	Soils - nutrient poor - sandy - rocky soils	Climatic conditions - moist - dry Type of areas - exposed areas - young and old tree - sun exposure - free from other tree species	Beetles Bees Woodpeckers Tits Owls	Pinus Betula Sorbus aucuparia	*Meadow* *Pasture* Pond Lakes other types of water
	Fagus			Soils - well-drained - moderately fertile - calcified or slightly acidic	Climatic conditions . humid Type of areas Young - shade - protection Old - light exposure			

Closed habitat

Woodlands

According to Niklasson and Nilsson (2005) a primeval woodland in the southern parts of Sweden can be defined as a dynamic landscape where the woodland has partly been opened up by natural causes such as wind, fire, water, and animals, which create big varieties of heterogeneity (see Figure 12; Nitare and Skogsstyrelsen, 2019). In these complex woodland systems, a mixture of swamp, mixed, sparse pine dominated, and deciduous woodlands as well as open areas are found (Niklasson and Nilsson, 2005). As today's woodlands are mainly purposed for production, the trees never grow older than 60 to 100 years. Roughly 73% of the land area in Sweden consists of forests, of which 68% consist of production forests (Skogs Industrierna, n.d; SLU Institutionen för skoglig resurshushållning, 2020). Further, out of the 68 percent of the production forest, about 67% consists of forests dominated by either spruce or pine (SLU Institutionen för skoglig resurshushållning, 2020). The report also mentions the amounts of deadwood are extremely low. This has led to structures important to many woodland species becoming threatened, and thereby contributing to the biodiversity loss. There are many ways of measuring a healthy and diverse woodland. The Swedish Forest Agency has created a checklist for this purpose to assess nature with the focus on woodlands by looking for structural indicators (Nilsson, 2017). The checklist consists of three colons to fill in after; existing, non-existing, can become existing and they build up a basis for knowing if the place holds potential, does not hold potential or can in the future hold the potential to support/harbor woodland species.

Water is fundamental for woodland's species richness and wet and moist woodland habitats are usually found in areas close to bodies of water (Nitare and Skogsstyrelsen, 2019). The design of different types of vegetation and biotope is determined by the water's main source, quality, and movement. The water's ecological role in the woodland's ecosystem is multifaceted and complex and therefore very difficult to summarize and will be explained as follows. The surface water, such as ponds, lakes, rills, streams, rivers, or other watercourses that affect the transportation of nutrients, generate erosion and sedimentation. At the same time favorable living conditions are created for dehydration-sensitive species through moist soil and microclimates with high humidity. The network of streams and other watercourses link together in a woodland to create a "life of veins" that link both limnic and terrestrial ecosystems, thus creating species-rich transition zones that affect both small-scale and large-scale ecological processes.

Figure 12 . Sunlight in woodlands are important to allow a variation of habitats, Hällefors. Ulrika Ebelin

Trees and woodlands of boreal-deciduous trees

Dry habitat

Woodlands with a large feature of old Populus tremula and Salix have very high natural values and can house many important species (Nitare and Skogsstyrelsen, 2019). The following species combined with the mixture of old boreal-deciduous trees such as Sorbus aucuparia, Sorbus intermedia, Prunus padus, Alnus glutinosa and Alnus incana are also important as they create a variety in the woodland. The trivial species are important for their source of pollen and fruits but also wood that *Mycorrhiza* can grow in. Our most common trivial trees such as Betula, Populus tremula, Salix and Ulmus are light loving deciduous trees that are evolutionarily adapted to rely on natural disturbances (see Figure 13).

Lichen, mosses and fungi need trees older in than 80 years and some of these need more specific qualities such as *Betula* spp. trees older than 150 years with coarse branches and bark with high texture and nutrient levels (high - *Populus tremula*, and *Salix caprea* (goat willow), low- *Betula pendula* (European white birch), burnt wood from *Betula*, pollarded *Betula*, *Alnus* trees that are both old and fixate nitrogen, young plants of spruce, older oak and beech stands, cavities on wood, and/or dead trees (Nitare and Skogsstyrelsen, 2019). The indicator species groups also favor areas such as nutrient rich soils, high sun exposure, high moisture, bright woodlands and groves, older woodlands that have been grazed on and signs of past fires, contact with groundwater flow hillsides, slopes that face north and are connected to swamps or wetlands, stones, rock walls and/or, areas with long continuity.

Wet and moist habitat

These wet and moist woodlands were once ancient woodlands and many of these areas were a water kingdom with vast spring lands and swamps (Nitare and Skogsstyrelsen, 2019). There was a mosaic of wet and damp biotopes with extremely rich plant and animal life. An example are swamp woodlands, which are often found with features of *Prunus padus*, *Rhamnus frangula*, and *Salix caprea*, but sometimes also early signs of spruce.

Some species of lichen, mosses, and fungi need a natural plinth and leaves from *Alnus* spp. trees, P*opulus tremula*, Alnus spp. or *Quercus* spp. trees combined with *Salix caprea*, *Sorbus aucuparia*, *Prunus padus*, *Rhamnus frangula*, and *Betula* spp., remaining branches of some *Salix* species, large amounts of both standing, lying, wide, thin, and moist deadwood and/or tree roots in shade as well as cavities in trees (Nitare and Skogsstyrelsen, 2019). This indicator species groups also favor areas with hollow terrain where water is stagnant over long periods of time, moving water, times of flooding, next to lakes and streams, sunken streams, damp rocks, ravines, canyons and open to semi-open woodlands. The climatic conditions should be stable with normal or high humidity, have normal or high levels of sunlight, or shade, and/or equalized temperature. The soil should be low in oxygen content and moist or wet as well as nutrient rich.

A list of these important structures and features has been summarized in Table 4

Figure 13. The larger variety of plant species in areas will create many different types of deadwood, Beuningen. Elin Fänge

Table 4. Describes structures and features important for biodiversity in woodlands of boreal-deciduous trees as well as describing which climatic conditions it should include. It also describes species and surrounding landscapes linked to these habitats.

		Indicator structures and features	Ground conditions	Climatic conditions and areas	Linked species	Surrounding landscapes/ connectivity
Trees and woodlands of boreal-deciduous trees	Dry	**Trees** - deciduous trees - solitary trees - woodland trees - older in than 80 years -bark that is nutrient high or low - shaded trunks - bases of old trees - exposed roots **Damage** -cavities **Deadwood** - dead trees - fallen trees - stumps **Stones** Rock walls	**Soil** - calcified - exposed - thin layers - dry - nutrient rich - moist humus - rich in humus	**Climatic conditions** - heat - high moisture - stable microclimates **Type of areas** - sun exposure - shade - bright woodlands - bright groves - signs of past fires - stones - rock walls - areas with long continuity - Older woodlands that have been grazed on	Mycorrhiza Pollen and fruit species Betula trees older than 150 years with coarse branches Burnt wood from betula Pollarded betula Alnus trees that are both old and fixate nitrogen Young plants of abies Older quercus and fagus stands Alnus glutinosa A. Incana Betula Borkhausenia intermedia Populus tremula Prunus padus Salix Salix caprea Sorbus aucuparia Ulmus	Swamps *Wetlands* *Wooded meadow* *Wooded pasture*
	Wet and moist	**Trees** - tree roots in shade **Damage** - cavities **Deadwood** - standing - lying - wide - thin - moist - soft and rotten wood that is constantly damp Damp rocks	**Soils** - low in oxygen content - moist - wet - nutrient-rich and fine - calcareous - rich in humus - peat	**Climatic conditions** - constant normal or high humidity - equalized temperature **Type of areas** - sun exposure - hollow terrain where water is stagnant over long periods of time - sunken streams - times of flooding - moving water - contact with groundwater flow hillsides - open to semi-open woodlands - normal or high levels of sunlight - normal or high levels of shade - delta areas and at the bottom of brook valleys - slopes that face north - sedimentation of sludge particles that create rich soils	Early signs of Abies Alnus A natural plinth and leaves from Alnus trees Betula Populus tremula Prunus padus Quercus Rhamnus frangula Salix caprea Remaining branches of some Salix species Sorbus aucuparia	Lake Stream Swamp *Wetland*

Natural or semi-natural coniferous woodlands

Dry habitat

In a coniferous woodland large stand of deciduous tree stands consist mainly of *Betula* spp., *Populus tremula*, and *Salix caprea* that have been able to grow there because of natural disturbances (Nitare and Skogsstyrelsen, 2019). The diversity in these woodlands is mainly dominated by cryptogrammic and invertebrate species and they along with other species are mainly dependent on the following examples of structures:

Coniferous woodlands such as older mosaic woodland composed of spruces and coniferous-mixed deciduous woodlands (Nitare and Skogsstyrelsen, 2019). The indicator species need moderate soil moisture, older woodlands, and trees, and some of them can only grow on pine trees or spruce.

Pine woodlands are usually found on drier soil and/or on wet peat bogs and they are always the first to establish after a disturbance but because fires are not as common anymore pine woodlands are now threatened (Nitare and Skogsstyrelsen, 2019).

Spruce woodlands shift in lightness and darkness as they can grow close together but that makes them also vulnerable to natural disturbances which can result with many trees falling over in one area (see Figure 15, p 36; Nitare and Skogsstyrelsen, 2019). The spruce ability to grow close together in the woodland creates high and consistent humidity. It is commonly found in areas where natural disturbance is less, such as, valleys, slopes facing north and/or, at the bottom of it. Species that are sensitive to dehydration like shade-loving are usually found here.

The indicator species groups need to be shaded and protected from exposure, surrounded by mosses that capture moisture, and deadwood from fallen trees as well as old and slow growing conifer trees that lean on another tree for decades or centuries, remaining and/or non-remaining bark on deadwood, dead branches still attached to the tree, different environments of bark and exposed wood mainly on deciduous trees, and coarse stumps such as oak (Nitare and Skogsstyrelsen, 2019). Some of the indicator species groups favor areas such as moist areas, slopes or at the bottom of them, and valleys. Other species, however, prefer drier areas such as poor soil woodlands.

Wet and moist

Just as mentioned above in *Natural or semi-natural coniferous woodlands* the indicator species groups of lichen mosses and fungi favor other species, such as spruce and pine (Nitare and Skogsstyrelsen, 2019). However, the wet and moist coniferous woodland usually grows in mixed-woodland systems and can also be split into two main dominating species: Spruce and Pine. These biotopes are sensitive to activity caused by the forest production industry as well as ditching.

Pine – *A poor soil pine woodland* consists of open areas that usually grow in the vicinity of peat bogs and rely on groundwater movement that is mainly provided by rainwater (see Figure 14; Nitare and Skogsstyrelsen, 2019). As well as other species growing in this biotope, such as pine that favors acidic and malnourished conditions. Since Pine species grow slowly in malnourished soils it becomes an optimal habitat for species that need long living habitats.

Spruce – *Rich herb spruce woodlands* and spruce groves or Poor spruce woodlands consist of closed areas such as shifting slopes, at the bottom of a gorge, or brook valley (Nitare and Skogsstyrelsen, 2019). The conditions needed are a continuous water level that never completely disappears, e.g., where the groundwater has surfaced, or a spring appeared. spruce species either need nutrient rich or poor soil as well as shady and moist conditions to thrive and thereby house many endangered species.

The indicator species from wet and/or moist woodlands favor moist soils rich in humus and areas that have a consistency of high moisture levels, shade, and moisture (Nitare and Skogsstyrelsen, 2019). Areas with streams, brook ravine, springs, rivers, and overlying slopes and/or steep south-facing hillsides are to prefer.

A list of these important structures and features has been summarized in Table 5

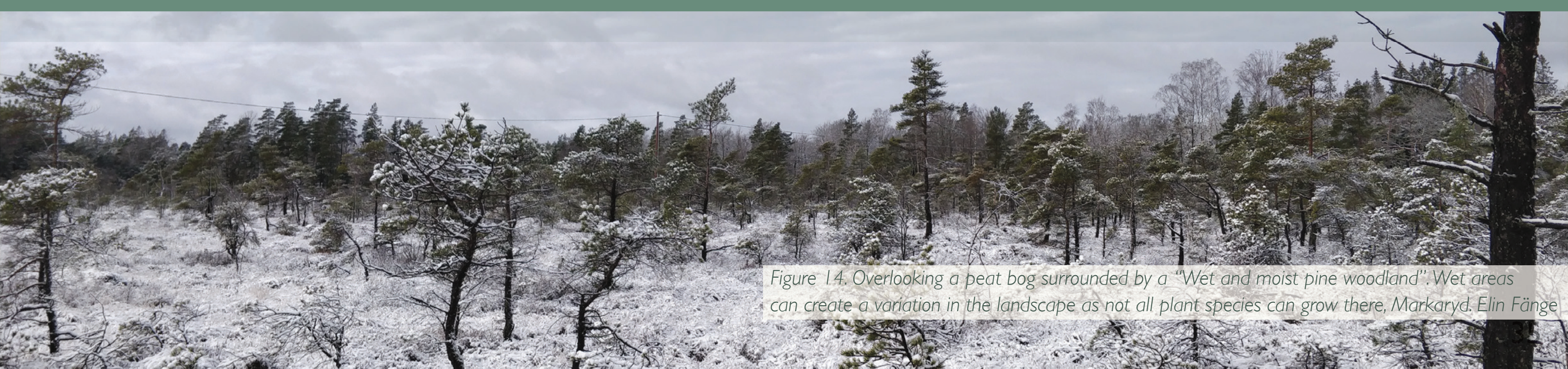

Figure 14. Overlooking a peat bog surrounded by a "Wet and moist pine woodland". Wet areas can create a variation in the landscape as not all plant species can grow there, Markaryd. Elin Fänge

Figure 15. A dark and dry Norwegian spruce woodland, Skinnskatteberg. Ulrika Ebelin

Table 5. Describes structures and features important for biodiversity in natural or semi-natural coniferous woodlands as well as describing which climatic conditions it should include. It also describes species and surrounding landscapes linked to these habitats.

			Indicator structures and features	Ground conditions	Climatic conditions and areas	Linked species	Surrounding landscapes/ connectivity
Natural or semi-natural coniferous woodlands	Dry	Abies	**Trees** - old - slow growing conifer - conifers that lean on another tree for decades or centuries - different textures of bark		**Climatic conditions** - moist - high and consistent humidity **Type of areas** - older woodlands - shift in lightness and darkness - shaded and protected from exposure - half-shaded		
		Pinus	**Damage** - exposed wood mainly on deciduous trees	**Soils** - dry - wet peat bogs - rocky	**Climatic conditions** - moist	Mosses	
	Wet and moist	Abies	**Deadwood** - rotten - fallen trees - burnt - dry - remaining bark on deadwood - non remaining bark on deadwood - dead branches still attached to the tree - coarse stumps such as; Betalus, Quercus and Sobus aucuparia	**Soils** - moist - rich in humus - malnourished conditions Peat bogs Rainwater Groundwater movement	**Climatic conditions** - moisture - consistency of high moisture levels	Mosses	
		Pinus		**Soils** - moist - rich in humus - nutrient rich - nutrient poor Continuous water level Groundwater has surfaced	**Type of areas** - shade - older woodlands - waters (e.g., streams, springs, brook)		Spring Stream River

Nemoral woodlands and coppices on calcareous soils

No other woodland environment houses as many threatened species as deciduous woodlands and groves on calcareous soils do (Nitare and Skogsstyrelsen, 2019). The total area of these biotopes is very limited in Sweden today and the biotopes that are included in this category (stands dominated by *Fagus sylvatica, Carpinus betulus, Quercus, Corylus avellana*, and *Tilia*) have many common denominators, such as sun exposure, soil rich in humus, but they also constitute several completely different ecosystems with species adapted to different tree species as well as different soil and climatic conditions. In rich deciduous woodlands, there are often several threatened species within one and the same area, which of course are not a coincidence but a reflection of the area's natural conditions, history, and continuity, such as coppiced trees (see Figure 16). The term "biodiversity hotspots" is sometimes used for these deciduous woodlands to illustrate that there are high species concentrations. Field layer species favor areas where deciduous trees grow as they allow the early light of the spring to reach the floor of the woodland. The following stands are some of the main stands found in these habitats:

Stands dominated by Beech

Areas with low growing and sparse vegetation, exposed soil, ravines, muddy slopes, moist and soils rich in humus (Nitare and Skogsstyrelsen, 2019).

Stands dominated by Common hornbeam

Grows together with *Fagus sylvatica* and *Corylus avellana*, exposure to sun, rich humus, and calcified soil (Nitare and Skogsstyrelsen, 2019).

Stands dominated by Oak and Common hazel

Characteristics of a mixed deciduous tree stand, older spices of *Tilia* spp. (pollarded), *Malus sylvestris, Pyrus pyraster, Rhamnus cathartica,* and *Crataegus*, relict Corylus avellana, old *Quercus* and some recurring *Tilia cordata* spp (Nitare and Skogsstyrelsen, 2019).

Stands dominated by Lime trees

Warm, dry, and sun-exposed areas, it grows with *Quercus* and *Corylus avellana*, rocky and soil grounds (Nitare and Skogsstyrelsen, 2019).

The indicator species group of lichen, mosses and fungi living in these types of biotope structures favor old noble and non-noble deciduous trees (see Figure 17, p 38), solitary trees, woodland trees with shaded trunks, exposed roots, stumps, fallen trees, as well as soft and rotten wood that is constantly damp (Nitare and Skogsstyrelsen, 2019). Areas with stable microclimates, high abundance of boulders, south facing edges, wooded pastures or wooded meadows are important features for this indicator species groups. The soil should either be moist and rich in humus, open and exposed, have thin layers, or be warm and exposed to the sun.

A list of these important structures and features has been summarized in Table 6

Figure 16. Coppicing trees have a variety of living and deadwood that in turn create optimal living places for species to live in, Malmö. Elin Fänge

Figure 17. The beech tree is an important species that is connected to many species, Höör. Elin Fänge

Table 6. Describes structures and features important for biodiversity in nemoral woodlands and coppices on calcareous soils as well as describing which climatic conditions it should include. It also describes species and surrounding landscapes linked to these habitats.

		Indicator structures and features		Ground conditions	Climatic conditions and areas	Linked species	Surrounding landscapes/ connectivity
Nemoral woodlands and coppices on calcareous soils	Fagus sylvestris	**Trees** - deciduous trees - solitary - woodland - shaded, - bases of old trees - exposed roots **Deadwood** - stumps - fallen trees - soft and rotten wood that is constantly damp	Low growing vegetation Sparse vegetation	**Soils** - moist humus - rich in humus - calcified - exposed - thin layer - dry	**Climatic conditions** - heat - stable microclimates **Type of areas** - sun exposed - shade - WOODED PASTURE - WOODED MEADOW - Peatbogs		
	Carpinus betulus		Mixed deciduous tree stand			Fagus Corylus avellana	
	Quercus and Corylus avellana					Malus sylvestris Pyrus pyraster Rhamnus cathartica Crataegus Older spices of Tilia (pollarded) Old Quercus Relict Corylus avellana Some recurring Tilia cordata	
	Tilia					Quercus Corylus avellana	

Additional habitats

Edge zones

Forest edges serve as a transition zone in the landscape and are according to Wiström (2014) a feature used in landscape architecture to create and define rooms and spatiality in the landscape. As a landscape feature, forest edges can be perceived and characterized by their functions or by their users as they can be experienced as visual borders, barriers or corridors for movement, or buffers against disturbance (Herlin, 2001; Wiström, 2014). Forest edge zones are also important habitats for a range of species as they are the transition between forests and open land such as fields, meadows, pastures, or wetlands, and consist of features from both the closed forest and the more open land (see Figure 18 and 19 p 40; Skogsstyrelsen, 2014a, 2014b). Edge zones are a main habitat for many species while for others it can offer shelter and food supply or be used as a corridor.

Structural indicators

An edge zone should have a crown level gradually increasing in height from the open area to the closed forest — a structure called *the stair step appliance* — and it is a structure considered as valuable (Nilsson, 2017). The edge zone should consist of shrubs, small trees as well as larger trees that are more resistant to storms (Skogsstyrelsen, 2014a). Piles of small deadwood as well as a few larger dead trees are, especially if they are in the sun, important features for many smaller mammals as well as many species of insects. The microclimate in forest edges can vary affecting the vegetation structure, e.g., increased sunlight promotes plant growth and often results in a higher amount of vegetation cover in several layers, higher density in seedlings and plant mortality, compared to the forest interior vegetation (Herlin, 2001).

Indicator species

Birds

Fruit-bearing shrubs and trees growing in edges are important structures, especially for birds as they provide nutrient sources of food as well as protection from predators (Skogsstyrelsen, 2014a).

Mammals

Erinaceus europaeus (hedgehog) are another species that once thrived in the agricultural landscape shaped by the traditional techniques as they consisted of a patchwork of smaller fields surrounded by luscious edge zones in which they lived (Dacke, 2021). The edge zones are a preferred habitat as they are filled with both leaves, for their nesting, and insects for them to eat. Today's intensified agricultural landscape has decreased the amount of edge zones to create bigger fields, which in turn is threatening the hedgehog's existence. However, in order for them to survive they need to find a new place to live in have had to find a new place to liv-e in - in - our gardens filled with shrubs and leaves. Although the gardens are not free from danger; self steering lawn mowers can run them over and fences stop them from moving in between gardens, leaving them to cross roads and risking death. Further clearing out leaves from our gardens makes it hard for the hedgehogs to build their winter dens and find food. Using pesticides and creating hard surfaces in our gardens has also shown to have a negative effect on their sources of food. All this has led the species to decrease to an estimated one third between 2010 and 2020, leaving them as nearly endangered species.

A list of these important structures and features has been summarized in Table 7

Figure 18. Edge zones provide an important shelter for many species. Lund. Elin Fänge

Figure 19. Edge zones help species move between biotopes, Beuningen. Elin Fänge

Table 7. Describes structures and features important for biodiversity in edge zones as well as describing which climatic conditions it should include It also describes species and surrounding landscapes linked to these habitats.

	Indicator structures and features	Ground conditions	Climatic conditions and areas	Linked species	Surrounding landscapes/ connectivity
Edge zones	Crown level gradually increasing in height Luscious vegetation **Trees** - small - large Shrubs Leaves Deadwood	Found in all areas	**Climatic conditions** - heat **Type of areas** - patchwork of smaller fields - sun exposed - closed forest and open land - many edge zones surrounding field land	Deciduous Species berry Bearing Species insects mammals	Fields *Meadow* *Wooded pasture* *Wetland* *Corridor*

Figure 20. Wetlands can store water for longer periods of time and it creates areas of moisture which certain species thrive in, Malmö. Elin Fänge

Wetlands

Wetlands are often defined as land covered with vegetation and with the groundwater level just underneath or just above the ground surface, and they often hold a great number of species of both plants and animals (see Figure 20 and 21, p 42; Götbrink and Hindborg, 2015). However, wetlands have been ditched and lakes lowered in favor of agricultural land and forest production since the 19th hundred century which have led to several important functions in the landscape, such as water regulation and retention, to disappear as well as many species (Emanuelsson *et al.*, 2002).

Indicator species

Amphibians and reptiles

Wet environments, both temporary and permanent waters, are important for most amphibians (Jordbruksverket, 2003). Water free from fish is especially important for their reproductive phase, but they are equally important for shelter during hot and dry summers. Features such as sun exposed stones, cavities, and waters are also important.

Triturus cristatus (Northern crested newt)

Northern crested newt is an example of an indicator species for wetlands with high biodiversity as it has, similar to many other amphibians, complex demands and needs of several habitats (Jordbruksverket, 2003). The most important habitats for *Triturus cristatus* are small, open waters exposed to the sun with plenty of vegetation and free from predators, with a mature forest stand close by (Malmgren and Gustafsson, 2005; Artdatabanken, 2022). The mature forest stand should have long continuity with a complex ground structure for hiding spots (such as cavities, stones, and deadwood) and food supply. This is also an important habitat for their overwintering; however, the small waters are important for their reproduction phase and larva evolution. The optimal reproduction water has a relatively oligotrophic water edge with a diversity of aquatic plants with an even water temperature. The *Triturus cristatus* prefers water bodies that are at least 10 meters in diameter (but can also occur in smaller waters) and that have a minimum depth that rarely falls below 0.5 meters. It is important that the site has a permanent water level as the salamander lays its eggs under water, and their larva has a long period of development.

A list of these important structures and features has been summarized in Table 8

Figure 21. Vegetation that grows long wetlands provide optimal places for many species. Wijchen. Elin Fänge

Table 8. Describes structures and features important for biodiversity in wetlands as well as describing which climatic conditions it should include. It also describes species and surrounding landscapes linked to these habitats.

	Indicator structures and features	Ground conditions	Climatic conditions and areas	Linked species	Surrounding landscapes/ connectivity
Wetlands	**Water** - small - open - exposed to the sun - different depths Vegetation above water Vegetation submerged in water Cavities in the ground Stones Deadwood	Water with relatively even temperatures Waters and stones exposed to the sun Small water bodies - at least 10 m in diameter and 0.5 m depth	**Climatic condition** - hot and dry summers - moist **Type of areas** - no fish (for salamanders)	Insects aquatic Plants salamanders fish	Mature forest stands Other areas

BIODIVERSITY IN THE URBAN LANDSCAPE

Figure 22. In a splash of green, the tram can transport people around the city of Barcelona. Elin Fänge

What shapes urban biodiversity?

Urban biodiversity differs from the more natural biodiversity by the harsh environment of urban areas in which fewer species can live depending on their ability to adapt (Persson and Smith, 2014). They found in Sweden the urban areas often hold more diversity than the surrounding landscapes of production of both forest and agriculture. A green space can be a small urban park, including public parks, street verges, cemeteries, and sports grounds. Urban green spaces are highly influenced by humans, surrounding buildings and infrastructure (see Figure 22, p 44 and Figure 23). Streets and roads divide and separate green areas from each other, which also influences the urban biodiversity. However, the biggest difference between urban biodiversity and the more natural is that the species composition, especially among plants, consists to a large extent of exotic species.

Human activities in urban areas are affecting water quality, dynamics of habitats, food and water availability, species communities and populations, as well as ecosystem dynamics (Alberti *et al.*, 2020). Urban areas have modified both the structures and functions of natural habitats. According to Persson and Smith (2014) the variation and composition of species in urban areas are affected by both local and regional landscape processes, e.g., how the local area is designed and how it is affected by surrounding areas. Urban green spaces are, in comparison to natural environments, often small in size, hold a lower quality, are exposed to other types of disturbances, and often contain simplified habitats (Persson and Smith, 2014; Alberti *et al.*, 2020). For species to survive in urban areas they must be able to adapt their ecological niche (i.e., the resources they need to survive) to the new supply of resources that is the urban environment (Persson and Smith, 2014). How well species can survive and reproduce depends not only on their ability to adapt to the resources at hand, but also their ability to adapt to the processes that control the dynamic of the species population.

Figure 23. Green areas that are often low in quality and simplified are not suitable habitats for specialist species, Lund. Elin Fänge

Vegetation structure and animal communities

Land use, the age of a site, soil conditions and microclimate are all factors that drive the development and growth of vegetation, which affects the communities of birds and insects (Diamond, 1988; Bonthoux *et al.*, 2014). The vegetation structure manages the microclimate, food supply and other resources that have a strong effect on the composition and distribution of bird and insect communities. Landscapes surrounding urban green spaces have also been found to heighten the traits of species found in an area and explain their behavioral patterns and distribution patterns in that area (Bonthoux *et al.*, 2014) Increasingly, research reveals that urban areas can contain relatively high levels of biodiversity, and that important percentages of species are found in the surrounding natural habitat, including endangered species that also have been found in urban forests (Alvey, 2006).

Vegetation structure

Urbanization and land cover conversion changes the structure and function of natural habitats and has resulted in rapid loss of native habitats (Alberti *et al.*, 2020). An example of this is the human interest in exotic species as it has led to a change in the species diversity in urban parks (Kowarik, 1990). The exotic species that have been planted in people's gardens have spread into the urban forests where they have had a negative effect on the native species composition in the forests (plants, birds, mammals, and insects).

For the last 5000 years humans have had an interest in exotic species (Kowarik, 1990) and throughout that time the species had been shipped for months by boat to then be displayed for spectators in luxurious gardens (Blennow, 2002). With today's effective transportation exotic species have become cheaper to buy and thereby planted into most gardens and parks for aesthetic purposes as they can for example display more elusive autumn colors (Plantagen, no date; Blennow, 2002; Sjöman and Slagstedt, 2015). Imported species have the potential to throw off the balance that our native species have developed during thousands of years, as the exotic species have the potential of becoming invasive (Harkawik, 2021). The invasive species can outcompete native species and dramatically change the structures of forests. However, according to Sjöman *et al.*, (2016) only four of fourteen tree species from the Scandinavian region that are not facing severe problems with pests and diseases can have the potential to successfully develop and perform in urban environments. This makes the catalog of urban tree species very limited. Further, he advocates the usage of both native and exotic species to eliminate the risk of spreading pests and diseases, even though some exotic species can be invasive.

The woody understory is an example of a vegetation structure that has a significant effect on biodiversity (Heyman, 2010). It consists of dwarf shrubs, small trees, young variations of tall trees and woody liana. The ecological function of the woody understory is very important for many species because it forms habitats for many birds, produces food and nectar, moderate the stand climate, and influences the humus and topsoil conditions. However, it also nourishes tree species during the regeneration (Leonardsson and Götmark, 2015). In the Swedish urban woodlands, there are often a larger amount of deadwood and more deciduous trees than in the average rural forests, which make them potentially more important for the conservation of biodiversity.

Grass lawns are other phenomena that became popular during the 60s and 70s after the Second World War, when the pressure of housing increased because of the baby boom children that grew up (Rådberg and Friberg, 1996). This dramatic increase led to municipalities needing to build housing fast and, in the hurry, green areas were not a priority and were therefore often left as grass lawns. This has led to many places today to be dominated by grass lawns which give little to no variation in structural diversity. This in turn has led to detrimental effects on biodiversity since many habitats have been lost (Borman, Balmori, and Geballe, 2001). Having only lawns in residential areas is something not recommended by Boverket (2007) since natural environments have been shown to be better for HHWB, more attractive to buyers, and should therefore be promoted in green areas.

Animals

Birds

The expansion and densification of urban structures has led to increasingly artificial environments with new conditions, whereas light and noise conditions have had negative effects on birds (Tryjanowski, Morelli, and Møller, 2021). However, urban areas also offer new breeding sites and sources of food. The urbanization process of birds has led to behavioral changes, e.g., urban birds have a shorter flight initiation distance which is the distance in which birds move away when approached by humans or other potential predators. Further, people walking along trails can also have detrimental effects on bird species living in the shrubs (Ballantyne and Pickering, 2015; Thompson, 2015).

Heyman, (2010) found that the density of breeding forest birds in urban woodlands decreases in places where the understory vegetation was totally removed. When the clearance, however, was done in smaller patches, he found no significant effect. Even though open forests often are perceived as safe and pleasant to humans, clearance is likely to have a negative effect on the woodland birds living in the shrub layer. Nevertheless, Mason *et al.*, (2007) found that bird species living on the forest ground level can be promoted by minimizing the number of mowed surfaces.

Mammals

Urban environments are challenging for many mammal species, and at first glance it may seem that there are only rats, mice and squirrels that can live and thrive in these conditions (Chatelain and Szulkin, 2021). However, many of the urban mammal dwellers go unseen. In Europe there have been 14 abundant mammal species encountered. A major part of the mammals living in urban areas (69%) have, in contrast to birds, evolved to be nocturnal and thereby go unseen by many people. Rogala *et al.*, (2011) and Dyer *et al.*, (2001) found that wild animals avoid hiking trails and development sites and that the distance the mammals keep can vary from 50 to 1000 meters. However, they also found that elks were more willing to be closer to trails — possibly functioning as a refuge from the shyer wolves.

Species thriving in urban areas are often referred to as "urban exploiters" (see Figure 24), as they efficiently can benefit and use resources in urban areas (Chatelain and Szulkin, 2021). The most attractive urban resources are probably food availability, but also attributes such as the climatic conditions and the presence of exotic species can affect how well species survive. The climatic conditions in urban areas influence the growing seasons due to the urban heat island effect. Together with exotic species the growing seasons makes food available much longer and together with anthropogenic leftovers this leads to food availability almost all year round in urban areas.

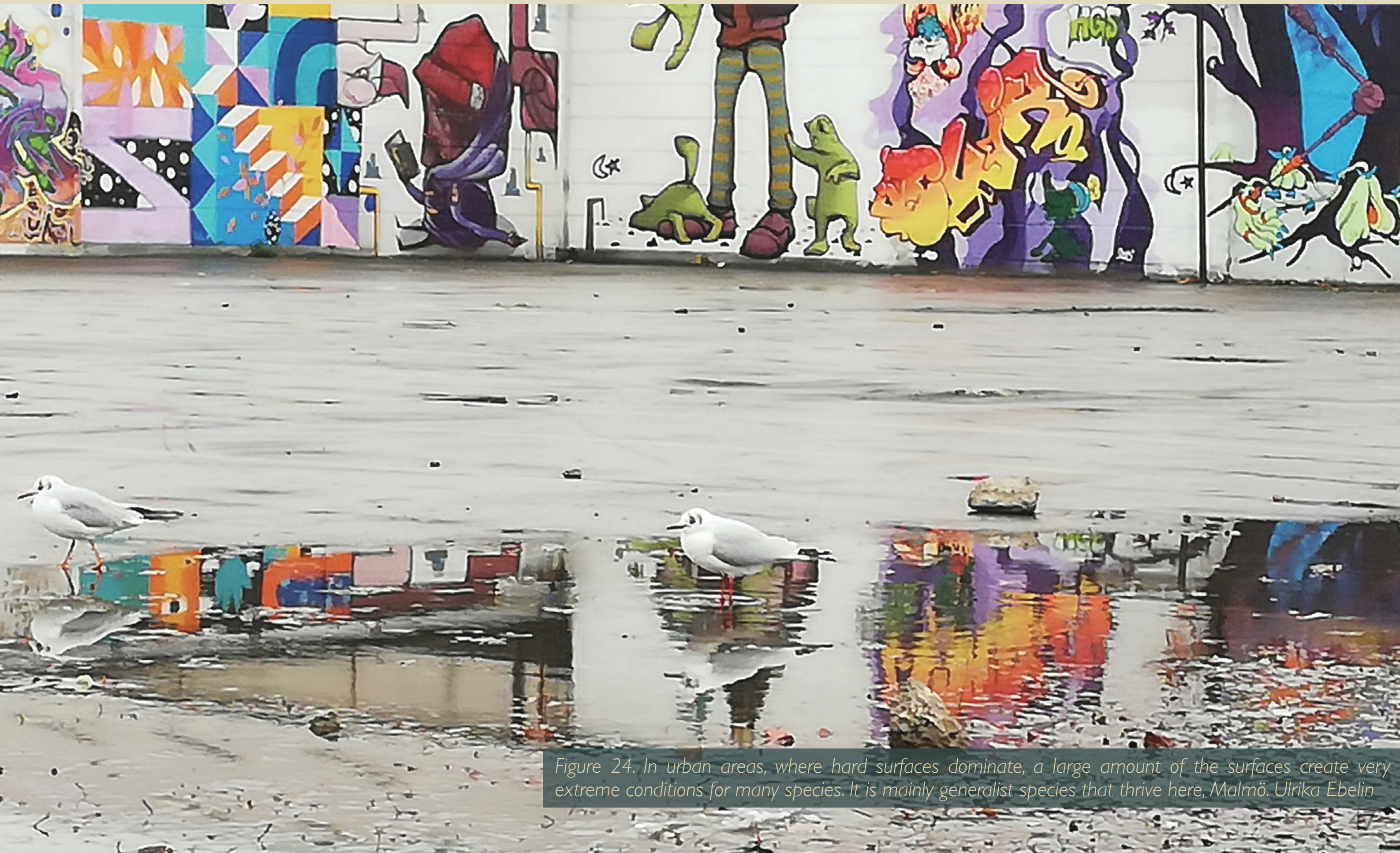

Figure 24. In urban areas, where hard surfaces dominate, a large amount of the surfaces create very extreme conditions for many species. It is mainly generalist species that thrive here, Malmö. Ulrika Ebelin

Insects

Insects are one of the most diverse groups of species on Earth with 4 to 6 million estimated species (Wenzel *et al.*, 2020). Habitats of insects in urban green areas can consist of a wide variety of habitat types, from private and community gardens as well as public parks and botanical gardens to urban farms, vacant lots, green walls, and green roofs. With such a large and diverse group of organisms it is no surprise that these areas host diverse and abundant insect communities. A diversity of landscape features such as scale, composition, and context are important for insects' diversity, dispersal, population structure and abundance. However, several studies have shown that species richness and diversity among insects is reduced in the urban core (see Figure 25). A gradient in species richness seems to have emerged between rural and the most urban areas along which different species thrive, e.g., Wenzel *et al.*, (2020) found that in urban areas, with high levels of densification and high percentages of sealed built-up areas, the diversity among pollinators declined. However, they also found that diversity among pollinators generally increased at landscape scale with the number of green spaces, and that at local scale the availability of nesting resources and flowering plants had a positive effect on pollinator diversity. The origin of flowering plants, i.e., native, or exotic species, did not however have a significant effect on the diversity of insects.

Figure 25. Understory vegetation is usually removed in urban areas, and the monocultural lawns are not beneficial to biodiversity, Kävlinge. Elin Fänge

Figure 26. Connectivity needs to have the qualities that are beneficial to biodiversity. Unfortunately, raised crowns and lawns do not contribute to that, Burlöv. Elin Fänge

Landscape elements affecting the dynamics of urban biodiversity

Size

The age and size of an area affects vegetation structure, density, and height, which in turn also affects the species assemblages and variations (Bonthoux *et al.*, 2014). Both the number of species and individuals, both plants and animals, increases with the size of the area as a larger area can serve more resources and a greater variation in habitats than a smaller (Bonthoux *et al.*, 2014; Persson and Smith, 2014). Some species need areas that are not disturbed as much by human activity and the larger a green space is, the more these types of species can thrive in the area. In other words, the "edge effect" is reduced.

Connectivity

The composition of species communities and the distribution of individuals can also be affected by the landscape composition around an urban green space (Bonthoux *et al.*, 2014). Structural and functional connectivity patterns between landscape features are strongly affected by the urban structures and it is a key concept in landscape ecology (Alberti *et al.*, 2020; Douglas, 2021). Habitat fragmentation is a result of the homogenization of urban structures and leads to isolated populations and homogenization in the gene flow (see Figure 26; Alberti *et al.*, 2020). With urban growth new barriers occur which isolate natural habitats and makes the dispersal of less-mobile species difficult. Many rivers, highways or railway corridors are often identified as green corridors; however, they are often broken up by bridges, tunnels or other features cutting through with little or no vegetation cover and shelter for animals (Douglas, 2021). Although the evidence of landscape connectivity enhancing biodiversity in fragmented habitats is growing, rare species are unlikely to benefit from enhanced connectivity as they have very low dispersal abilities. Invasive species however can spread much more easily and therefore present a bigger threat to native species with enhanced connectivity. Different forms of connectivity can be accomplished by edge zones, green corridors, and/or gardens.

Edge zones

The edges are the most occurring landscape feature in urban green spaces due to the small area urban green spaces often have (Persson and Smith, 2014). This leads to a large part of many urban green spaces to consist of edge zones creating a transition between habitats and built environments. The edge zones are characterized to a larger extent by disturbances than the internal parts of the green spaces. This has led to species that more easily can adapt to the urban disturbances and are favored at the expense of more shy species needing nature with less human disturbance.

Green corridors

Green infrastructure is often seen as an interconnected web of spaces with vegetation, including streets with trees, private gardens, and peri-urban forests, which provide essential ecosystem services in urban areas (Douglas, 2021). Urban green corridors are usually defined as a network of fragmented urban green spaces with various components connecting them linearly, and they are a key component in the web of green infrastructure. However, the term 'corridor' has been used in many diverse ways within the context of design and planning and can therefore be defined in multiple ways. Green corridors are often considered to promote the movement and dispersal of flora and fauna between different patches of green spaces. In addition to serving as a pathway for species to spread, corridors often serve additional functions such as offering habitats, shelter, and food supply for wildlife. Mason *et al*., (2007) found that the size of a corridor influences the amount of forest interior bird species living there and that the wider the corridor the higher diversity among birds was found. The number of bird species nesting on the ground was found to be highest when the corridor had a width of 300 m. When the corridors were at a width of 100 m and mainly prioritized as greenways for humans, crown dwelling birds dominated instead. Corridors less than 50 m in width showed no record of forest-interior bird species. A wider corridor also decreases the wind speed as well as turbulence which can have an important effect on future climate change with extreme weather (Skogsstyrelsen, 2014a)

When assessing urban green corridors, the fundamental issue is to define for whom or what types of species the corridors should be designed for and even though a corridor is designed for one purpose it can still be used for multiple other purposes (Douglas, 2021).

Gardens

Gardens and backyards are in some urban areas a large part of the urban green structures and to change gardens to fit the needs of biodiversity can have a tremendous effect on the urban biodiversity. Goddard, Dougill, and Benton, (2010) concluded that gardens should promote more places for biodiversity as there is a need for it. According to the Swedish national list of threatened species. Many bumblebee species are registered as seriously threatened (Naturvårdsverket, n.d.) and (Goulson *et al*., 2002) discovered that *Bombus therisis* (one of the more common bumblebees) have the ability to thrive in gardens and backyards if given the habitats they need

Artificial light

During the dark hours of the day urban areas and cities are filled with lights from streets, roads, and highways, but also from housing and industrial areas (see Figure 27; Grose and Jones, 2021). How this affects our health and well-being as well as the ecological impacts has been little understood. However, there is a global trend moving towards whiter light sources as a result of increasing use of LED lights with a strong blue component that, to the human eye, simulates daylight.

Figure 27. Blue/white lighting in urban areas disrupt our daily rhythms, Lund. Ulrika Ebelin

Blue light is important for most life as it is a key driver of biological rhythms by suppressing the production of melatonin. Melatonin is found in most life forms on earth including bacteria, plants, and animals and it is thought to have similar effect for different taxa. As melatonin peaks during the periods of darkness and ceases with daylight, the blue artificial light can disrupt the production of melatonin affecting the biological rhythms such as natural sleep-wake cycles.

Between the corridors of light in urban areas, dark patches are interspersed and can function as isolated fragments of habitats affecting both nocturnal and diurnal animals (Grose and Jones, 2021). Alterations in light and dark can have a significant effect on animal behavior patterns as well as the daily rhythms and seasonality of both animals and plants. Presumably, the most obvious change in behavioral pattern is the attraction to light at night by many species, resulting in the familiar view of insects, birds and even bats flying around the light source. Such light sources can act as ecological traps for some species as it can have a disorienting effect on animals attracted to light, which can lead to e.g., birds and bats dying of exhaustion. Spoelstra *et al.*, (2017) investigated how bats react to different colors of artificial light during the dark hours of the day and could conclude that when the light source was red that the activity among bats showed no significant difference to their natural activity. According to Spoelstra *et al.* (2017) the long wavelengths in red lights resemble darkness more than light from green or white light sources. When using white and green light sources the activity among slow-flying light-shy bat species decreased. However, they also found that introducing white and green light sources in natural habitats favored synanthropic species/urban exploiters. Although, it has also been shown that artificial light at night can have a broadscale dramatic effect on invertebrate communities leading to alteration in predator and prey relationships as insectivorous predators can e.g., take advantage of the disorientated prey (Grose and Jones, 2021). However, some diurnal species can benefit from artificial light as their temporal range of foraging can expand into the night.

Microclimate

In urban areas the climatic conditions can vary greatly from one site to another, whereas variation in temperature and humidity have the largest effect on the composition in plant communities (see Figure 28; Bonthoux *et al.*, 2014). The urban flora has a higher share of drought-resistant plants than natural environments due to the more rapid rainwater runoff and higher temperatures. In addition, the flora and fauna must also adapt to the high number of pollutants and contaminated land while at the same time compete with exotic species. According to Bonthoux *et al.*, (2014) it is estimated that of all the species that were found in urban parks worldwide, 40% of them consisted of exotic species.

Figure 28. Dense buildings in urban areas create microclimatic conditions, in which only drought resistant plants can live, Malmö. Elin Fänge

MITIGATING EFFECTS IN THE URBAN LANDSCAPE

Figure 29. Green areas and vegetation can mitigate the effects of increased rainfall by storing and infiltrating, and still have high values of biodiversity, Ronneby. Ulrika Ebelin

Climate change, human development and population growth will increase the impacts of overexploitation and agricultural expansion (Maxwell *et al.*, 2016; Persson *et al.*, 2020). Inhabitants in urban areas use disproportionate amounts of resources and through transportation of both people, goods, and industrial processes, they are major sources of carbon dioxide emissions (Grimmond, 2021). With urbanization increasing around the world, understanding the impact of climate change is more important than ever (Naison *et al.*, 2011). Urban areas are facing new challenges due to climate change and large numbers of people and their assets are vulnerable to a range of disruptive and damaging risks. If urban areas continue to grow rapidly without any regard to the resource demands and climate change of both today and the future, the vulnerability will increase. Because of climate change the most basic services, such as water- and food supply can become especially difficult to provide in urban areas.

The climate in urban areas is influenced by its geographical location which also affects the meteorological conditions, such as the solar radiation and seasonal extremes (Grimmond, 2021). However, urban areas also create distinct climates on a local and micro scale, which can vary within the urban areas and over the year. The urban climate is a result of a large number of hard surfaces and activities by the urban inhabitants that generate heat and contribute to the greenhouse effect. Although cities and urban areas only cover a small fraction of the Earth (less than two percent of the land surface) they are a key driver in global climate change (Maxwell *et al.*, 2016; Grimmond, 2021).

However, urban biodiversity or urban nature can mitigate many of the potential negative effects of climate change in urban areas (Ordóñez, Steenberg, and Dunker, 2021). Furthermore, there are and have been many biodiversity hotspots in urban areas and these areas need to be either protected or restored (Miller and Hobbs, 2002). Thus, these effects make the adaptation to a new climate a priority as urban areas are expected to face increased extreme weather events.

Extreme weather

Water is necessary for all life forms on earth and necessary for many of their basic processes for survival (Sjöman and Slagstedt, 2015). However, many species of vegetation are not adapted to the urban climate and can therefore have difficulties surviving in urban areas (Sjöman and Slagstedt, 2015; Ordóñez, Steenberg and Duinker, 2021). Climate change and the effects that follow, such as decreased water availability through drought or extreme temperatures, may therefore create more extreme growing conditions for many species and cause higher mortality among trees and other plants that are unable to adapt to the new conditions. Hard surfaces and bare soil can cause a number of problems as water from rainfall is more quickly transported away from these types of surfaces compared to a vegetated ground surface (Ashman and Puri, 2002). Another problem is erosion, which is particles, such as hummus and minerals, being transported away from bare surfaces by the rain. Vegetation slows down the water, giving it more time to filter into the ground where it can be stored.

Increased rainfall and flooding

The urbanization and densification processes have led to an increased number of hard surfaces in urban areas and cities (Myndigheten för samhällsskydd och beredskap, 2017), while at the same time modernization and industrialization of urban areas has also led to extremely efficient stormwater systems where the goal is to transport the storm water from the hard surfaces to the nearest recipient or water treatment plant as fast as possible (Sjöman and Slagstedt, 2015). During the last decade the frequency and severity of heavy rainfall and flooding have increased in urban areas, and flooding has become one of the most critical and costly problems city planners are facing due to climate change (Naison D *et al.*, 2011). However, the stormwater runoff system has a very limited capacity and with increased intensity in rainfalls the system becomes overloaded. This can lead to flooding which in turn can cause severe problems such as paralyzed transportation systems, mobilized trash, debris and pollutants but also increased spread of waterborne diseases.

Figure 30. Areas that are designed to be flooded can mitigate the effects of increased rainfall and flooding in urban areas, Malmö. Elin Fänge

Urban green areas can mitigate the effects of intense rainfall and flooding by open stormwater runoff systems where water can infiltrate into the ground and benefit the vegetation that can absorb water through its roots (Sjöman and Slagstedt, 2015). Another way urban green spaces can mitigate intense rainfall and flooding is through the interception in the foliage of plants (see Figure 29, p 53 and Figure 30, p 54). Interception is the process whereby water is absorbed through the vegetation's foliage and from the foliage water can evaporate directly and therefore never touch the ground. This has the best effect in large natural looking plantings where the vegetation grows in several layers with a large volume of foliage.

Heat and Drought

Drought is a phenomenon that occurs when the amount of precipitation is significantly lower than normal (Naison *et al.*, 2011). It can occur because of several different factors and can affect urban areas in a number of ways. The frequency of droughts is predicted to increase because of changes in weather patterns and extreme high temperatures. Drought can have a negative effect on the ground's resources and production systems, compromising the water quality (Naison *et al.*, 2011). It can also lead to declining water supply while at the same time the demand for water is expected to increase as a result of climate change.

Extended periods of higher than average temperatures are typically defined as heat waves and are expected to become more frequent, more intense and longer lasting over the world (Naison D *et al.*, 2011). This is a result of climate change, and it will affect both rural and urban areas. However urban areas tend to have higher temperatures than rural areas due to the urban heat-island effect, which means that cities tend to retain heat more than the surrounding rural areas (Naison D *et al.*, 2011; Sjöman and Slagstedt, 2015). The strength of the urban heat-island effect depends on the size of a city´s population, its density, physical layout, and structures of built-up areas. However urban areas can exhibit a diversity of microclimates with varying levels of heat radiation and temperatures (Sjöman and Slagstedt, 2015).

Cities that have a higher density of buildings and limited areas of green space tend to have stronger heat-island effects (Naison D *et al.*, 2011). Preserving and developing urban vegetation are two of the most important tools for decreasing the effects of climate change and the urban heat-island effect (Sjöman and Slagstedt, 2015). Both the temperature on the ground and the air can be managed by the vegetation through the cooling effect of both the shading and evapotranspiration. Urban green spaces with a lot of vegetation (e.g., trees and shrubs) normally have a temperature 1-2°C lower than surrounding built up areas, a difference that can increase during periods of higher temperatures. It has been shown that trees in a forest can have positive effects on the climatic conditions in cities and act as an ecosystem service (Hale *et al.*, 2015). The forest can work as insulation for buildings, to keep them warm or cool, thereby keeping the energy costs down, improves air quality and carbon capture, increases biodiversity, improves water quality, and shows a direct improvement of HHWB. However, increased temperatures increase the evapotranspiration processes as well as drying out the plants water resources causing drought and severe damage to the vegetation.

Increased wind speeds

The wind speed in urban areas is often lower than in rural areas because of the dense structures of buildings creating friction and breaking the wind speed (Sjöman and Johansson, 2011; Sjöman and Slagstedt, 2015). Although some urban structures can have the opposite effect creating high wind speeds. Buildings, walls, and other large obstacles create differences in pressure between the windward and the leeward leading to higher wind speed around the corner of the obstacle. Behind the obstacle the average wind speed is often low but at the same time heavy turbulence can emerge.

According to Sjöman and Slagstedt (2015), movement of the wind is an important aspect in urban planning as it can affect other climatic factors such as the spreading of air pollutants, perception of microclimatic conditions and by regulating temperature. During the winter when the winds are strong and cold it can intensify the energy usage in buildings, but also affect people's outdoor recreation (Sjöman and Johansson, 2011). However, in summer when the temperatures are high the need for cooling in buildings and outdoor spaces increases. The likelihood of people walking or cycling to social activities and local commerce decrease in areas with high and uncomfortable wind speed.

The spatial layout of buildings and infrastructure in urban areas have a strong effect on the urban climate (Sjöman and Johansson, 2011; Sjöman and Slagstedt, 2015). Factors such as the width, height and form of the streets increase the speed of the wind when they are orientated in the dominated wind direction (Sjöman and Slagstedt, 2015). Even though the wind speed often is lower in urban areas than in rural areas, the phenomena such as wind turbulence is more common in urban areas as the variation and higher buildings can affect the winds and create turbulence on ground level. By strategically placing vegetation, pollutants and particles carried by the wind can to some extent be controlled and directed up and away from the street. The factors of where, how, and which vegetation material that is used are crucial for how the conditions created by winds will be affected by the strategically placed vegetation. Groups of trees and vegetated curtains have long been used in the agricultural landscape as sheltering vegetation - something that according to Sjöman and Slagstedt (2015) can be used as inspiration in green urban spaces in the outskirts of urban areas. Sjöman and Slagstedt also recommends planting both shrubs and trees together in several rows, where deciduous and conifer species are combined to create optimal conditions for reducing the wind all year around.

High levels of air pollution

Urban areas are major sources of warm polluted air which influences both the urban area and other surrounding areas downwind (see Figure 31; Grimmond, 2021). Polluted air has a negative effect on both HHWB, but also on the vegetation and animals (Grimmond, 2021; Naturvårdsverket, 2021). It has also come to be a cause of unnatural corrosion, contamination, acidification and overfertilization, and it has also had a major impact on climate change. The anthropogenic pollutants have been classified as primary and secondary, where primary pollutants are those directly emitted by humans and other organisms, while secondary pollutants are results from chemical interactions in the

Figure 31. High levels of air pollution are negative for our health and well-being, Malmö. Elin Fänge

lower atmosphere between e.g., pollutants and ozone. Air pollutants are also one of the major causes of health problems worldwide, and the effects range from disrupted reproduction to premature aging and death (Sabelström *et al.*, 2017). Infants and children are the most vulnerable groups as air pollutants can cause harm to the respiratory tract and reduce lung capacity from an early age. The air pollution problem can only be mitigated by reduced emissions; however, urban green spaces have shown to have an important role in mitigating the negative effects of air pollution. Pollutants bound to particles (secondary) can be bound to the surfaces of leaves, and the gaseous pollutants (primary) can be taken up by plants through their cleavage openings and small pores in the leaves. However, trees in urban settings contribute differently to their environment depending on which species, age, and location (Niklasson and Nilsson, 2005). Young and dense forests are important for urban areas with high levels of carbon dioxide as they are better at storing and filtering greenhouse emissions (Pugh, 2020). As the trees get older their growth slows down and so does their ability to store and filter carbon dioxide from the air (Hale *et al.*, 2015; Olsson 2006). Older trees have the ability to collect dust from nearby roads and can also help buffer against acid rain. However, this raises the pH-level on the bark, which is not preferred by some species of lichens and mosses (Niklasson and Nilsson, 2005).

The positive effect that vegetation has on air pollutants has the best effect during summer when vegetation is leafy. However, the emissions of air pollutants in Sweden peaks during the winter, when most vegetation is defoliated, even though according to Sabelström *et al.* (2017), they can still have a positive effect on air pollution during winter. In Gothenburg the percentage of nitrogen oxide along a heavily trafficked road was 16% less in green areas compared to open spaces. Exercising along roads can have a reducing effect on the activity as the polluted air increases the risk of cancer, inflammation, and lung diseases (World Health Organization, 2021). Air pollution can also affect the neurological development of fetuses and children, leading to learning difficulties and poor lung and brain capacities. The WHO (2021) also states that long-term exposure to air pollutants and road traffic noise can also increase the risk of cardiovascular diseases. see Figure 32

Figure 32. The use of vehicles today is risking our health and wellbeing, Malmö. Elin Fänge

HUMAN NEEDS

Figure 33. Artificial light increases the feeling of safety and can also contribute to the aesthetics of an urban area, Norrköping. Elin Fänge

Humans have needs, just as all other creatures (Kaplan, Kaplan, and Ryan, 1998a). How these needs are met affects our health and well-being. However, in the process to meet our needs humans have transformed and affected the environment with devastating consequences for the planet and for all living things. Although, urban green spaces have, as mentioned before, been proven to have positive effects on our health and well-being (Grahn and Stigsdotter, 2003; Grahn, Stigsdotter, and Berggren-Bärring, 2005) and with the rapid urbanization and population growth, they are becoming increasingly important for biodiversity as well (Qiu, Lindberg, and Nielsen, 2013). However, human needs in urban areas are often in conflict with the needs of biodiversity (Qiu, Lindberg, and Nielsen, 2013) as urban green spaces can have a negative effect on our health by introducing allergens, trapping pollutant emissions and they are often seen as unsafe places (Kuo and Sullivan, 2001; Maas *et al.*, 2009; Gatersleben and Andrews, 2013a; Pataki, 2021).

The hierarchy of the basic human needs

Physiological

The physiological needs are the starting point for the human motivation theory and according to the American psychologist Abraham H. Maslow (1943) who first presented the theory, when the physiological needs are met, other needs will occupy the organism. When those needs are met, new and "higher" needs will emerge once more, and by this theory the basic human needs can be organized in a hierarchy of basic needs, which is called the human motivation theory. The physiological needs are the needs that maintain the stable and normal state of the body's blood stream (Maslow, 1943). These are the most necessary needs for a human being, or any other living organism, because in lack of everything in life the most important motivation would be, according to Maslow (1943), to fulfill the physiological needs above all else.

"The urge to write poetry, the desire to acquire an automobile, the interest in American history, the desire for a new pair of shoes is, in the extreme case, forgotten or become of secondary importance. For the man who is extremely and dangerously hungry, no other interests exist but food. He dreams food, he remembers food, he thinks about food, he emotes only about food, he perceives only food, and he wants only food." (Page 5, Maslow (1943).

Safety

The safety needs are the need that, according to Maslow (1943), emerges when the physiological needs are relatively satisfied. Although the need for safety can sometimes, if the state is extreme enough, become more important than the physiological needs and in this state, it could be as if one would live only for safety. Fortunately, most people in our culture are adults living in a society where the common citizen's everyday lives run smoothly and peacefully without the constant threat of e.g., wild animals, criminals, or natural disasters. In other words, the common human being in our culture is to a large extent satisfied with their needs for safety. This can however change, and already has to some extent, with the threat of climate change and mass extinction. Our safety for survival is, because of this, threatened.

In the search for safety a broader aspect can be found: the preference for familiarity of things (Maslow, 1943; Kaplan, Kaplan and Ryan, 1998b). We tend to want things and our surroundings to be organized, coherent and meaningful.

Love, affection, and a sense of belonging

The needs for love, affection and a sense of belonging emerge when the two previous mentioned needs are fulfilled (Maslow, 1943). Just as one might feel hunger for food or the need for safety, the need to attain affection and love can be just as strong as the need for food or safety, but only if the previous needs have been met

Esteem

The esteem needs are based on our need or desire for a stable and high respect for ourselves (Maslow, 1943). The need is built on both the need of the desire for achievement and confidence to face the challenges of the world, but also based on the desire of esteem from others where prestige and reputation play crucial parts. The satisfaction of the needs of esteem leads to emotions of self-confidence, worth and strength, but also the feeling of capability and adequacy to being useful and necessary to the world and people around us.

Self-actualization

When all the previous needs are satisfied, soon there might be a feeling of discontent and restlessness (Maslow, 1943). The need for self-actualization will emerge if the individual is not doing what he or she is fitted for. How the need will be satisfied varies from person to person but according to Maslow (1943), basic satisfaction will finally be achieved when the need for self-actualization is satisfied.

Promoting human needs in urban areas

The needs of humans and the human perspective have, according to Carr *et al.*, (1992) been neglected in both the design and management of public spaces. Much of the built environment is proposed and assessed by designers, their clients and space managers with the assumption of what it should be used for rather than what people need.

Comfort

In urban areas/public spaces the basic physiological needs can be satisfied through comfort (Carr *et al.*, 1992). Comfort includes the need for drinking water, the need for food, shelter, and a place to rest when tired. In cities located in warmer latitudes, the need for a cooling shade can be urgent while in cooler cities e.g., cities in Sweden, the need for sunlight is much more important. They also found that comfort can also tend to the need for safety by how people experience a public space. Crime and assault are common concerns for the feeling of security in public spaces.

Safety

The perceived personal safety is defined as a feeling and not the actual safety and is highly individual (Blöbaum and Hunecke, 2005; Jansson *et al.*, 2013; Boomsma and Steg, 2014). However, the perceived safety or risk is often associated with the fear of crime and may be a reflection on the cognitive and affective responses to risks (Boomsma and Steg, 2014). Women, elderly, and immigrants are particularly vulnerable groups that tend to feel less safe in urban environments and the feeling of safety decreases after dark (see Figure 33, p59; Blöbaum and Hunecke, 2005; Jansson *et al.*, 2013). Boomsma and Steg (2014) found that the environment provides information about potentially dangerous or frightening situations and the design of built environments can therefore be crucial for the feeling of safety in urban areas, especially for women. Results from Olsson's (2006) thesis has shown that lighting in green areas would encourage inhabitants to visit them more often and Madge's (2008) showed that park visitors, and particularly women avoided areas with poor lighting, dense understory vegetation or a high density of trees. Two characteristics in urban areas have been identified as indicators of immediate danger: concealment and entrapment (Boomsma and Steg 2014).

Concealed places can be defined as a space big enough to conceal a potential offender, such as a larger trunk or dense vegetation, a wall, or a dark spot (Blöbaum and Hunecke, 2005; Boomsma and Steg, 2014). However, concealed places can also offer a place for escaping a dangerous situation but also to find shelter, however, it has been found that concealed places are most associated with opportunities for offenders to hide (Blöbaum and Hunecke, 2005; Gatersleben and Andrews, 2013b; Boomsma and Steg, 2014). Entrapment refers to the blocking of the ability to escape and it has a strong negative effect on personal safety, even when there are no potential offenders present (Boomsma and Steg, 2014). The feeling of entrapment can depend on both a social aspect; the inability to contact people in the physical surrounding, and the physical aspect which are the inability to escape because of physical features in the environment blocking the view or the physical accessibility.

Jansson *et al.*, (2013) found that fear itself can often be more dangerous than the actual risk of being exposed to a crime as the fear can lead to inactivity and self-isolation. Woodland areas in this study were often pointed out as unsafe areas and the vegetation was pointed out as having a significant effect on the perceived personal safety (Jansson *et al.*, 2013). The negative effect that shrubs and shrubs have is that they block the view and can therefore create environments that are perceived as unpleasant for some individuals. Although vegetation can in some settings be positively linked to personal safety, a study by Kuo and Sullivan (2001) showed that greener residential areas have fewer reported crimes and the residents living in these areas have reported lower levels of fear and less aggressive behavior. Even though the authors suggest that the main strategy in reducing crimes should be to address underlying factors, such as poverty and gun-availability, they also argue that designing and maintaining urban areas to promote good overview and a sense of stewardship can make the environment to be perceived as much safer.

Recreation

Recreation can be defined as activities that are fundamentally rewarding and take place in outdoor environments (Chen, 2021). These activities are often performed by people's own personal choice during free time, either individually or in groups. Recreation can have a wide range of functions as it can be relaxing or energetic, foster social, cultural, intellectual and/or creative development, and it can also be restorative and revitalizing (Kaplan, Kaplan, and Ryan, 1998a; Chen, 2021). It can thus take many forms, be conducted in different places, for various purposes and by any number of people. However, contact with nature and open-air recreation has been shown to have a positive effect on restoration and has long been seen as the key need for human recreation, health, and well-being (Chen, 2021).

While recreation can be characterized in many ways, in this paper we have chosen to limit it to 1) restorative and stress-releasing experiences, 2) physical activity, and 3) social activities (Chen, 2021).

Restorative and stress-releasing experiences

It is vital for our survival to receive information about e.g., our environment and other people to make the right decisions (Kaplan, Kaplan, and Ryan, 1998a). However, some information is more important than others and sorting through information in urban areas, which are filled with excessive information such as noise, smells and many forms, shapes, and materials, can lead to mental fatigue. The grass lawns that dominated the 60s and 70s have given a small variety in diversity of species but functional use for humans. If urban areas were to have a higher variety of green spaces, it would in turn offer a larger number of different activities and more diversity (Rådberg and Friberg, 1996; Lucas and Dyment, 2010; Hartig *et al.*, 2014). Restorative settings are often described as being different from the daily norm with less information, and such a setting can aid in recovering from mental fatigue. In a survey, the main disturbing factors in an urban setting were shown to be trash, traffic, and vehicle disturbance, and while visiting nature, those were the top three factors that visitors did not want to see during their visit (Olsson, 2006; Fredman, Ankre, and Chekalina, 2018). Restoration has also shown to be more effective when inhabitants walk in a nature reserve compared to an urban setting. Exposure to nature and healthy ecosystems have many different effects on an individual's sense of connectedness (i.e., biophilic needs) (Barrera-Hernández *et al.*, 2020) and enhanced psychological restoration (e.g., feeling relaxed/refreshed) (Ulrich, 1983). Urban settings have been shown to increase levels of anger of inhabitants (Barrera-Hernández *et al.*, 2020). Children need peace and quiet in nature so that they themselves can calm down and for that to happen the proximity to rough terrain, water, shrubs, and trees are what is most desired (see Figure 34; Beck-Friis, 2003). Children are shown to have better motor systems, concentration, increased learning ability, gender equality play, less frustration and increased activity when having access to natural areas where they can play (Dyment, 2005; Boverket, 2007; Jansson, 2008; Lucas and Dyment, 2010; Jansson *et al.*, 2014).

Figure 34. Access to nature improves children's motor systems, concentration, learning ability, improves gender equality play, less frustration and increased activity, Åskersund. Ulrika Ebelin

Physical activity

WHO (2020) has defined physical activity as all forms of bodily movement produced by skeletal muscles, including movement such as walking, cycling, sports, or as active recreation and play. Physical activity has also been proven to give significant health benefits for both the body and mind and it contributes to reducing symptoms of depression and anxiety as well as preventing and managing diseases such as cardiovascular disease, cancer, and diabetes. It has also been shown to enhance cognitive processes at the same time as it ensures healthy growth and development in children and young people. According to WHO, physical activity of both moderate and vigorous intensity improves overall health. Access to urban nature and other natural outdoor environments are likely to have a positive influence on the time people spend on physical activities outdoors by offering suitable settings (Hartig *et al.*, 2014; Chen, 2021). Different environmental settings promote different types of activities. Such settings could be a playground, trails in parks, promenades, and water bodies (Chen, 2021). However, the presence of natural features, such as trees, shrubs, flowers, and water features in synergy with natural sounds and serenity have a supporting effect on both active and passive recreational activities. Olsson (2006) found that when asked, more inhabitants were positive to the idea of new walking and bike paths and Hartig *et al.*, (2014) concluded that green spaces may also influence people's choice of transport as natural features may encourage people to favor walking and cycling over other transportation modes.

Children have a strong need for physical activity (Ek, 2012). Jansson (2008) found that when only a playground was present children tended to be more frustrated as they had to wait for other children to finish playing before they could start. However, when a natural environment with trees, shrubs and deadwood was next to the playground the children felt that they were welcome to play there as well as they could climb on them. Furthermore, Jansson (2008) also showed that children preferred to play with natural material over bought materials and that they preferred a forest over a lawn area.

Social activities

Urban green spaces can attract urban dwellers as they can provide opportunities for relaxed social interactions with friends, family and neighbors and thus contributing to community building and empowerment (Chen, 2021). In a survey of people's outdoor habits 75% of the people enjoyed a picnic (Fredman, Ankre, and Chekalina, 2018) and in addition to this, urban green spaces can also offer opportunities to interact with other creatures such as pets and wildlife (Chen, 2021). Furthermore, birds' songs in particular have shown to have a positive effect on the level of happiness and well-being of humans (Alvarsson, Wiens and Nilsson, 2010; Annerstedt *et al.*, 2013).

Accessibility

The ability to access green spaces is needed to use and benefit from the positive effects of natural environments (see Figure 35; Carr *et al.*, 1992; Ode Sang and Hedblom, 2021). Access is defined as "…the ease and distance involved in entering an area" (page 609, Ode

Figure 35. Bike paths on all roads are a great way to increase accessibility in urban areas, Wijchen. Elin Fänge

Sang and Hedblom, 2021) and can be conceptualized in three main types of accessibility; physical access, visual access, and symbolic access (Carr *et al.*, 1992). Green spaces that are easy to access are important to reduce the level of stress experienced by some in the urban area and to promote the positive benefits (Ode Sang and Hedblom, 2021).

Physical access

Physical access to an area is determined by distance, barriers, and connection to surrounding infrastructure (Carr *et al.*, 1992; Ode Sang and Hedblom, 2021). Grahn and Stigsdotter (2003) investigated people's health related to their use of urban green spaces and found that the greatest obstacle for people to use urban green spaces every day was time and distance. People living greater distances from green spaces used those spaces much less often and it has also been found that they prefer to live close to forests (Grahn and Stigsdotter, 2003; Olsson, 2006; Fredman, Ankre and Chekalina, 2018). However, Grahn and Stigsdotter (2003) have suggested that time and distance are interrelated and how long it takes to go to a recreation area by foot can be crucial to how leisure time is spent. Boverket (2007) suggests that an inhabitant should have access to a green space within 300 m from their place of residence. Although the true distance between homes and urban green spaces, including barriers such as roads, railroads, and water streams, seems to be unexplored (Ode Sang and Hedblom, 2021). The National Society for Road Safety committee recommends that children under the age of 10 (depending on their stage in development) should not move around roads alone (NTF, n.d.). In areas with low accessibility these children must rely on adults to escort them to green areas. (see Figure 36)

Visual access

Visual access is important to make people feel safe and free to enter a space (Carr *et al.*, 1992). To be able to see what lies ahead in a space, especially when entering, is important for people to feel safe. Clear visibility gives assurance that a space is safe. However, the visual access must be balanced to people's need for privacy and our desire for places that provide shelter and refuge.

Symbolic access

Symbolic access is defined by Carr *et al.* (1992) as a type with cues in the form of either people or design features suggesting who is welcome or not welcome to the area. People, as individuals or as groups, and the design features can be perceived as threatening, comforting, or inviting and thereby affect an individu-

Figure 36. Red bike paths are a way of creating higher accessibility, Wijchen. Elin Fänge

al's willingness to enter into a space. It is the observer that determines if a green space is accessible or not - different areas can be perceived as useful or inviting for different people (Ode Sang and Hedblom, 2021). A very small green space in a neighborhood can for instance be a useful play area for young children, while for adults it is not seen as a green space at all. However, the areas are also affected by surrounding landscapes because if the same area would be separated from the neighborhood by a road it would no longer be accessible for young children.

Aesthetic preferences

The human sensory system is closely linked to our emotions, in which pleasure has a fundamental influence on how we respond to information and stimuli from our surroundings (Gobster *et al.*, 2007). The aesthetics of an environment is therefore important for how people perceive and interpret a place or environment. The visual aspect of an aesthetic experience may be the most dominant component to consider when planning urban areas (Ode Sang, 2003). However, an aesthetic experience also involves other senses as well, such as smell, touch, and sound. For example, birdsong comes across as positive and can lower stress-levels for humans (Alvarsson, Wiens, and Nilsson, 2010; Annerstedt *et al.*, 2013) How an environment is perceived by humans affects the experience of the place, and if it is perceived positively, it is more likely to be revisited (see Figure 37; Gobster *et al.*, 2007). However, if it is negatively perceived it can have the opposite effect, as it can evoke boredom or even destructiveness. It is important to understand how people experience and perceive different types of landscapes as well as what is seen as aesthetically preferable to achieve public support of any landscape change towards an ecological and sustainable development.

Ode Sang (2003) found that visual aspects of urban forests can be reduced to different concepts, such as stewardship, naturalness, complexity, and coherence. Stewardship gives the forest a sense of human touch and a sense of order and care. The contrast to this concept is naturalness, which means that the forest or green space has a feeling of closeness to a preconceived natural state. This concept varies though with people's background and knowledge of nature. Concepts such as coherence and complexity affect the structure, biodiversity, and the density of the forest. A forest with high coherence also has a high complexity whereas the coherence gives structure and order to the complexity.

Figure 37. How an environment is perceived by people affects the experience of a place, and if it is perceived positively, it is more likely to be revisited, Enköping. Ulrika Ebelin

It has been shown that the quality and location of nature is important for HHWB (Hartig and Staats, 2006; Björk *et al.*, 2008; Mavoa *et al.*, 2019; Gramkow *et al.*, 2021) and respondents' preference of the English landscape and dense shrubs, which more resemble natural looking structures (Harris *et al.*, 2018). Another study has shown that respondents felt more of a belonging to nature and restoration following visits to rural and coastal locations and to sites of higher environmental quality compared to urban green spaces (Hartig and Staats, 2006). Being alongside nature is also a way to experience the diversity of nature, even though when answering a study, most respondents who lived in urban areas were unwilling to coexist with many wild animals and plants (Björk *et al.*, 2008). However, their attitudes became more positive through increased interaction with the wild side of nature and old trees. Whereas another study has concluded that natural features in the environment, such as greenness and biodiversity, had a positive effect on HHWB (Gramkow et al, 2021). The results from Barrera-Hernández *et al.*, (2020) study showed that there was a significant relationship between people having a positive connection to nature and their will to act with a more sustainable behavior.

Discovery and Mystery

Discovery is another reason for people to visit urban green spaces as it represents the desire for exploration and stimulation (Carr *et al.*, 1992; Kaplan, Kaplan and Ryan, 1998a). According to Carr *et al.*, (1992) exploration is a human need and forcing people to remain in constrained, empty settings is a form of torture. Discovery in urban settings means that people can observe other people and creatures and their actions.

Adding mystery to a place enhances the desire to explore and to keep moving in the green space as it reveals that there is more to explore (Kaplan, Kaplan and Ryan, 1998a). This hint is very compelling for humans and a landscape can provide such hints in various ways. A simple curved path instead of a straight one often enhances the desire to discover. Mystery has been shown to be a very important factor for a place as it is highly favored by people.

Figure 38. Mystery to a place enhances the desire to explore and to keep moving in the green space, Helsingborg. Ulrika Ebelin.

ANALYSIS AND DISCUS-SION

The shared landscape

The natural landscape has over a long period of time been fragmented by urbanization, agriculture and forest production causing simplified habitats and monocultures (Maxwell *et al.*, 2016; Persson *et al.*, 2020). With the changes of land use and with the challenges of climate change, the importance of keeping areas of nature in urban areas becomes even more important. (see Figure 39) Although urban areas have the potential to preserve nature, urban biodiversity has often been left to evolve on its own. This has resulted in urban areas to favor synanthropic species and not a rich diversity of specialist species nor natural habitats.

The literature has shown that nature and sustainable development are important for HHWB (Grahn, Stigsdotter, and Berggren-Bärring, 2005; Sustainable Development Commission, 2008), however, with population growth, urbanization and densification processes urban areas will face new challenges which will not only have implications for urban inhabitants but also on biodiversity (Haaland and van den Bosch, 2015). It is therefore, in our opinion, important to understand the needs of both humans and biodiversity in urban areas in order to develop in a sustainable way so that both humans and biodiversity can thrive. However, urban areas have in many places been developed with a focus on other priorities rather than focusing on fulfilling the basic human needs or promoting biodiversity (Miller and Hobbs, 2002; Qiu, Lindberg, and Nielsen, 2013; Wild, Henneberry, and Gill, 2017). It is also important to highlight the negative effects that urban development has on both humans and biodiversity, to learn from our mistakes and to do better in the future.

The human motivation theory has been based on the hierarchy of the basic human needs with the physiological needs as a starting point (Maslow, 1943). The physiological needs include the most necessary needs such as food, water and others that maintain a stable state of the body's blood stream. The needs for safety, love, affection, belongingness, esteem, and self-actualization have all strong effects on our mental health, and thereby also our physiological health. When external and internal factors affect us negatively it can cause increased stress, irritation, and a decrease in our ability to concentrate (Grahn and Stigsdotter, 2003; Bengtsson and Grahn, 2014; Hartig *et al.*, 2014). Therefore, basic human needs are crucial for our health and well-being, and that is why it is important to understand and meet humans' needs to integrate nature and biodiversity in urban areas in a sustainable way.

Figure 39. The development in urban areas should prioritize promoting both human needs and biodiversity, Lund. Elin Fänge

Improving urban areas by looking at the natural landscape

Nature's restorative effects

Nature has been shown to have a restorative effect on our health and well-being, through lowering stress-levels, reducing irritation and enhancing our ability to concentrate (Grahn and Stigsdotter, 2003; Bengtsson and Grahn, 2014). It has also been shown that nature has positive effects on our will and ability to exercise (Hartig *et al.*, 2014), but it is not only the perception of nature that is restorative — healthy ecosystems can also contribute to a higher restorative effect (Giusti and Samuelsson, 2020). Peace and quiet in nature are important for children to calm down and the nearness to natural features such as rough terrain, water, shrubs, and trees are the most preferred settings (Beck-Friis, 2003; Jansson, 2008; Ek, 2012; Harris *et al.*, 2018). Urban green spaces provide opportunities for restoration and relaxation, but also interactions with friends, family and neighbors through physical activities and picnics, and thereby contributing to community building (Chen, 2021).

It has been shown that natural structures and features support both active and passive recreational activities (see Figure 40; Chen, 2021). Large trees with low hanging branches, often found growing apart from other trees, can be used by children to climb on, and their leaves and seeds can be used as play props or as material for various crafting. Natural areas have also shown to give more positive effects on psychological restoration and a sense of connectedness than urban settings (Barrera-Hernández *et al.*, 2020). The main structures and features from the meadow, such as high growing herbs and perennials can support social activities such as, picnicking and play. Structures of the English landscape and dense shrubs are preferred over lawns and suburban gardens (Harris *et al.*, 2018). More vegetation, both trees, shrubs, and herbs promote wildlife, such as birds, which in turn will increase the HHWB as natural sounds, such as birdsongs, can have restorative effects (Alvarsson, Wiens and Nilsson, 2010; Annerstedt *et al.*, 2013). However, too much human activity conflicts with the interests of biodiversity as it has negative effects on the vegetation because of wear and tear as well as soil compaction caused by anthropogenic activity. In addition to this, human presence can cause bird species living on the forest ground level to decrease in numbers´ (Mason *et al.*, 2007). It is important to create places that are beneficial to both humans and biodiversity, i.e., structures such as dense vegetation or those found in the English landscape create a synergy between human preferences and biodiversity as many species, such as bats and birds favor these kinds of structures and features. Since both birds and bats are well established indicator species these structures can therefore be important for many more species as well.

Figure 40. Natural structures and features will encourage people to do more recreational activities, Malmö. Elin Fänge

How to integrate biodiversity from the natural landscape into in urban areas

Urban biodiversity has been shaped and formed by many different urban factors, both local and regional, which in turn have affected the variation and composition of species (Persson and Smith, 2014). However, as biodiversity has seldom been included in the development process (Kirk *et al.*, 2021), it has often been left to evolve on its own in the harsh urban conditions where only the most tolerant, adaptable, and vital species and individuals can survive, and therefore allowing generalist species a higher chance of survival (Niklasson and Nilsson, 2005; Persson and Smith, 2014). This has led to a homogenization and fragmentation of habitats and species, and when compared to natural environments urban green spaces are often smaller in size, more susceptible to human disturbances, and they often contain simplified habitats that hold a lower quality. Natural landscapes have also been fragmented for a long period of time causing some species to be isolated and threatened by extinction due to industrialized agriculture and forest production as well as urbanization. Niklasson and Nilsson (2005) also argues that preserving a habitat is often more important than creating a new one or rebuilding a lost habitat - as it can be too late to bring species back to an area. To cope with future challenges the needs of biodiversity from the natural landscape must be preserved and promoted.

Since urban green spaces are usually small in size (Persson and Smith, 2014; Alberti *et al.*, 2020) it can have an effect on what structures can be found there, and an example of this could be a woodland, that with all its different structures and habitats would be hard to fit into a very small area (Niklasson and Nilsson, 2005; Nitare and Skogsstyrelsen, 2019). Therefore, when looking at natural landscapes, the habitats, structures, and elements can reveal how green spaces in urban areas should be designed, but also how urban areas as a whole should be strategically planned to integrate the features of the natural landscape to promote biodiversity.

The perception of safety in green spaces

Feeling of safety and vegetation structure

Woody understories and shrubs are important for biodiversity, and the literature has shown that birds in particular are highly dependent on understory vegetation in several habitats in the natural landscape as well as in urban areas (Jordbruksverket, 2003; Bernes, 2011; Skogsstyrelsen, 2014a). However, Heyman (2010) and Jansson *et al.* (2013) found that for humans' dense vegetation contributes to not feeling safe as it blocks both the view and escape routes, thereby enhancing the feeling of entrapment. Vegetation where the canopy can be raised provides a better overview which increases the ability to escape if something threatening were to appear, which in turn will increase the feeling of safety. (see Figure 41) However, dense understory vegetation and larger trunks that enhance darkness during night are often perceived as unsafe as they block the view (Blöbaum and Hunecke, 2005; Boomsma and Steg, 2014). Open areas on the other hand (e.g., mowed lawns) provide visual overview and an ability to escape, thereby increasing the feeling of safety (Boomsma and Steg, 2014). Unfortunately, these monoculture grass lawns are not great areas to support biodiversity (Borman, Balmori and Geballe, 2001). However, this is not in line with the results that Harris (2018) had in his study where he concluded that dense shrubs are preferred over lawn areas. Perhaps, many lawns could be turned into meadows with flowering herbs and perennials to create a synergy to the human need of safety and overview, and thereby promoting a diversity of species.

Figure 41. Open areas like a wooded meadow/pasture allow for a clear overview and a place for a long term in management continuity by grazing of mowed surfaces, Lund. Ulrika Ebelin

The effects of artificial lights

All species are dependent on the natural day and night cycle in which the light from the sun regulates the levels of melatonin that influence the biological rhythms in living organisms (Grose and Jones, 2021). However, at night urban areas are filled with blue LED-lights disrupting the production of melatonin. The artificial lights have fragmented the dark landscape in urban areas affecting the daily rhythms and seasonality of both animals and plants as well as behavioral patterns of both nocturnal and diurnal species. The changes in behavioral patterns can result in insects, bats and birds flying around a light source for a whole night leading to exhaustion or even death. However, this effect has also been shown to have a positive effect for some animals as the insects flying by light become an easy food source. Spoelstra *et al.*, (2017) has shown that red lights promote nocturnal species more than white or green lights. This could imply that by switching the color of lights to red in urban areas could decrease the fragmentation among nocturnal species and thereby restore the natural rhythms of night and day.

A well-lit path can, from a human perspective, increase the feeling of safety as it gives a clearer overview of an area (Blöbaum and Hunecke, 2005; Olsson, 2006; Madge, 2008; Jansson *et al.*, 2013). It is also important for humans who are diurnal mammals, to prolong the day and to feel safe during the night. The problem is that LED lights today have very blue lights and are not beneficial to biodiversity nor humans (Grose and Jones, 2021). This is because many insects, birds and mammals are active during the night and have adapted to the darkness. Further, urban green spaces today are very small in size (Persson and Smith, 2014; Alberti *et al.*, 2020) which could result in many of those surfaces being completely lit up. A larger area would allow fewer areas to be disturbed by humans and lights, and by choosing one or two main paths to be lit up it could leave other paths unlit and decrease the risk of disturbing the natural rhythm of species (Grose and Jones, 2021). These larger areas would thus contain more areas that would not be disturbed by humans, hold a higher variety of habitats, species, as well as the number of individuals of both plants and animals (Diamond, 1988; Mason *et al.*, 2007; Bonthoux *et al.*, 2014; Persson and Smith, 2014). (see Figure 42)

Although lighting at night is often associated with positive feelings and safety for humans, when the light is blue it can disrupt the melatonin levels in humans as well as in other species. Therefore, by changing the lights to red, it could result in improved sleep patterns of humans. However, this could conflict with the human perception of safety as the color of red often indicates danger and thereby it can enhance the feeling of unsafety. It is therefore needed to balance the light and choose carefully when and where to promote biodiversity through the color of the light, and where to enhance the perception of safety for humans.

Figure 42. Lighting central paths will allow people to move around and on them and at the same time leave areas where darkness can be, Lund. Ulrika Ebelin

Movement, recreation and connectivity

Connectivity — a mosaic of habitats

Fragmentation of the natural landscape caused by urbanization and the monocultural landscapes of both forest and agricultural production (Alberti *et al.*, 2020) has led species to become isolated and threatened as they have had little chance of moving to other habitats to maintain gene flow (Niklasson and Nilsson, 2005). In urban areas the connections between green spaces and the surrounding landscapes are strongly affected by urban structures acting as barriers, such as roads, highways, and railways, for both people and animals (Alberti *et al.*, 2020) Many mobile animal species, e.g., birds, amphibians, reptiles, insects, and mammals are dependent on certain combinations of habitats within a landscape matrix (Jordbruksverket, 2003). One habitat can serve as a place for nesting, another for food supply and a third for reproduction, and if one is cut off it can result in species becoming threatened or even extinct (Douglas, 2021). The green corridor has been formed as a response to this fragmentation process and can serve both as a connection between habitats but also form a habitat in itself.

While investigating the natural landscape we found that a diversity of habitats is one of the most important factors for biodiversity as species have over thousands of years adapted to different conditions, structures, and food availability (Diamond, 1988; Niklasson and Nilsson, 2005; Sveriges miljömål, 2021). Weiss and Sjöberg (2018) argues that it can be a challenge for many insects to find water, food, and reproduction sites as they may have difficulties to move over larger areas without any place to rest. Urban areas are filled with large amounts of hard surfaces and fragmented green spaces, which makes green corridors very important for e.g., insects. Bumblebees are one example as they can only be active in the air for about 40 min before they need to fill up their energy supply (Weiss and Sjöberg, 2018). Since urban green spaces often are low in quality and may only consist of one or a few elements of vegetation, many species will have difficulties to find resources for both food, shelter, and reproduction sites. It is therefore important to increase the variety of habitats in every green space so that more species can thrive. Creating more natural habitats would also promote endangered and threatened species.

The edge zone is the most occurring landscape element in urban green spaces (Persson and Smith, 2014) and serves as transition zones in both the natural and urban landscape (Herlin, 2001; Persson and Smith, 2014; Skogsstyrelsen, 2014a, 2014b). Edge zones in urban areas are characterized by species that can adapt to human disturbances. In the natural landscape it serves as a buffer against disturbances, provides shelter, food, corridors for movement, and spreading for different kinds of creatures (Herlin, 2001; Wiström, 2014). An edge zone should according to Nilsson (2017) have a crown level gradually increasing in height from an open area to a closed forest structure including elements such as herbs, shrubs, small and larger trees as well as piles of deadwood and leaves to favor conditions where insects and smaller mammals thrive. Birds often favor forest edges facing the sun with a lot of fruit-bearing shrubs as they provide both a dense shelter and food supply (Skogsstyrelsen, 2014a). Hedgehogs are another species that thrive in edge zones as it is a habitat that contains elements such as deadwood, leaves, and shrubs in which the hedgehogs can nest in and find insects to eat (Dacke, 2021). In addition to this, it can also serve as a green corridor as they both usually contain the same habitat/structure serving as a transition and at the same time be used as a design element to create and enhance connectivity. The gradually increasing vegetation structure can also create the base of green corridors blocking out traffic and sheltering both humans and animals on the move.

Further, a web of connection is not only important on a large landscape scale, but also on a smaller scale such as the connection between gardens. Hedgehogs that have found a new habitat in gardens as their original habitat has been lost to modern agriculture are now threatened by things such as grass mowers, pesticide that kill insects, and fences that stop them from moving between gardens resulting in them being driven over by cars (Dacke, 2021). The habitats that have been presented in the literature can vary in different scales, structures, and connections, but also in forms from e.g., wet to dry meadow (Jordbruksverket, 2003) or wet to dry woodlands (Nitare and Skogsstyrelsen, 2019) and this makes it very hard to always choose what is good for biodiversity overall. However, the literature has shown that a mosaic of habitats (Nitare and Skogsstyrelsen, 2019; Sveriges miljömål, 2021) in a web of connections (Weiss and Sjöberg, 2018; Douglas, 2021) are important for a greater diversity of species. We believe that in urban areas this can be implemented through a variety of urban green spaces where relevant habitats are represented and connected by green corridors. By doing this it would also be in synergy with the human need for accessibility as humans themselves are not benefited by barriers. It should be in the interest of both humans and biodiversity that the number of barriers in urban areas are minimized to increase the movement and connectivity. It is also important to look at a smaller scale, e.g., gardens and what certain animals, such as hedgehogs need to move safely around. Their need to move safely between areas can be achieved by e.g., making holes in fences between gardens.

Accessibility

Green spaces and nature have several positive effects on HHWB, however the physical access to urban green spaces plays a crucial part in the frequency of visitations and thereby also the general HHWB (Grahn and Stigsdotter, 2003). Time, distance and barriers are the main obstacles for people that want to access green spaces, and even though green urban spaces are likely to have a positive influence on people's physical activity, those living at greater distances from green spaces tend to use them much less often. The presence of trees, shrubs, flowers, and water in a synergy with natural sounds and serenity increases the effects of both passive and physical activity, which in turn increases HHWB. To increase frequency in visitations to urban green spaces the green infrastructure becomes very important as the natural features can influence people to walk and bike rather than use other transportation modes, and thereby influence the HHWB by increasing the physical activity and decreasing the amount of polluted air. This is in synergy with connectivity such as green corridors that promote biodiversity. (see Figure 43)

Various sorts of vegetation, such as the woody understory, high growing herbs, and perennials as well as features, such as deadwood and bare soil, can conflict with the accessibility to a place as it can decrease physical access. This can especially affect people that have difficulties in moving around as they can create physical barriers and increasing distances. Dense and thorny shrubs are important for many diverse species, not least for smaller birds as hiding and nesting places as well as a source of food (Jordbruksverket, 2003; Bernes, 2011). For humans to enter an area it must be inviting (Carr *et al.*, 1992; Ode Sang and Hedblom, 2021), meaning that the vegetation needs to display symbolic access and not obstruct the view too much. Flowering herbs and perennials however provide both a good overview and can have a positive effect on the symbolic access, inviting people to visit an area. Areas with varied and inviting vegetation can be in synergy with the human need to discover and explore as it lures people into the area and awakens their will to explore what the area has to offer. This also implies that the vegetation to some extent obscures the view and creates a bit of mystery.

Figure 43. Connecting green areas with each other allows for more exposure to natural environments, Wijchen. Elin Fänge

Physical activity and green corridors

Green spaces have been shown to influence people's choice of transportation and as natural features can encourage people to increase their physical activity, a green corridor with walking and bike paths could encourage walking and cycling (see Figure44; Olsson, 2006). Olsson (2006) found that adding bike and walking paths also increased inhabitants' will to use them for transportation rather than other using transportation modes, such as a car, and by integrating bike and walking paths in the green infrastructure could thereby have several positive effects. As green corridors can be used for the movement and dispersal of flora and fauna (Douglas, 2021), they are in synergy with a human's need for recreation and physical activity. In addition to serving as a pathway for species to spread between different green patches, the corridor can also offer habitats, shelter, and food supply. However, according to Douglas (2021), the fundamental issue when assessing green corridors is to define for whom and/or what types of species the corridor is to be designed for. To design green corridors or green infrastructure with a certain purpose, e.g., to promote walking and cycling, will therefore be an important design tool to promote both biodiversity and human needs. (see Figure 45 and 46, p 75)

However, all human activity has more or less negative effects on different species, depending on how vulnerable species are to human disturbances, e.g., walking and biking can have detrimental effects on birds living in the shrub layer (Ballantyne and Pickering, 2015; Thompson, 2015). Still, many bird species living in urban areas have displayed a decrease in flight initiation distance which means that they are more adapted to regular human disturbances, and this may already promote synanthropic species (Tryjanowski, Morelli, and Møller, 2021). Humans move mainly along paths and if there were to be paths throughout the whole width of the corridor it would not provide suitable habitats for many animals because of the regular disturbances which would emerge (Diamond, 1988; Bonthoux *et al.*, 2014). Green areas without any paths for humans to use could provide higher levels of biodiversity in an area, but also higher levels of endangered species that according to Alvey (2006) also has been found in urban forests. Creating more space for biodiversity in combination with human movement, through e.g., a green corridor, would create more encounters with natural features and sounds, such as birdsong, and therefore increase HHWB (Alvarsson, Wiens, and Nilsson, 2010; Annerstedt *et al.*, 2013).

Figure 44. Converting a country road into a bike path is a great way to promote biking, Wijchen. Elin Fänge

Figure 45 and 46 Green corridors can increase people's will to bike and walk to places, Malmö-Lund, Elin Fänge-Ulrika Ebelin

The size of green spaces matters

People living in large, densely populated urban areas are at a greater risk of reduced mental health than people in smaller urban areas, and mental disorders are much higher in urban areas than in rural areas (Ode Sang and Hedblom, 2021).

The literature has shown that the size of a green space is important for the diversity in both the urban and natural landscape. Since many urban green spaces are small, they are at risk of not being able to house many species (see Figure 47; Bonthoux *et al.*, 2014; Alberti *et al.*, 2020). However, the larger the area is, the more variety of habitats, species, as well as number of individuals it can harbor (Diamond, 1988; Bonthoux *et al.*, 2014; Persson and Smith, 2014). Larger areas can provide more resources and because of the larger distances the impact from human activity decreases and if it is large enough it could even harbor almost totally undisturbed areas, which some species need (Bonthoux *et al.*, 2014; Persson and Smith, 2014). The width of a green corridor is important for e.g., bird species nesting on the ground level as they are easily disturbed by human activity and therefore need enough space to avoid humans (Mason *et al.*, 2007). The quality and connectivity within these areas are also important factors for species that have difficulties moving over larger areas without any resources they can benefit from. Increased numbers of species and healthy ecosystems are in synergy with humans' psychological benefits to both biodiversity and healthy ecosystems (Fuller *et al.*, 2007; Giusti and Samuelsson, 2020).

Corridors and edge zones are great ways for humans to experience nature but to continue to provide these experiences it is important that the needs for biodiversity are also met so that the natural environment can persist. It has been shown that the width of a corridor is important and that it should not be less than 300m (Mason *et al.*, 2007), which should also be relevant to small green spaces in urban areas (Persson and Smith, 2014; Alberti *et al.*, 2020) that are less than 300m in width. Corridors and edge zones can be found in the natural landscape where transitions between forests and open land occur, and they consist of elements from both the closed forest and the open land (Skogsstyrelsen, 2014b, 2014a). It is not only the width of the corridor (Mason *et al.*, 2007) that is important but the structure and elements within it (Herlin, 2001; Skogsstyrelsen, 2014a; Nilsson, 2017; Dacke, 2021). For instance, the more paths there are in an area the more human disturbance there would be (Hartig *et al.*, 2014). Birds are great indicator species because of their mobility and the fascination of them with the common man (Heyman, 2010), and since it has been shown that ground dwelling birds are sensitive to human disturbances (Mason *et al.*, 2007) they can indicate a decrease in other groups of species. Creating wider green areas and corridors could lead to certain areas to be free from human disturbance and then allow areas where ground dwelling birds can thrive, and thereby also other species connected to those birds.

Figure 47. Small places do not allow a lot of variety, Malmö. Elin Fänge

Climatic conditions and human comfort

Climatic conditions

The climatic conditions in urban areas can vary greatly depending on the geographical location, meteorological conditions, number of hard surfaces and anthropogenic activities that generate heat and greenhouse emissions (Grimmond, 2021). Temperature and humidity have shown to have the largest effect on the composition in plant communities resulting in that the urban flora holds a higher share of drought-resistant plants due to the more rapid rainwater runoff, hard surfaces, and higher temperatures (Naison *et al.*, 2011; Bonthoux *et al.*, 2014; Sjöman and Slagstedt, 2015). Some species thrive in urban areas as they can benefit from the resources at hand in an efficient way (Chatelain and Szulkin, 2021). However, many species and particularly specialist species, are not adapted to live in these conditions (Bonthoux *et al.*, 2014; Sjöman and Slagstedt, 2015). The urban climatic conditions affect attributes such as the growing season, and thereby also food availability through longer seasons as well as by anthropogenic influences providing more food for many species.

In the natural landscape where a higher diversity of specialist species is present the climatic conditions are stable, although a larger variety between the habitats exist (Jordbruksverket, 2003; Niklasson and Nilsson, 2005; Nitare and Skogsstyrelsen, 2019). In open habitats, such as meadows where butterflies are one of the main indicator species groups among insects, it is important to have warmth and sunlight for butterflies to thrive but also shade when temperatures are very high (Jordbruksverket, 2003). However, for their larva to have a successful development, more humid conditions are required, which can often be found among leafy vegetation. In half open and closed habitats, such as wooded meadows and woodlands, the main indicator species groups are lichen, mosses, and fungi, which favor stable microclimatic conditions and equalized temperatures (Nitare and Skogsstyrelsen, 2019). On the other hand, the climatic conditions can vary greatly in edge zones, thereby affecting the species composition and vegetation structure (Jordbruksverket, 2003). In the natural landscape the different habitats are often interlinked which make it possible for species to move in between (Douglas, 2021). The urban landscape on the other hand is filled with barriers and built areas separating green spaces and habitats from each other. Furthermore, when green spaces hold a lower quality the variation of habitats become even more sparse — the climatic conditions can become extreme. With the increasing urbanization and the effects of climate change, urban areas are facing new challenges (Naison *et al.*, 2011). Drought and extreme weather with an increased number of hard surfaces may decrease water and food availability conditions in urban areas. Nevertheless, green spaces with a higher quality of vegetation, e.g., plantings where trees and shrubs are combined, can have a strong effect on the climatic conditions by reducing winds, providing shade, and contributing to stable humidity and temperatures (Sjöman and Slagstedt, 2015). Greenspaces with a variation of vegetation, where open, windy, and sunlit areas are interspersed with vegetated areas, providing shade, wind, and higher humidity, enable species from both open, half open and closed habitats to thrive within the same area.

Urbanization has led to an increased number of hard surfaces in urban areas and cities (Myndigheten för samhällsskydd och beredskap, 2017). Combined with the modernization and industrialization of urban areas it has also led to extremely efficient stormwater systems where the goal is to transport stormwater from the hard surfaces to the nearest recipient or water treatment plant as fast as possible (Sjöman and Slagstedt, 2015). Further, during the last decade the frequency and severity of heavy rainfall and flooding have increased in urban areas causing more areas to become flooded, which is one of the most critical and costly problems city planners are facing (Naison *et al.*, 2011). It is important to create more surfaces that water can infiltrate through, i.e., creating less hard surfaces and more vegetated. Vegetated surfaces are also a great way of slowing down the water and allowing it to infiltrate the ground and halting nutrients and minerals from being transported away (Ashman and Puri, 2002). Many of these vegetated surfaces can store water in the ground with the help from mycorrhiza but also without.

The effect of green structures on human comfort

Just as the physiological needs are important to satisfy other needs such as safety and esteem, in urban areas comfort is needed for the physiological needs to be met. Comfort includes the need for sheltering from weather and wind, a cooling shade during warmer periods, and during the colder seasons. Deciduous trees can satisfy both sheltering from weather and wind as well as give a cooling shade during warmer periods, which become more important with climate change and extreme heat events (Sjöman and Slagstedt, 2015). Because trees can supply a cooling shade, they also provide shade in both green spaces, streets, and other urban areas. Trees that form a covering canopy have the ability to hold moisture, therefore creating climatic conditions that certain species prefer (Nitare and Skogsstyrelsen, 2019) and the shade is beneficial to many species, and especially indicator species in the natural landscape such as lichen, mosses, and fungi. This is a strong synergy that is beneficial to humans as it provides shade. (see Figure 48)

Forests can contribute to maintaining the temperature in houses when they grow next to buildings as they obstruct strong winds in the winter and shade the facade during the warm summer months. The vegetation in the forest would also be a great way of storing carbon dioxide and cleaning the air from pollutants (Niklasson and Nilsson, 2005; Sabelström *et al.*, 2017). Older and younger trees, when densely planted together help in different ways, younger trees are better at filtering carbon dioxide in the air, while older trees are better at collecting dust and buffering acid rain (Pugh, 2020). During the summer deciduous trees are best at storing carbon dioxide as they produce leaves that fall to the ground, thereby with time, the carbon will be stored in the soil, mitigating the effects on climate change (National environmental treasure, n.d.; Sabelström *et al.*, 2017). However, in winter coniferous trees are much better at filtering the polluted air since deciduous trees are inactive, and that is why it is important to have a mixture of both. Areas where leaves cover the ground act as a lid keeping the ground wet and moist (National Environmental Treasure, n.d.), making it important that stewardship and management regimes do not remove leaves and irregular vegetated surfaces as this can disrupt the water balance in the ground affecting microorganisms. Hereby it can be motivated that both leaves on the ground and vegetated surfaces are important for both flooding and the hydrological balance in the ground. Vegetated curtains should be strategically placed so that pollutants and particles carried by the wind can to

Figure 48. Trees and woodlands close to buildings insulate them from coldness in winter and warmth in summer. This keeps down heating and cooling costs. They also prevent air pollutants from coming into people's homes, Malmö. Elin Fänge

some extent be controlled and directed up and away from the streets, decreasing the amount of polluted air (Sjöman and Slagstedt, 2015). This is a conflict, as there are not many lichen and moss species that can survive on acidic polluted surfaces on the bark of the trees, it is therefore important to have trees that can house lichen and mosses further away from trafficked areas (Niklasson and Nilsson, 2005). It is also further recommended to plant both shrubs and trees together in several rows, where deciduous and conifer species are combined to create the most optimal conditions for reducing the wind all year around.

All of the previous things mentioned act as ecosystem services as the forests filter unclean air and regulate extreme temperatures that further create better environments for both humans and biodiversity (Sabelström *et al.*, 2017; Nitare and Skogsstyrelsen, 2019). If more trees were to be planted many human health problems, such as risk of cancer, inflammation, and lung diseases, would decrease (Sabelström *et al.*, 2017; World Health Organization, 2021). It would also have a positive effect on the neurological development, respiratory tracts, and increase the lung capacity in infants and children — who are very vulnerable to air pollutants (Sabelström *et al.*, 2017; Grimmond, 2021; World Health Organization, 2021). Areas in the urban environments would also contain fewer allergens as the trees can trap polluted air and thereby become safer places for humans (Kuo and Sullivan, 2001; Maas *et al.*, 2009; Gatersleben and Andrews, 2013b; Pataki, 2021). Planting more trees and forests in urban areas would thereby be in synergy with the needs humans have for recreation and accessibility (Sjöman and Johansson, 2011; Sjöman and Slagstedt, 2015; Grimmond, 2021). Habitats that would possibly cope in these environments would be woodlands dominated by beech, pine woodlands, and/or acidic meadows. It is important to keep in mind that biodiversity is complex (Weiss and Sjöberg, 2018) and one should reflect if a habitat should exist close to trafficked roads or if it should have a buffer of vegetation protecting habitats that contain species such as lichen, mosses and fungi, as it has been shown that air pollutants from traffic can have a negative effect on these species (Niklasson and Nilsson, 2005). The protecting layer of vegetation could also decrease other disturbances than air pollution, and at the same time form corridors or edge zones promoting urban exploiters/generalist species instead (Herlin, 2001; Wiström, 2014).

As pollution from vehicles and other anthropogenic sources are not good for either HHWB or biodiversity the levels of pollutants must decrease. A solution would be, as described more thoroughly above, to use vegetation as a barrier and a filter for areas where people and fragile habitats are present.

Aesthetic preferences

Stewardship and cleared vegetation

Stewardship gives a place a sense of the human touch, order, and care but most importantly, as it can create areas that help humans perceive the place as safe (Kuo and Sullivan, 2001). The concept of stewardship is to the human eye clearly built on anthropogenic influences, while the attributes of the concept of naturalness is perceived to have been shaped by natural processes, even though it may not be the case. Ode Sang (2003) argues that by enhancing the attributes of stewardship the naturalness will decrease, and by enhancing stewardship, the human touch, order, and care increases. The concept of coherence provides order to the naturalness and the concept of complexity, which may appear as unkempt and chaotic. According to Giusti and Samuelsson (2020) the perception of healthy ecosystems has high restorative effects. A healthy ecosystem is logically diverse in species and structures, thereby the concepts of both complexity, coherence and naturalness would be high in those ecosystems. This is in synergy with the needs humans have for complexity, coherence, and naturalness as these have restorative effects.

Clearing vegetation to create a clearer view is an example of stewardship and according to Heyman (2010) it may not have an effect on bird populations — and since birds are a group of indicator species it could be relevant for other species as well. Mason *et al.* (2007) suggests that even when there are shrubs along walking and cycling paths that screen human activity from the rest of the woodland, it can minimize the amount of bird species living on the forest ground level. If all vegetation along paths would be cut down to create a better overview and increase the feeling of safety, the need for discovery and mystery would decrease (Carr *et al.*, 1992; Kaplan, Kaplan and Ryan, 1998b). Although this would have been beneficial for humans from a perceived safety perspective, it will have devastating effects on birds living in the shrub layer.

It is also important to understand that by enforcing stewardship, such as cutting up bushes along paths will result in natural structures being lost. By doing that the values nature provides humans would be lost — values that otherwise have shown to be beneficial to HHWB (Ulrich, 1983; Carr *et al.*, 1992; Beck-Friis, 2003; Grahn and Stigsdotter, 2003; Dyment, 2005; Hartig and Staats, 2006; Jansson, 2008; Björk *et al.*, 2008; Alvarsson, Wiens and Nilsson, 2010; Lucas and Dyment, 2010; Annerstedt *et al.*, 2013; Hartig *et al.*, 2014; Jansson *et al.*, 2014; Mavoa *et al.*, 2019; Barrera-Hernández *et al.*, 2020; Ode Sang and Hedblom, 2021; Gramkow *et al.*, 2021). Ode Sang also points out that what is seen as stewardship and what is seen as naturalness depends on people's background and preferences. Some people prefer nature — others do not (Hofmann *et al.*, 2012; Rosa, Profice and Collado, 2018), and that is probably what makes places so different today when defining what the concept of stewardship is.

The literature has shown that natural elements are very positive for both our physiological and psychological health and should therefore be promoted in urban green areas. Still, the concept of stewardship contributes to the feeling of safety, which in turn is one of the basic human needs and by making places feel unsafe it will therefore also affect HHWB negatively. However, urban green spaces need to also be designed for biodiversity, e.g., through creating places where birds, and species connected to them, can thrive. For this to happen areas with vegetation need to be dense and exist in various heights, even those that obstruct the view for humans. A solution to this would be to create an area that contains structures and features in synergy with both safety and mystery. Since safety affects the will to enter an area the main paths should allow an open site, e.g., a meadow at a certain width that humans feel safe in. Further away, in the middle or in a corner of the green space there can be a place for mystery with a small woodland or edge zone where humans can choose whether to walk into it or not. It is important to note that the area must be big enough for human disturbance to not affect the species.

Vegetation structure and natural elements

Vegetation does not only form a foundation for ecosystems and habitats (Jordbruksverket, 2003), it is also used as a design element in landscape architecture as it forms the floor, walls and roof in an outdoor environment. Grass, herbs, and other low growing plants constitute the floor; higher perennials and shrubs form the walls together with the woody understory, while the large trees create a sheltering roof protecting creatures from both rain and sunlight. Other natural elements such as deadwood, stones and cairns can be used by designers as interior/furnishings decorating the "room" and at the same time creating prerequisites for biodiversity to thrive. According to Wiström (2014), forest edge zones can be used in landscape architecture as a landscape element as it creates, defines rooms and spatiality. In urban areas it does not only create a transition zone between the built areas and green spaces, but it can also be used as an element defining rooms and spatiality as well as blocking out disturbances. Structure and features, such as those presented in the appendix can, with creativity, be used in many ways.

The floor

Free growing grass and flowering herbs are a common feature in meadows where it is usually cut once or a few times a year, and/or grazed by domestic animals, creating specific conditions where a diversity of many species can thrive (Jordbruksverket, 2003). The meadow is a habitat and ecosystem that has evolved together with humans as we have for a long time cultivated the land, thus creating a rich abundance of flowers that many species can thrive on, both plants and animals — unlike in mowed grass lawns (Borman, Balmori, and Geballe, 2001). Flowers provide shelter, mating spots and food supply for various insects (Weiss and Sjöberg, 2018), which in turn becomes food for larger animals such as birds and bats (Jordbruksverket, 2003). The species composition in the meadow is determined by which time during the season the management regimes are implemented and to which intensity. Having free growing grasses and herbs in urban green spaces could benefit the diversity of species in that area, while at the same time it could lower maintenance costs as it only needs cutting once or a few times a year (Jordbruksverket, 2003), unlike a mowed lawn that needs maintenance at least once a week and it never blooms. Mason *et al.*, (2007) also found that bird species were sensitive to habitats on the ground level being mowed. By decreasing the number of mowed surfaces more birds nesting on the ground can thrive. This conflicts with the monoculture mowed grass lawns created in the 60's and 70's that have led to detrimental effects on biodiversity (Borman, Balmori, and Geballe, 2001) as they have little to no variety in vegetation at all. Boverket's (2007) recommendation is that residential areas should not only consist of lawns, but they should also contain more natural elements and that developers and municipalities should be encouraged to design green areas that benefit biodiversity.

Leaves from deciduous trees that have fallen to the ground supply the ground with humus, and it can also be used by mammals, birds, amphibians, and reptiles as material for overwintering habitats and nesting (National environmental treasure, n.d.; Jordbruksverket, 2003). The leaves also help prevent early growing vegetation and therefore the need to remove unwanted plants decreases. Worms are important in the creation of humus as they in the process of pulling down the leaves into the ground they kickstart the decomposition stage (National environmental treasure, no date; Ashman and Puri, 2002). It is important to not compact the soil layer as it makes it hard for the worms to dig. Thus, by leaving leaves on the ground in urban green spaces the humus and soil conditions improves, as well as improving conditions for many animals. This creates a synergy by mitigating climate change but a conflict as it decreases the sense of stewardship. (see Figure 49)

The walls

The woody understory, shrubs and small trees form walls in the outdoor environment defining rooms and spatiality (Jordbruksverket, 2003; Wiström, 2014). In addition to this it also has many important ecological functions as this vegetation is important for e.g., birds nesting, insects foraging, and mammals seeking shelter (Jordbruksverket, 2003). Thorny shrubs protect smaller birds from predators, and smaller plants from being grazed away. According to Bernes (2011) the number of birds, butterflies, and bumblebees increase with the number of trees and shrubs as long as the canopy layer does not exceed over ten percent of the surface. This shows that many species thrive in areas with a combination of both open and closed vegetation. In the open areas they can find warmth, food, and sunlight while in the more densely vegetated areas they can find protection from both weather, wind, and predators. The meadow can in this case be both a synergy and a conflict with human needs, as humans can perceive it both as beautiful and untidy, as well as shrubs can both be perceived as unsafe but other times be preferred by humans (Harris, 2018). Formed after safety and aesthetic preferences that do not support biodiversity. A solution to increase stewardship would be to by forming the shrubs, but still keeping the traits of naturalness by letting grass and herbs grow more freely, or the other way around.

The roof

Different trees and shrubs provide shelter and food for many insects, birds and mammals in their bark and foliage (Jordbruksverket, 2003; Weiss and Sjöberg, 2018). Generalist species are usually found on younger trees, which in contrast to older trees have very little structural diversity with their weak, smooth trunk and branches (Nitare and Skogsstyrelsen, 2019). The structure and texture of a tree gets more complex and diverse with age, creating conditions for a larger diversity for species to inhabit. Some species are more dependent on deciduous trees and others on conifers, which is the case for e.g., the diverse group of indicator species representing lichen, mosses, and fungi. This group of species are favored by stable environments and old trees as most lichens are limited to only growing on trees that are older than 150 years, as the bark on those trees have a lot of texture (Niklasson and Nilsson, 2005). It is mainly the pH-level in the bark that determines which species grows on different trees.

According to Bernes (2011) and Hartel, Plieninger, and Varga (2015), large old trees are also a key structure and habitat for many species in the natural landscape and a common feature in both wooded meadows, woodlands, and edge zones. Older trees have usually sustained many types of damages leaving the inner part of the trees exposed and as a response to the damages the trees start to produce sap (Niklasson and Nilsson, 2005; Nitare and Skogsstyrelsen, 2019). Both sap and the exposed inner wood attracts many species, especially insects such as beetles, but also birds and bats can live and thrive in the cavities of old trees (Jordbruksverket, 2003; Nitare and Skogsstyrelsen, 2019).

Figure 49. Leaves on the ground and vegetated surfaces are good for biodiversity and at the same time it keeps moisture in the ground, Kävlinge. Elin Fänge

The continuity of long-term management practices of trees is therefore also of great importance for both the structure and habitats, e.g., pollarding can lead to hollow trees which are an important habitat and shelter for both insects, smaller birds, and predators such as owls (Nitare and Skogsstyrelsen, 2019). However, Nitare and Skogsstyrelsen (2019) argues that the main component in exposed inner wood — the mulm — is in shortage today. One of the major factors to the shortage of deadwood could be that old trees are a rarity, especially in forests of production as these forests have the purpose to produce timber that is harvested before it reaches the age of 60- 80 years old. Although, the conflict that occurs in the urban landscapes is that older trees with damages can be seen as unsafe as to humans, e.g., their branches can fall off.

Older trees and habitats with long continuity are rare in urban landscapes as many of those areas are relatively young. In some cases, an old tree may still be present but the environment around it will have been lost to a more modern park with mowed grass around it (Niklasson and Nilsson, 2005). Urban areas may still have many old trees, but it is important to understand that the species that are connected to the tree need other habitats to find shelter, food, and reproduction sites. Further, the shade from the tree can shade other vegetative species as well as other elements such as deadwood, damaged wood, trunks, and roots etc., which many indicator species need (Nitare and Skogsstyrelsen, 2019). The leaves shed by deciduous trees can help store carbon dioxide in the soil and further provide other sources of shelter, food, and reproductive area for many species (National environmental treasure, n.d.). It is thus important that the leaves are left on the ground and not cleaned away due to stewardship. (see Figure 50)

Other natural elements

Deadwood in different sizes, shapes and forms has proven to be very important for biodiversity as it provides habitats, shelter, and food supply for a wide range of species ((National environmental treasure, n.d.; Leonardsson and Götmark, 2015; Weiss and Sjöberg, 2018; Nitare and Skogsstyrelsen, 2019). Further, different species are connected to different types of deadwoods, e.g., different species of insects, lichen, mosses, and fungi are bound to different stages of deadwood. Some need standing deadwood in direct sunlight, others need almost fully decomposed deadwood while others need half-fallen trees resting on another for centuries. Standing deadwood in direct sunlight is probably the type of deadwood with the highest value

Figure 50. Older trees in urban areas can be seen as unsafe as damaged trees have a higher risk of falling and destroying property and hurting people, Barcelona. Elin Fänge

for biodiversity as they provide both warmth, shelter, and food as well as cavities (Weiss and Sjöberg, 2018). However, Nitare and Skogsstyrelsen, 2019 argues that it is the variety of different stages of deadwood that is most important to preserve and promote. Leonardsson and Götmark (2015) found that when a woodland was present in an urban area it often contained higher amounts of both deciduous trees and deadwood than the average rural forest and argue that this makes them potentially more important for conserving biodiversity than the rural forests. Urban green spaces are, however, in comparison to natural environments, often small in size, hold a lower quality, are exposed, and often contain simplified habitats (Persson and Smith, 2014; Alberti *et al.*, 2020). Further, Sweden's landmass is dominated by monocultures of spruce and pine due to the forest production (Skogs Industrierna, no date; SLU Institutionen för skoglig resurshushållning, 2020), which makes the results from Leonardsson and Götmark's (2015) study questionable. The comparison they make is between the rural forest (which often contains monocultures with little deadwood) and woodlands in urban areas — had the comparison looked at natural woodlands their result would have been different. However, their argument about preserving nature in urban areas is still important if the forest production system continues to mainly grow monocultures of only two species.

Other natural elements that are important for promoting biodiversity are stones and cairns, which can benefit especially birds, but also amphibians and reptiles (Jordbruksverket, 2003). They are often used by birds for overlooking an area while amphibians and reptiles use them more for shelter and nesting as well as basking in the sun. As children like to climb on objects (Jansson, 2008) they will most likely climb on the stones and cairns, which will not benefit birds, amphibians nor reptiles as they do not prefer human disturbance (Hartig *et al.*, 2014; Persson and Smith, 2014; Ballantyne and Pickering, 2015; Thompson, 2015; Alberti *et al.*, 2020).

Exotic and native species

It has been found that people who grow up close to nature tend to prefer natural structures and elements (Hofmann *et al.*, 2012; Rosa, Profice, and Collado, 2018)), although Kowarik (1990) argues that humans have long had a strong fascination of exotic species (Kowarik, 1990). However, exotic species could both contribute to a sense of naturalness, but it could also increase the sense of stewardship and thereby affect the perception of natural structures. Exotic species are frequently used in private gardens and public parks for aesthetic purposes as they can e.g., display more elusive autumn colors (Plantagen, no date; Blennow, 2002; Sjöman and Slagstedt, 2015). According to Bonthoux *et al.*, (2014) it is estimated that out of all the species that were found in urban parks worldwide, 40% of them consisted of exotic species. Exotic species that have been planted in people's gardens have spread into urban forests where they often have had a negative effect on composition of native species in the forests (plants, birds, mammals, and insects) (Kowarik, 1990).

Alvey (2006) highlights that in order to increase the natural quality of urban forests and other green spaces, the need for addressing the issue with homogenization is important. This is because exotic species should not be able to disturb the ecosystem created by native species as they have the potential to throw off the balance in native ecosystems and become invasive (Harkawik, 2021). Invasive species can outcompete native species and dramatically change the structures of forests. Native species, both plant and animal, have over a long period of time developed to coexist with each other in several connected ecosystems and thereby formed a balance. Native species have also shown to better support each other as they have evolved in these supporting ecosystems.(see Figure 51). However, Sjöman *et al.*, (2016) advocates the usage of both native and exotic species in urban areas to eliminate the risk of spreading pests and diseases, and even though some exotic species can be invasive it could increase the catalog of e.g., tree species that can be used in urban

Figure 51. Native plant species are better at supporting native insect species than exotic, Lomma. Elin Fänge

environments. Although exotic species offer a way for landscape architects to provide a higher diversity in the urban landscape, exotic species should be planted with serious reflection over the impacts it may have on both urban and rural ecosystems.

In order to allow the spread of native species to urban areas it is important to create a large web of connected habitats (Weiss and Sjöberg, 2018; Douglas, 2021). Although, it is just as important for exotic species that are invasive to not get a chance to spread (Kowarik, 1990; Sjöman *et al.*, 2016). Especially insects have shown to be vulnerable for new vegetated and exotic species as they can have difficulties extracting the nectar from its flowers, but also as the exotic plants can bloom at other times of the year when the insects are not active (Corbet *et al.*, 2001). Other species groups, such as birds, have been found to not be affected at all as they seem to have no preference. However, birds living off insects would be affected if they were to disappear. Wenzel *et al.*, (2020) on the other hand, found that neither the native nor the exotic flowering plants did have any significant effect on the diversity of insects. Instead, it was the percentages of greenspace within urban areas that increased the diversity among pollinators. Exotic species may therefore be of great importance when designing urban green spaces to increase the catalog of species but also to prolong the flowering season. Further, native plant species should be prioritized as they better support the native ecosystems and other native species. (see Figure 52)

Although native plant species may have difficulties establishing and developing in urban areas, integrating more nature in urban areas may alter the conditions in favor of the native species, while at the same time it can help mitigate the negative effects of climate change. It is also important to reflect upon if a web of connection should be promoted or not. If invasive species have a chance to spread, then it is not supported to create that connection. However, if it benefits the spread of the native species then it is supported.

Figure 52. The rose - a cultivated plant that supplies pollinating insects with food, and at the same time contributes to people's experiences, Kågeröd. Ulrika Ebelin

Choice of method

As natural features have such a positive impact on our health and well-being it is important to get nature into our cities so that more people can start to embrace pro-environmental actions and can get back in touch with nature (Anderson, 2013; Hosaka, Sugimoto, and Numata, 2017).

The choice of method has been made between only conducting a literature study or conducting both a literature study combined with a case study. Although, it has mainly been the limitation in time that has affected the choice of method. There are however some problems with the choice of method even though the literature study has given a relevant and reasonable result that answers the questions and purposes. A case study could have investigated e.g., natural habitats in depth or it could have investigated how biodiversity in urban green spaces have evolved in more detail. Further, in a case study we could also have put the solutions of synergies and conflicts into practice. This could have given a deeper understanding for both the subject and the problem, as well as given more concrete results and a more realistic image of how biodiversity can be improved in urban areas. However, the literature study has provided a result with a deep understanding on the difference between biodiversity in urban and natural landscapes as well as what humans need to promote HHWB. Even though a case study could have provided a more concrete and realistic image, the deeper understanding between biodiversity in both urban and natural landscapes as well as their relation to human needs could have been lost.

In the literature study several scientists and researchers within the field of ecology, biology, environmental physiology, and forest science have been referenced to. Although, the number of authors within the field of landscape architecture could have been larger. However, the subject requires a deeper understanding for biology, ecology etc. to understand biodiversity. More references within the field of landscape architecture could however have made the arguments about design and urban planning stronger and given a result which would be easier to implement and put into practice.
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The literature study has included a diverse number of searches in different databases as well as a lot of sifting through literature. Other choices of words during the search could have given a different selection of literature, which in turn would have affected the result.

The strengths of the study have been the variation of literature and references used, but also that the number of literatures used is relatively large. The main weaknesses have been that the reliability of some sources may be doubtful, e.g., the references within the field of environmental psychology may be questionable as this field of science is in its infancy. Other literature used may also affect the credibility as it is relatively old, however, most of the literature used are written within the past ten years. The research within all fields used in this literature is constantly updating and although research made within the past ten years may seem as relatively fresh, more recent studies could have given a more reliable result.

CONC-
LUSION


Figure 53. Since nature has many benefits to humans, we should work to integrate natural habitats into urban areas, Kågeröd. Ulrika Ebelin.

This study has investigated biodiversity and nature in both urban and natural landscapes, and it has shown that biodiversity in urban areas compared to the biodiversity in the natural landscape. It differs because habitats in urban areas have been homogenized, simplified and fragmented. Urban areas also have different conditions to which mainly generalist species can adapt to, thereby affecting the diversity in flora and fauna. This study has also shown that incorporating and promoting natural structures and features, as well as biodiversity, is very complex and that it has to be applied to the individual site and case. Therefore, we have drawn the conclusion that it is not possible to make a list of criteria in how to prioritize humans and biodiversity when designing green urban spaces. However, by looking at the different habitats (Open, Half-open, Closed, and Additional) and the list of structures and features important to biodiversity found in appendix A, the structures and features used to build urban green spaces can be improved. Sometimes there can be a synergy and/or a conflict in one site or case and not in another, which would make it hard to apply those criteria to all places — therefore it must be site specific. However, many synergies and conflicts have been identified in the discussion and can be used when designing or creating an urban green space. There are both synergies and conflicts between human needs and biodiversity but when synergies between both exist, it has been shown that urbanization can be a conflict to both of them.

The study has also shown that nature provides many benefits to our health and well-being, which is a strong argument for prioritizing nature in urban areas. Further, when looking at people's preferences of nature it shows a difference in results. People with knowledge of nature tend to prefer it more than people who have no knowledge and people who grow up close to nature have shown tendencies to prefer more natural areas and are generally more eager to embrace a pro environmental stance. Further, if children have more knowledge of nature and have regular access to it, they display more appreciation, and less fear towards it. Urban green spaces can also be used in many ways to mitigate climate change and therefore also achieve our environmental goals. To do this, many habitats and species need to be protected as they are at risk of disappearing and more urban green spaces that hold structures and features important to biodiversity need to be added in the urban landscape to both mitigate climate effects and promote human needs as well as biodiversity. Since nature has many benefits to humans, we should work to integrate nature into urban areas where 80% of the world's populations are present today. To integrate nature in urban areas one needs to want to live close to nature, because it is only then that the relationship between humans and biodiversity can be fully appreciated. Finally, this study has shown that in future development of urban areas, nature, and biodiversity must be integrated in a sufficient and sustainable way so that future generations can experience the diversity and richness we have had the pleasure to know.

Figure 54. People who grow up close to nature have shown tendencies to prefer more natural areas, Paris. Ulrika Ebelin.

Figure 64. Where do you want to walk?. Elin Fänge

FURTHER RESEARCH/ OUTLOOK

This study has given a general overview of the relation between urban areas, biodiversity, and human needs. The subject needs further research to investigate other synergies and conflicts between human needs and biodiversity that this study has not been able to discuss. Different structures and features that have been identified in the natural landscape will have different effects on humans, and therefore it would be interesting to explore the subject in more detail and depth. Such investigation could provide deeper insights on how structures and features from the Natural Landscape could be put in relation to human needs and further develop urban areas to promote both humans and biodiversity.

This study has clarified that we are dependent on nature and biodiversity and that urban areas need to be developed to integrate nature for us to cope with future challenges that we will face due to climate change, but also to improve our living conditions and overall health. How urban areas will develop in relation to nature and biodiversity only time will tell, but the matter of designing and planning urban areas for both humans and biodiversity to flourish must be discussed and landscape architecture will play a crucial role in this discussion. Further research is needed to better understand what is needed to promote biodiversity and how to put it into context in urban areas.

We have in this literature not identified which tree species contribute to HHWB and this would be something to look further into.

How the needs of today can be satisfied through urban development without compromising the needs and possibilities of future generations needs to be further investigated. Nevertheless, this study has shown that in future development of urban areas, nature, and biodiversity must be integrated in a sufficient and sustainable way so that future generations can experience the diversity and richness we have had the pleasure to know.

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APPENDIX

APPENDIX A

STRUCTURES AND FEATURES

IN GENERAL

Native species
Pollen and fruits

TREES

Living trees
Different structures of deep and rough bark
Deep cracks in bark
Sunlit Scots pine and Norwegian spruce bark that stand in an open and sparse forest
Acid/poor barked trees
Basic/rich barked trees
Thick brak
Small
Large
Old
Ancient oak and beech species
Coarse
Coarse branches
Diverse structure
Complex structure
Rich in branches
Shaded roots
Shaded trunks
Sun exposed stems
Sun exposed wood
Bases of old trees
Woody liana

DAMAGE

Cavities
Mull filled trees
Damaged branches
Damaged trunks
Damaged roots
Trees damaged by fires
Broad crowns
Broken off branches
Broken treetops
Dry and sun-exposed heartwood
Exposed roots
Exposed wood mainly on deciduous trees
Sap
Resin
Different stages of decaying
Trees that are both alive, rotting and dead all at once
Fallen trees in different angles

DEADWOOD

Dead trees
Dead branches still attached to the tree
Deadwood from trees
Sunlit wood/deadwood/bark
Different aging of deadwood (age of tree when it died)
Non remaining bark on deadwood
Remaining bark on deadwood
Stumps

Large amounts of
- standing deadwood in sunlight
- lying deadwood
- wide deadwood
- thin deadwood
- moist deadwood

Coarse stumps such a
- *Betalus*
- *Quercus*
- *Sobus aucuparia*

Different decomposer stages and species of deadwood
Rotten deadwood
Burnt deadwood

SHRUBS

Dense
Thorny
Understory vegetation
Smaller patches of understory vegetation
Dwarf