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Nature-Based Solutions in Urban Contexts

A Case Study of Malmö, Sweden

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Abstract

Nature-based solutions (NBS) offer the potential to sustainably address environmental problems in an urban context, with environmental, social, and economic benefits. As a relatively new concept, NBS is poorly defined in the literature and there is great need for more empirical information about implementation and impacts. This case study of the city of Malmö, Sweden, attempts to understand the structure and function of communities working on NBS within the city in the context of a practice theory framework. It identifies how previous NBS have been implemented, and what outcomes were observed, as well as drivers and barriers to NBS implementation and mainstreaming. A narrower definition of NBS is proposed, requiring both a problem to address and an alternative conventional solution that may be rejected. Three key developments with NBS projects were identified: the redevelopment of Augustenborg with an open stormwater drainage system in response to severe flooding; open drainage systems, green roofs, and other features in the Western Harbour; and the large green roof in the new development of Hyllie. These NBS projects were implemented by a complex interdisciplinary community consisting of members from city departments, public utilities, developers, architects, and academic researchers. Historical drivers include pressure from serious problems, such as flooding, and the dedicated work of individuals, while barriers include institutional inertia and lack of knowledge, particularly of the cost-benefit side of NBS. Over time the city's planning focus has shifted from problem-solving NBS with strong, measurable goals, to more symbolic projects better described as green-blue infrastructure, lacking clear goals and in many cases a conventional alternative. This appears to be due in part to the weakening of connections between different communities, and thus a weakening of the NBS community of practice in Malmö. Recommendations are provided for strengthening the NBS community of practice and facilitating knowledge transfer within the city, as well as for areas of further research, both in evaluating environmental impacts and in social impacts and aspects of implementation. NBS have the potential to play an important role in addressing some of Malmö's environmental and social challenges in the future, but the concept and goals must be clearly defined, and projects implemented equitably and evaluated for effectiveness.

Keywords: nature-based solutions, sustainability, green cities, green and blue infrastructure, urban planning

Executive Summary

Problem Definition and Research Question

As a relatively new concept, nature-based solutions (NBS) are not clearly defined in the literature, making them difficult to evaluate and utilize. Relatively little is empirically known about current NBS practices in Sweden, and most research focuses on technical outcomes rather than the social factors in their implementation. Finally, there is insufficient understanding of the drivers of and barriers to effective implementation. A clear and workable definition of NBS is required in order to evaluate the impacts of implemented NBS, so they may be compared with conventional solutions. If NBS are to be more widely implemented in Sweden, the key actors and communities involved must be understood, as well as the drivers and barriers affecting them. Taking the city of Malmö in southern Sweden as a case study, this project seeks to answer three research questions:

1. What were the objectives and outcomes of NBS projects in Malmö?

2. Who conceived and implemented NBS in Malmö?

3. What are the drivers for and barriers to more widespread and effective use of NBS?

Methodology

Practice theory and communities of practice are used to construct a theoretical framework for understanding the implementation of NBS in Malmö as a political and social construction or collection of actions rather than simply a technical problem. Using the practice theory defined by Theodore Schatzki (2002), a "practice" consists of four elements: practical understandings (technical knowledge), rules, normative goals and purposes, and general understandings (shared beliefs and concerns). "Communities of practice" consist of individuals sharing a craft or profession, and are composed of the practice itself, a notion of community, and a domain of knowledge. This framework is used to conceptualize NBS in Malmö as a practice conducted by communities.

The project is structured as an exploratory single-case study with embedded units. A broad literature review was conducted to synthesize the current understanding of NBS and identify research gaps. Semi-structured interviews were conducted with planners, researchers, and architects working or conducting research in Malmö or on relevant national legislation. Additional and corroborating information was obtained through documents published by the municipality government and site observations in Malmö. Interviews, literature, documents, and observations were collectively analyzed in the context of a communities of practice framework in order to address the research questions.

Key Findings

As a relatively new concept in the literature, NBS still lacks a consensus definition. Existing definitions are so broad as to be difficult to apply. This risks NBS being perceived as simply a new buzzword, perhaps better as a pedagogical or communication term because of its apparent simplicity, but not particularly useful. Based on the literature review and analyzing the situation in Malmö, a narrower definition is proposed, which can be used as a conceptual tool by city planners and managers in assessing how to respond to problems. This definition requires that in order to be an NBS, not only must a solution address a specific problem, but it must also be an *alternative* to a conventional solution (e.g. technological, economic, etc.). Thus, when faced with a problem and considering possible approaches, NBS would be part of a toolkit for planners and managers.

NBS projects in Malmö have historically been implemented by interdisciplinary project groups, composed of members from various city departments, researchers, and partners from private industry, with varying levels of public participation. Projects can be divided into two general categories: open stormwater drainage systems implemented in response to flooding risk, which constitute NBS in the narrow sense, and more broadly defined "green-blue infrastructure" projects, which may contribute to stormwater handling but which have other primary goals, such as biodiversity, recreation, and aesthetic value.

The best example of the former is the drainage system in the Augustenborg redevelopment in the 1990s, which revived a declining neighborhood. This project was strongly driven by individuals in the Water and Wastewater Department (later merged with the public utility VA SYD), in cooperation with Service Administration and the public housing company MKB. The second group of projects includes various green roofs, habitat plantings, and other landscaping features in the Western Harbour and Hyllie, the latter of which is still under construction. The NBS implemented in these developments were intended primarily to encourage biodiversity, with other possible benefits including cooling, water management, aesthetic value, and contributions to psychological health of residents. The first part of the Western Harbour development, Bo01, was overseen by an independent secretariat, and this project included an area ecologist to address biodiversity elements. Current projects focus primarily on enhancing ecosystem services, with the Environment Department and City Planning Office as key actors.

Augustenborg has been admired worldwide as a successful use of nature to solve a serious environmental problem in an urban context. In addition to the greatly improved stormwater handling, the redevelopment also produced beneficial social and economic effects, including increased civic engagement, reduced unemployment, and the creation of three new companies. The impacts of the Western Harbour developments (Bo01, Bo02, and Bo03) are less clear, in part because the goals were more difficult to measure and in part because less follow-up was published. However, it seems likely that the strong aesthetic emphasis of the NBS featured in these developments contributes to the desirability and thus the expense of living in these developments, which are more expensive than the city average.

Stakeholders interviewed emphasized the importance of key individuals as drivers of previous projects, as well as the impetus of serious problems such as the Augustenborg flooding, and city policies. They saw lack of knowledge, separation of departments, obstacles posed by national legislation, and general institutional inertia as key barriers. The containment of much knowledge within "silos" of individual departments, along with the loss of key individuals from the more engineering-focused communities within Malmö, has weakened connections between different communities of practice and thus the capacity of the municipality government to innovate new NBS in response to critical problems.

Conclusions

The NBS concept, if defined narrowly as a nature-based alternative to a conventional solution, seems to hold potential as a tool for city planners and managers to use when comparing potential solutions to a problem. At present, the term is not widely used in Swedish planning, although many planners are familiar with related concepts, such as ecosystem services and green-blue infrastructure, and examples of NBS have been implemented in Malmö.

It is not necessary to choose between NBS and more general green-blue infrastructure that produces less tangible benefits; however, it is important to be clear about the goals and desired outcomes of an individual project, and to follow-up with assessment in order to build on

previous successes and failures. Within the practice theory framework, there are four areas in which Malmö can build NBS capacity in particular:

1. Practical understandings, by focusing on knowledge gathering and transfer, including expansion of solution-focused pilot projects.

2. Rules, by continuing to work with national actors on interpretation of the law, not only to implement ecosystem services but specifically for NBS.

3. Teleoaffective structure, by establishing clear, measurable goals for NBS, both in general and for specific projects.

4. Communities of practice, by strengthening informal links and knowledge sharing between project teams, departments, and other actors involved in NBS development and implementation.

In addition, possibilities for NBS implementation in stressed neighborhoods facing poverty, unemployment, and social segregation should be assessed, and a strong public participation component included whenever possible. NBS have the potential to play an important role in addressing some of Malmö's environmental and social challenges in the future, but the concept and goals must be clearly defined, and projects implemented equitably and evaluated for effectiveness.

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Abbreviations

BAF – Biotope Area Factor (see GSF)

BEST – Boverket and Ecosystem Services (*Boverket och EkoSystemTjänsterna*)

EC – European Commission

EDS – Ecosystem Disservices

ES – Ecosystem Services

GBI – Green and Blue Infrastructure

GSF – Green Space Factor (see BAF)

IUCN – International Union for Conservation of Nature

MEST – Malmö and Ecosystem Services (*Malmö och EkoSystemTjänsterna*)

NBS – Nature-Based Solutions

PBL – Swedish National Planning and Building Act (*Plan- och bygglag*)

1 Introduction

Cities commonly face complex and interconnected environmental, social, and economic problems, such as climate change, pollution, waste management, food security, social segregation, and poverty (Potschin et al., 2014). These problems have often traditionally been treated as separate infrastructure issues to be addressed using conventional "grey" solutions—infrastructure designed to solve specific problems without necessarily considering environmental or social impact, sustainability, or resilience. As the discourse on sustainability and urban resilience has evolved, city planners and policy-makers have experimented with novel solutions that consider social, economic, and environmental concerns as interconnected, and which strive to reduce environmental impact or even improve environmental protection. Since the 1970s, environmental or ecosystem services—the economic valuation of "services" provided by nature—have increasingly entered mainstream discourse (Chaudhary, McGregor, Houston, and Chettri, 2015). These services can form the basis of alternatives to conventional grey infrastructure, resulting in "green" or "green-blue" infrastructure: urban planning which incorporates nature to alleviate the impacts of stresses such as climate change, flooding, and poor air quality on urban society (Brink, Alders, and Ádám et al., 2016; Deak and Bucht, 2011; Demuzere, et. al., 2014; Matthews, Lo, and Byrne, 2015; Sandström, 2015). Other related concepts include nature-based interventions, ecosystem-based solutions, and ecosystem-based adaptation (Potschin et al., 2015).

Green and blue infrastructure, ecosystem services, nature-based intervention, ecosystem-based solutions, and ecosystem-based adaptation are closely related concepts and often overlap. Recently, nature-based solutions (NBS) have been proposed as an umbrella concept for various approaches to environmental problems, primarily in urban settings (EC, 2015; Potschin et al., 2015). This umbrella concept of NBS provides a framework for encouraging sustainable development and ecosystem protection within the larger context of meeting environmental, social, and economic challenges by enhancing community sustainability and resilience. Crucially, the framing of nature-based *solutions* requires a specific *problem* to be addressed, distinguishing it from more neutral concepts like ecosystem services, which may enhance wellbeing (Potschin et al., 2015).

NBS are inspired by, supported by, or copied from nature, and range from directly utilizing natural system processes to engineering solutions emulating nature (biomimicry) (EC 2015). According to the European Commission (2015), NBS can benefit public health, society, economy, and environment, sometimes more cost-effectively and efficiently than conventional approaches. NBS have been identified as a priority area for the EU's Horizon 2020 Research Programme (Potschin et al., 2014), as well as the BiodivERsA program (Balian, Eggermont, and Le Roux, 2014) and the International Union for Nature Conservation's non-binding Jeju Declaration (IUCN, 2012), all focusing on different aspects of NBS. The European Commission has identified four principal goals that it believes can be addressed by nature-based solutions (EC, 2015):

- Enhancing sustainable urbanization
- Restoring degraded ecosystems
- Developing climate change adaptation and mitigation
- Improving risk management and resilience

Nature-based solutions appeal to the "triple bottom line" of social, environmental, and economic concerns, which make them appealing to business as well as political actors, including major development investors such as the World Bank (WB, 2008).

1.1 Problem Definition

Despite current interest in NBS in policy circles (EC, 2015; Potschin et al., 2014), the concept is relatively new, although some of the underlying ideas may be very old. NBS are primarily described in gray literature such as organizational reports and working papers. This poses three problems: first, the definition of NBS may not be widely agreed upon, and if policy makers are unsure what they are, they are unlikely to support them effectively; second, little is empirically known about current NBS experiences and practices; and third, there is insufficient social understanding of how NBS are implemented, both in terms of the communities and actors involved and how these interact with drivers and barriers.

The OpenNESS project, which seeks to translate the concepts of natural capital and ecosystem services into operational frameworks that can be used in decision-making asks a crucial question about NBS: what new insights does the concept bring?

> "Is it intended to re-package the demand for sustainable development and nature conservation in a way that concepts of biodiversity and ecosystem services do not? Does it represent an approach to policy and management distinctly different from those already being applied?" (Potschin et al., 2014)

Even if NBS does not represent a distinctly different approach from prior related concepts, OpenNESS argues that NBS might still provide a useful new framework for discussion. Given that mainstreaming of concepts into policy debate can take years or even decades, there is a risk that policy makers might be resistant to adopting what seems to be merely a new buzzword. First, NBS has to be defined—as with green infrastructure, definitional ambiguity regarding NBS may contribute to inaction and path dependency by confusion of "existing programs and initiatives that are to do with green-space more broadly" (Matthews, Lo, and Byrne, 2015:155).

Second, working from that definition, more empirical study of the positive and negative impacts of NBS is needed, in order to better compare them with conventional solutions.

Finally, if NBS are to be more widely implemented in Sweden, it is necessary to understand how and why they are implemented from a social standpoint. This includes the actors and communities involved and the drivers that motivate them, as well as the barriers to mainstream adoption of NBS into urban planning.

1.2 Scope

Since both NBS and planning and policy processes tend to be localized, this study will focus on a case study of Malmö, Sweden.

Within the EU, Sweden is known for its commitment to environmental and social sustainability. Many Swedish cities have green infrastructure plans that include NBS in their goals in some form ("biological solutions to technical problems") (Sandström, 2015:375).

Malmö Municipality (here styled City of Malmö), located on the southern coast of Sweden, offers a commitment to sustainability and a relatively high density of implemented and pilot

projects incorporating NBS and related concepts. For example, the Augustenborg Eco-city (Ekostaden Augustenborg) is one of Sweden's largest urban sustainability projects Rolfsdotter-Jansson, n.d.). Malmö's Environment Department has been highly successful at obtaining funding, and ecosystem services have been to some degree incorporated into the city's urban planning (Wamsler et al., 2014). Malmö aims to become a "close, dense, green mixed-function city" by the 2030s (City of Malmö, 2014:3).

Malmö offers examples of success and innovation in NBS and sustainable urban planning, but also faces the challenge of whether long-term planning for sustainable urban densification can be done equitably while still addressing urgent short-term needs. These factors make Malmö a rich choice for a case study on NBS and the hypothetical "green city."

1.3 Research Questions and Objectives

This study concerns three research questions, all focused primarily on Malmö:

1. What were the objectives and outcomes of NBS projects in Malmö?

2. Who conceived and implemented NBS in Malmö?

3. What are the drivers for and barriers to more widespread and effective use of NBS?

In order to determine whether NBS provide additional value as a development, planning, and policy tool over related concepts such as ecosystem services and green-blue infrastructure, it is necessary to define NBS more precisely. Where do NBS overlap and diverge from existing concepts? Are planners and researchers familiar with the concept? Does NBS cover new territory or provide a useful pedagogical or communication tool that meets planning needs?

A better understanding of the role of NBS in urban planning could facilitate cost-effective future solutions to some of the environmental challenges facing Sweden, while benefiting communities socially and/or economically. This research aims to assess potential use of the NBS concept as a pedagogical, communication, and/or planning tool, as well as drivers and barriers to implementation and scaling of NBS solutions in Malmö.

In order to answer these questions, the project has four specific objectives:

1. Refining the definition of NBS in urban contexts.

2. Describing the impacts of key NBS projects in Malmö.

3. Identifying the actors and communities involved in NBS development and implementation in Malmö.

4. Exploring drivers and barriers for NBS implementation in Malmö.

1.4 Audience

This research intends to serve the needs of researchers and urban planners, particularly working in the City of Malmö. Other potential audience members include government agencies or departments working with sustainability issues at both local and national levels. It is hoped that in identifying and explaining the drivers and barriers of NBS mainstreaming in Malmö's city planning that fruitful opportunities will be identified for strengthening NBS communities and using NBS to advance sustainability goals and exploit new opportunities.

1.5 Disposition

The structure of this paper is as follows:

Chapter 1 provides an introduction and overview of the identified problem, research questions, and study aims, as well as defining the scope and identifying the audience of the report.

Chapter 2, the literature review, outlines the existing definitions of nature-based solutions from the literature, explores their foundation in related concepts such as green and blue infrastructure, ecosystem services, and identifies gaps in the literature.

Chapter 3 outlines theoretical framework and methodology for the case study design. Research methods for the stakeholder interviews and synthesis and analysis are described, as well as limitations of the study.

Chapter 4, the results, presents research findings, divided into embedded units. Three key projects in Malmö are presented and discussed in terms of objectives, drivers, implementation, and impacts: Augustenborg, the Western Harbour, and Hyllie.

Chapter 5, the discussion, addresses the research questions and objectives in light of the results presented in chapter 4. These include definitions of NBS refined with stakeholder input, identification of benefits and drawbacks to NBS implementation in Malmö, description of relevant actors and communities of practice, and identification of drivers and barriers to NBS implementation.

Chapter 6, conclusions, answers the research questions by summarizing key findings. Suggestions for future research, both technical and social, are also provided.

2 Literature Review

This literature review draws from disciplines such as ecological economics, urban studies, landscape and urban planning, environmental policy, and sustainability studies. The review focuses on synthesizing existing information about NBS definitions and applications, identifying strengths, weaknesses, and summarizing criticisms of the concept. Relevant literature was selected through initial keyword searches, as well as through citations, in an iterative process. As nature-based solutions are a relatively new concept, currently discussed primarily in working papers, reports, and other "grey" literature (EC, 2015; Potschin et al., 2015), more established related concepts were also included in keyword searches, including ecosystem services, green and/or blue infrastructure, ecosystem-based adaptation/mitigation, and nature-based management.

2.1 Foundational Concepts for NBS

The concept of NBS is rooted in and related to a number of other concepts, most importantly the concepts of ecosystem services (ES) and green-blue infrastructure[1] (GBI). In many cases, subjects interviewed in this study were only passingly familiar with NBS, and preferred to speak in terms of more familiar concepts already known in Swedish planning. These concepts are more prevalent in literature describing projects in Malmö, and it is important to understand them as a foundation for NBS.

2.1.1 Ecosystem Services

"Ecosystem services" is a concept that has been extensively discussed in the literature since the 1980s, although its precursors, such as economic ornithology, date back to the 1880s (Chaudhary, McGregor, Houston, and Chettri, 2015; McCauley, 2006). In the 2000s, ecosystem services entered the mainstream of global environmental discourse, where they continue to feature in policy and international initiatives, and increasingly as a tool in urban planning (Chaudhary, McGregor, Houston, and Chettri, 2015; Hansen et al., 2015).

Simply defined, ES are "the benefits ecosystems people obtain from ecosystems" (MEA, 2005:v). They offer a way to economically value nature and biodiversity as they contribute to, for example, the human food supply (pollination services), climate regulation (carbon storage), and flood control (water retention), but can also encompass more subjective social and cultural values, such as the psychological value of green spaces in an urban setting, although these are often more difficult to place monetary values on in models (Demuzere et al., 2014; Farrugia et al., 2013; Kati and Jari 2016; Wamsler, 2015).

Sweden entered into a national discourse about ES relatively early (Hansen et al., 2015). In 2012, the Swedish government decided that ES should be integrated into urban planning and other decision processes by 2018 at the latest (Delshammer, 2015), and in 2014 the Swedish Parliament adopted a strategy for "strengthening biodiversity and securing ecosystem services" (Proposition 2013/14:141). As of 2015, a survey indicated that ES are still at an early stage of integration in Sweden, largely due to lack of practical experience. At least 78% of responding municipalities had at least one department that dealt with ES (Delshammer, 2015). Ecosystem services have been consciously integrated into urban planning in four municipalities in Skåne, including Malmö, where politicians had specifically requested ES workshops (Wamsler et al., 2014). Although progress has been made and the usage of ES is

[1] Alternately blue-green infrastructure, green and blue infrastructure, green-blue cities, or blue-green cities.

widely known in Sweden, they are not fully integrated into planning documents, and most planners perceive them as a technical rather than political issue (Delshammer, 2015).

2.1.2 Green and Blue Infrastructure

Green and blue infrastructure refers to vegetation and water bodies in an urban setting, in the context of the ecosystem services and support or recreation of a natural hydrological cycle that they provide (Wamsler, 2015). It is contrasted with conventional grey infrastructure, such as roads (Farrugia et al., 2013). Green and blue infrastructure includes components such as parks, watercourses, green roofs, and streetside trees, and provides ecosystem services such as cooling, flood control, and recreation (Farrugia et al., 2013); green cities are also perceived as more attractive, improving the psychological wellbeing and physical health of residents (Farrugia et al., 2013; Demuzere et al., 2014), although not without potential drawbacks, such as increased allergen exposure or urban safety concerns (Lyytimäki et al., 2008; von Döhren and Haase, 2015).

Green-blue infrastructure is already a relatively known concept in Swedish urban planning (Wamsler et al., 2014), and has been extensively worked with in Malmö, particularly in the development of its open stormwater handling systems (Stahre, 2008). GBI can be conceptualized from either a capital standpoint, maximizing public goods, or a risk-based standpoint, minimizing public 'bads'. For example, open stormwater systems can be conceptualized as capital that contributes to public wellbeing by providing recreational and aesthetic benefits and specific water management services. They can also be conceptualized as a form of risk mitigation against the threat of severe flooding (Matthews, Lo, and Byrne, 2015). Their overlap with NBS is particularly apparent in the risk-based conceptualization.

2.2 What Are Nature-Based Solutions?

The term "nature-based solutions" is initially appealing from a communications standpoint because it appears self-explanatory, especially compared with terms like "ecosystem services" and "green and blue infrastructure," which immediately require explanation for the uninitiated listener—*What is an ecosystem? How do ecosystems provide services? What kind of services? What kind of infrastructure? What does "green and blue" mean?* However, in practice, NBS as a concept does require some explanation to reach an unambiguous definition necessary for clear communication.

Potschin et al. (2015) break the term down into the component parts of "nature," "nature-based," and "solutions," which may be useful for approaching potential definitions. To take the last part first, NBS by definition are *solutions* to problems. The European Commission (EC), discussing NBS and re-naturing cities, states that these problems may be "environmental, social and economic" (EC, 2015), an umbrella so broad it encompasses most problems that concern urban planners. As basic premises for NBS, the EC further states that

> "(i) some societal challenges stem from human activities that have failed to recognize ecological limitations; (ii) sustainable alternatives to those activities can be found by looking to nature for design and process knowledge." (EC, 2015:24)

The IUCN identifies NBS as important for enhancing societal resilience to challenges in "climate change, sustainable energy, food security, and economic and social development,"

noting that valuing nature and ecosystem services is fundamental to being able to use nature to address problems (IUCN, 2012:2).

Once a problem is identified and the question is asked of whether a nature-based solution might exist, *nature* must be defined. In this context, Potschin et al. (2015) define "nature" as encompassing biodiversity "in aggregate," individual elements of biodiversity such as species or ecosystems, and/or ecosystem services (Potschin et al., 2015). In order to be *nature-based*, a solution must involve ecosystem or ecosystem-based approaches, biomimicry, or direct use of elements of biodiversity (Balian, Eggermont, and Le Roux, 2014; Potschin et al., 2015). Nature-based solutions use these "features and complex system processes of nature" to deliver services such as carbon storage and water management (EC, 2015).

Thus NBS are widely agreed (EC, 2015; IUCN, 2012; Balian, Eggermont, and Le Roux, 2014; Potschin et al., 2015) to

- Address a specific problem
- Be sustainable
- Utilize systems and processes of nature (ecosystems and elements of biodiversity) to deliver services

Possibly including

- Biomimicry (EC, 2015; Potschin et al., 2015)

And ideally

- Resilient to changing pressures (EC, 2015; IUCN, 2012)
- Adapted to local conditions (EC, 2015)
- Account for multiple interests among economic, social, and environmental (Balian *et al*, 2014)

According to the current EU definition, NBS can include biomimicry, but do not include methods that "artificially alter nature," such as genetic engineering (EC, 2015). The term has sometimes been used more broadly to include adaptive engineering measures, such as ecological engineering that minimizes interference with ecological processes and ecosystem services to mitigate flood risks (Balian, Eggermont, and Le Roux, 2014; van Wesenbeeck et al., 2015). Arguably, this falls on the same continuum as constructing, restoring, or enhancing habitat to deliver needed ecosystem services, which is widely accepted as a type of NBS (Potschin et al., 2014).

Others define biodiversity itself as a nature-based "policy option" for climate change mitigation, a use of the term so loose it becomes uninformative (Ding and Nunes, 2014), although within the paper they describe specific solutions and policies which would fit into the accepted definition of NBS. The World Bank (2008), similarly uses NBS as a synonym for "biodiversity projects," primarily the mainstreaming of biodiversity values into resource management, particularly forestry, coastal zone management, and agriculture, a contrast to the more common discussion of NBS in an urban setting. However, some projects discussed, such as biofuel production, do not fall into the usual definition of NBS, but rather are renewable resource production and use (WB, 2008).

Nature-based solutions are *not* a synonym for "green" solutions, which may include environmentally friendly or renewable technologies that do not utilize or emulate nature, e.g. energy-efficient buildings or bio-energy. Nature-based solutions as described above can be further divided into categories or types, at least the first three of which are on a continuum or gradient rather than existing as discrete categories (Balian, Eggermont, and Le Roux, 2014; Potschin et al., 2015):

- Type 1: non-interventional but more effective use of existing ecosystems
- Type 2: modifying and managing existing ecosystems to better deliver services
- Type 3: intrusive ecosystem management and creation of new ecosystems
- Type 4: solutions involving biomimicry

In general, less modification and management is associated with a greater variety of services; more management or creation of new ecosystems typically has a more focused goal to enhance or produce specific services (Balian, Eggermont, and Le Roux, 2014). This typology does not cover some of the best examples of NBS, for example bioremediation, which usually relies on a single organism rather than an ecosystem (EC, 2015). Similarly, sustainable urban drainage systems, while they may incorporate ecosystem features such as green roofs and pond vegetation, also rely on features which physically guide the flow of water, such as canals and floodable areas (Stahre, 2008). The degree to which NBS can rely on natural processes rather than on natural or managed ecosystems is ambiguous in the current definitions, as is the question of which processes can form the basis of NBS. It is widely accepted that the hydrological cycle can be utilized in NBS, yet geothermal energy is not generally considered to be a component of NBS.

2.3 Strengths of NBS

Nature-based solutions can offer a number of benefits over conventional, typically technological, solutions. In some cases they are cheaper than conventional solutions. For example, the open stormwater systems consisting of green spaces, channels, retention ponds, etc. used in many Malmö neighborhoods provide needed stormwater management at initial costs lower than comparable conventional solutions (Stahre, 2008).

Another strength of NBS is that they often provide additional, less tangible benefits in addition to the ecosystem services directly relevant to the problem addressed. These benefits include sociocultural values that are often difficult to measure, such as nature enjoyment, recreation, aesthetics, support of biodiversity, and cultural heritage (Kati and Jari, 2016).

2.4 Weaknesses of NBS

A crucial weakness of nature-based solutions is that they are frequently (although not always), slower solutions. For example, it takes significant time to restore or create a habitat. Plants grow on nature's timescale—although planners can sometimes choose plants that grow faster, these may not deliver the same benefits as slower-growing plants. For many problems, a short-term technological solution may be faster than a long-term but more sustainable solution based on nature (Balian, Eggermont, and Le Roux, 2014).

While NBS often provide beneficial side effects, not all side effects are positive. The concept of ecosystem disservices (EDS) has received more attention in recent years, and is expected to become more important with increasing urbanization. For example, wind-pollinated plants such as urban trees provide cooling services but also increase allergenic pollen loads (Lyytimäki, Petersen, Normander, and Bezák, 2008; von Döhren and Haase, 2015). Lethal

tropical diseases, whose ranges are already spreading northwards as the global climate warms, are also components of ecosystems, and NBS featuring open water or vegetation can provide breeding ground or shelter for disease reservoirs such as biting insects (Dunn, 2010). Any argument for nature-based solutions as superior to conventional solutions must account for EDS as well as ES.

There are other reasons that some urban residents perceive NBS such as green spaces and open water as negative rather than positive elements of the urban landscape. While some residents may enjoy the recreation potential of parks and waterways, others see them as unsafe, ugly, or polluted (Kati and Jari, 2016). There is also a potential "environmental gentrification" effect that is particularly strong for more aesthetically pleasing types of NBS, such as parks and vegetated elements. These environmental amenities may be opposed by low-income local residents, especially those who have seen other neighborhoods gentrified in part due to high-profile sustainability projects (Anguelovski, 2015). For example, a large-scale census study in the U.S. found that urban land cleanup, green or open space development, waterfront redevelopment, and green design have all been found to correlate with socioeconomic demographic profile changes—specifically, wealthier, more educated residents move in, forcing the original low-income residents to move to cheaper neighborhoods (Gamper-Rabindran and Timmins, 2011). Concerns about gentrification can result in strong community opposition to environmental projects that appear to benefit the community. The recently established Green Locally Unwanted Land Uses—GREENLULUS research project aims to identify conditions under which greening or sustainability projects are equitable for distressed communities in Europe and the U.S. (http://www.bcnej.org/greenlulus-2).

Perhaps the greatest weakness of NBS is that although some NBS, as described above, are cheaper than conventional solutions, others are more expensive or currently at an experimental stage that is not yet economically viable (Fredriksson, 2015). In these cases, utilizing NBS requires either a commitment to sustainability goals even if they cost more, a commitment to subsidies to support NBS until they become economically competitive, or both. Successful long-term sustainability project require economic sustainability as well as environmental and social sustainability.

2.5 Criticisms of the NBS Concept

Nature-based solutions appeal to both public and private actors, including entities such as the World Bank, and are a component of recent reframing of conservation and environmental concerns in global discourse. From a pragmatic perspective, many would argue that this is a good thing: appeal to economic and business interests increases the likelihood of funding and mainstreaming NBS. However, others have criticized the concept's adoption by conservation organizations such as IUCN as anthropocentric and short-sighted from a nature conservation standpoint.

Ecosystem services, a key component of NBS, at first appear attractive to conservationists because they provide a pragmatic appeal for preserving and encouraging ecosystems, habitats, and their biodiversity. They offer a way to gain broader support from entities which otherwise might be reluctant to commit money to conservation efforts. The danger, conservationists argue, is that valuing and monetizing nature is reductive. If nature does not offer services or solutions, if cheaper technological solutions are found, or if market needs change, there is no longer an incentive to conserve nature or choose NBS over technological solutions (Kronenberg, 2015; McCauley, 2006). Leaving aside philosophical questions about the existential value of nature, Kronenberg (2015) points out that excessive focus on

economic valuation of nature can lead to decisions with unforeseen economic and even environmental consequences.

For example, the ecosystem services provided by birds were discussed in terms of economic value—particularly as pest control—as early as the 1880s, long before the "ecosystem services" concept was suggested. Economic ornithology was seen as a political necessity for bird conservation (Kronenberg, 2015). Technological innovation throughout human history has been largely driven by a need to find artificial replacements for, and improvements upon, natural services (McCauley, 2006). Even in cases where nature-based solutions are more economically efficient, there is always pressure for new technological innovation to improve on nature (Kronenberg, 2015). In the heyday of economic ornithology from 1880-1920, birds were perceived as providing invaluable pest control services that offset the ecosystem *disservices* of birds, such as crop damage. But with the introduction of industrial pesticides in the 1930s, this argument became weaker—pesticides were cheaper and more effective for pest control than reliance upon wild birds. The wider negative impacts of pesticides themselves only became apparent later, after damage to the ecosystem and birds themselves was well underway (Kronenberg, 2015).

Despite the relative scarcity of cases clearly demonstrating that NBS are widely cheaper and more effective than technological solutions, key components of NBS such as ecosystem services and green and blue infrastructure have increasingly been mainstreamed into urban planning over the past few decades, including in Sweden (Wamsler et al., 2014). Because NBS can indeed be cheaper and more effective than technological solutions in *some* cases and provide side benefits, they are perceived as potential win-win solutions that appeal to the public, policy makers, and business concerns—but empirical data supporting this stance is not as abundant as arguments for NBS in general would suggest (McCauley, 2006). All NBS are not equally cost-effective and efficient.

Critics do not necessarily argue that there is no role for ecosystem services or NBS, but that these concepts have limited use as conservation tools, can potentially be replaced with technological solutions in the absence of non-economic motivations to preserve nature, and are easily over-sold as part of a nonexistent consensus on how to address environmental problems (McCauley, 2006; Fletcher, 2014).

2.6 Summary

Nature-based solutions can be conceptualized as methods for utilizing ES to solve problems, overlapping with green-blue infrastructure, which can be a type of NBS if it is used to target a specific problem.

The concept of NBS as currently defined in the literature is very broad, and its key difference from other concepts—the solution framing—is often treated loosely. This makes it difficult to utilize usefully. Most literature also focuses primarily on technical aspects of implementation and environmental outcomes. This leaves crucial research gaps in the area of how NBS are implemented socially, by what actors and communities, and in assessing the social impacts of NBS projects on urban communities.

3 Methodology

3.1 Theoretical Framework

In order to examine how NBS are implemented socially, this project proposes to examine them as a practice, implemented by communities of practice dealing with knowledge, rules, and normative goals driven by commonly shared beliefs.

Practice theory addresses how people construct and change the world through organized actions within a social context. According to one theory of social practice, practices consist of four components: practical understandings, rules, a teleoaffective structure, and general understandings (Schatzki, 2002). In the context of urban planning, "practical understandings" would refer to what planners call "technical knowledge"—the sum total of knowledge of how to identify, implement, and respond to things relevant to urban planning. For NBS, this could include the architectural and mechanical knowledge necessary to build features, the ecological knowledge of how to select and incorporate ecosystem features and estimate the ES they will provide, and the knowledge of how to identify problems and available solutions. In Schatzki's model, this practical knowledge refers to the *how* (in this case of planning), but not to the decision of *what* to plan. Individuals within a practice will all know at least some of the practical knowledge comprising it, although not necessarily all (Schatzki, 2002).

The second component, rules, refers to "formulations, principles, precepts, and instructions," which play a role in the adoption of norms (Schatzki, 2002:79). Modern urban planning is subject to a host of rules, ranging from national and local law to the municipality's various layers of plans, programs, and guidelines.

The third component of practice, teleoaffective structure, refers to the normative goals or "purpose" of the practice. The teleoaffective structure establishes which ends are acceptable or correct. Unlike practical understanding, individual actors within a practice do not necessarily have to know the teleoaffective structure governing the practice, and actual implementation may not perfectly conform to the overall structure (Schatzki, 1996; Schatzki, 2002). In an urban planning context, this could encompass such aspects as the vision for the city's further development, as well as more concrete implementation goals.

Finally, "general understandings" refers to commonly shared beliefs and concerns (Schatzki, 2002). This is not clearly separated from the teleoaffective structure, and in Schatzki's earlier work may be included with it (Schatzki, 1996). Perhaps the most relevant common belief in the case of Malmö is that developing as a green city is desirable—that protecting the environment is an important goal. This broad belief does not provide specific guidance or directives, but comprises a set of underlying assumptions that underpin urban planning choices.

In order to examine how the practice of NBS functions in Malmö in terms of actors and their relationships, practical and general knowledge, rules, and goals, this study will contextualize existing projects within communities of practice. Communities of practice (COP) are used in organizational theory to conceptualize groups of people who share a craft or profession, and may arise naturally or be consciously constructed (Cox, 2005; Lave and Wenger, 1991). There have been multiple conceptualizations of this theory over the years, including viewing the organization as a collection of interrelated and overlapping COPs (Cox, 2005; Wenger, 1998). Learning is central to the COP concept, as social participation,

knowledge transfer, and a way of continuously constructing a shared identity (Wenger, 2010). According to the model most applicable to the managed work of present-day organizations, COP is thus composed of the practice—as described above—a notion of community, and a domain of knowledge (Wenger, McDermott, and Synder, 2002). Within the COP, learning is a function of the social structure (Wenger, 2010). Communities of practice can facilitate capture of tacit knowledge and the learning of new members, speed response to changing conditions and needs, avoid the reinvention that is often the effect of poor organizational continuity, and generate new ideas (Lesser and Storck, 2001). As members of a COP are connected, they are also networks, but a shared identity, whether or not it is formally recognized, forms the basis for a community. Although COPs have always existed as a vehicle for peer-to-peer, horizontal transfer of knowledge and professional development, conscious recognition of them can facilitate strengthening and leveraging their capacity within an organization (Wenger, 2010).

In some ways, COPs are similar to project teams or departments; however, traditionally project teams and departments were under organizational control, while COPs were self-organized or under individual control. They were not driven by goals or milestones, nor was membership in a COP task-defined, but rather defined by expertise. Finally, COPs do not dissolve at the end of a project, but exist as long as they are useful and the members want to participate (McDermott, 1990). Increasingly, COPs have become formalized parts of organizations, with long-term goals, formal governance, and set-aside time for interaction (McDermott and Archibald, 2010).

Finally, in order to meaningfully identify the COPs operating in Malmö, NBS must be more narrowly defined as a nature-based *alternative* to a conventional solution. When city planners face a problem, they can then look to practical knowledge for potential solutions, including both conventional technological solutions and nature-based solutions. In this narrow definition, problems that can *only* be solved with nature, such as "declining biodiversity," are excluded from the NBS concept. In this thesis, examples of NBS that fit the broader definitions of the literature will be given, but analysis will compare the roles of broad and narrow definitions of NBS within the COPs operating in Malmö, roughly corresponding to capital and risk-based conceptual approaches, which corresponds better to GBI, nature is used as 'capital' which provides benefits to society. In the risk-based approach, which corresponds to the narrow definition of NBS proposed here, nature-based 'solutions' mitigate or buffer against risk (Matthews, Lo, and Byrne, 2015).

Because NBS are by their nature interdisciplinary, as are the problems they seek to address, implementing NBS effectively in response to a problem requires input from multiple COPs that collectively may form an interdisciplinary "NBS community of practice." These communities can include different departments within the city, such as Planning, Environment, or Water & Wastewater, as well as communities of academic researchers, the private development and construction community, and so on. It is the intersection of these COPs that creates the NBS community of practice. If links between otherwise functioning COPs are weak or severed, this can severely impact the NBS COP. If they are strong, the NBS COP will also be strong and thus able to practice effectively.

3.2 Case Study Design

This project is structured as an exploratory single-case study of NBS in Malmö, Sweden. Case studies can be useful to examine complex social phenomena and relationships in-depth and with reference to their real-life contexts (Yin, 2009), in this case the drivers and barriers to NBS mainstreaming in Swedish urban planning and the interrelated communities of

planners, architects, researchers, and other stakeholders who set and implement policy. Malmö presents particularly rich terrain for a single-case study due to its international status as a "demonstration" city for sustainability projects, including the Augustenborg and Western Harbour developments (Austin, 2013; Kazmierczak and Carter, 2010; Yin, 2009). These projects have taken different approaches and exhibited different degrees of success on environmental, economic, and social levels.

Through analysis of the literature, interviews with stakeholders, and document analysis (Wamsler et al., 2014), this case study seeks to generate an explanatory community-based theory for the patterns seen in Malmö's urban planning. Key individual projects identified through the literature review and stakeholder interviews are analyzed as embedded units (Yin, 2009).

At the same time, caution should be used in extrapolating too broadly to other Swedish municipalities or beyond. Although all are subject to a national planning framework, the high degree of autonomy at the municipality level in Sweden and the importance of individuals in driving change or maintaining the status quo mean factors in implementation and mainstreaming of NBS will vary from municipality to municipality.

3.3 Stakeholder Interviews

A total of nine interviews were conducted for this study. Researchers, architects, and planners were purposefully selected for initial interviews based on research profile and/or involvement with NBS projects in Malmö, similarly to a previous study on mainstreaming ecosystem-based adaptations into municipal planning (Wamsler et al., 2014). The interview subjects and their affiliations and specialties are given in *Annex I*.

The interviews were semi-structured and thematic, with open-ended questions, in order to collect narrative data that addresses complex and intangible aspects of stakeholder relationships to NBS (Kvale and Brinkmann, 2009). Most interviews covered a core set of questions (summarized in an interview protocol – see *Annex II*), but further questions were added based on the interview subject's role and themes that arose within the interview. Snowball sampling ensured interviewing of key stakeholders and provided information about the community network (Kati and Jari, 2016). Interviews were conducted face-to-face if possible, either at the International Industrial Institute for Environmental Economics in Lund or on-site at interview subjects' workplaces in Malmö or Lund. One interview was conducted over Skype and one by email; extensive notes were taken during all verbal interviews. A typical interview lasted 45-60 minutes, although some were longer or shorter. All interviews were recorded with subject consent and key passages transcribed, editing for clarity and to remove repetition.

Key passages and themes in interviews relevant to the theoretical framework were identified to address the aims of the study. Because interview responses are subject to factors such as bias, incomplete recall, or poor articulation, factually-based observations of interest were corroborated as much as possible with published literature, reports, and other sources (Yin, 2009). Opinions are presented when relevant; they do not require corroboration but could not be assessed quantitatively without conducting a formal survey (Yin, 2009).

3.4 Validation

A common criticism of interview-based research is that information reported by interview subjects may not be reliable or "valid." The question of validity is a complex philosophical

question, but frameworks exist for verification of interview data (Kvale and Brinkmann, 2009). The reliability and validity of interview data can refer to a number of factors, which can be addressed methodologically in different ways.

Validity refers to the "correctness" and strength of the data, a question relevant at all stages of the research process (Kvale and Brinkmann, 2009). First, the research questions were developed based on a literature review, a widely accepted theoretical approach. Second, the design of the study is based on previous studies examining similar questions, e.g. Wamsler et al. (2014). During the course of each interview, validation questions were asked throughout to ensure that the interview subject had clearly expressed what he or she hoped to express (Kvale and Brinkmann, 2009). This was done by the interviewer rephrasing the statement for confirmation or clarification of its ideas or by asking additional questions as a form of *in situ* validation. Next, to ensure the reliability of the interview data— the consistency and trustworthiness of the data—interviews were recorded and transcribed, rather than relying solely on notes (Kvale and Brinkmann, 2009). All transcriptions of key passages were made by the same interviewer, using the same methods, in order to ensure consistency:

1. Transcription, including repetitions and false starts, but excluding filler vocalizations and making note of any inaudible words.
2. Editing for clarity to remove repetitions and false starts while retaining information.

This choice was made because the goals of the study were to seek information on planning, policy, and perceptions, not to conduct a linguistic analysis of oral expression. Editing for clarity enhances the comprehensibility of the information in written language.

Next, validation was applied to the content of the interviews. This is a complex undertaking, as the interviews were to some extent seeking subjective perceptions that cannot be generalized beyond the specific interview subject. Interview subjects also discussed more traditionally verifiable information, such as details of a particular project. As memory can be unreliable and expression otherwise subject to factors such as a desire to be diplomatic, or a conscious or unconscious tendency to select data to support particular views, these claims were verified where possible by reference to corroborating literature (Kvale and Brinkmann, 2009).

3.5 Limitations

As an exploratory, qualitative case study, the obvious limitation is a lack of quantitative data, such as that obtained by surveys or empirical studies. The individuals interviewed represent a range of knowledgeable and often influential stakeholders involved in different aspects of Malmö's city planning or national regulation; however, they are not statistically representative of larger groups. In particular, this study does not incorporate the perceptions or priorities of the public. Most interviews also represented the community of practice dealing with architectural and ecological expertise, as key individuals involved in the engineering and infrastructural maintenance community that drove the open drainage projects of the 1990s had died or moved away from the city. To better incorporate this perspective, this project relies greatly on the writings of Peter Stahre (Stahre, 2002; Stahre, 2008; Stahre and Geldof, 2003).

The reliability of interview data is affected by the neutrality of the interviewer, the knowledge of the subject, and the subject's willingness to speak. While the interviewer attempted to phrase questions as neutrally as possible, subjects sometimes requested rephrasing. As interviewers were often interviewed in their professional capacity, it is likely that many felt

some sense of caution about their words. Most were Swedish speakers interviewed in a second language, English, and sometimes they found it difficult to translate particular concepts.

Finally, not all interview information was verifiable in a traditional sense, either because it represented subjective personal opinion or because corroborating documents were only available in Swedish.

4 Results

Nature-based solutions are likely to play a key role in sustainable or "green" cities, and particularly in providing the psychological and socio-cultural values of nature that often attract residents to a city (Kati and Jari, 2016). The parks, green corridors, green roofs, and water features residents enjoy recreationally can also provide more readily measurable ecosystem services, such as water management (Stahre, 2008). These NBS features have been implemented through complex collaborative partnerships and varying degrees of public participation, but their impacts are not evenly felt throughout the city.

Today Malmö, the third largest city in Sweden, has an international reputation as a model for sustainable development (Austin, 2013). But the roots of Malmö's commitment to sustainability lie in a difficult time: the collapse of the textile industry in the 1960s and 70s and the subsequent collapse of the shipbuilding industry in the 1980s. After an unsuccessful attempt to replace the shipbuilding industry with automotive manufacture the city faced crisis. In the 1990s, the city adopted a "post-industrial strategy," leading to a dramatic and rapid change in the city, largely centered around the Western Harbour development (Holgersen, 2014). According to one researcher:

> "The idea from the […] management of Malmö was—they sat down in the 90s and said 'What shall we do to avoid bankruptcy?' […] And then the strategy primarily concerned two aspects: one was bringing the university to Malmö, which succeeded within two years or so, started in 1997, and the other was to establish extremely attractive housing areas, because Malmö didn't have them. […] Many well-situated people left Malmö in the 70s, and 80s. They moved. […] And then the working people, the industries, the heavy industries, the wharf industry for instance […] was torn down in the 80s. It was the world's greatest wharf, the biggest in the whole world, with 5000 employees […] but it disappeared in the 80s. So Malmö was on its way to bankruptcy."

"Green" and "environmental" aspects of urban development formed an integral part of this new conceptualization of Malmö, but despite this the city still faces issues of poverty, segregation, and social unrest, as well as environmental challenges (Holgersen, 2014). At the same time the city was reconceptualizing itself as a sustainable city, it also accepted large numbers of refugees and immigrants from Eastern Europe and the Middle East. Population growth since the economic collapse can be attributed to the ongoing influx of immigrants, while Swedish-born citizens have continued to move out of the city or to more expensive neighborhoods in the western part of the city (Baeten, 2012; Rodenstedt, 2014).

Since the municipal government began to discuss sustainability in the 1990s (Stahre, 2008), Malmö has implemented many projects that fall under the umbrella of NBS, mostly in middle-class and wealthy neighborhoods located further from the city center. Many of the early projects dealt with stormwater management, as Malmö is vulnerable to flooding and the combined sewage and stormwater system could not handle high volumes of stormwater (Kazmierczak and Carter, 2010; Stahre, 2008). The best-known example is the retrofitting of the Augustenborg development with an open stormwater system consisting of canals, water channels, retention ponds, wetlands, green spaces, and green roofs (Kazmierczak and Carter, 2010). The earliest example was the Toftanäs Wetland Park, which was designed as an extensive park area that served as drainage and filtration for the Toftanäs development and

implemented in 1989-1990. Other nature-based drainage solutions are scattered throughout the city, often doubling as eco-corridors (Stahre, 2008).

Green roofs have been widely implemented in Malmö due to the municipality's adoption of the Green Space Factor first developed in Berlin as the Biotope Area Factor (Kruuse, 2011; Landschaft Planen and Bauen, 1990). The goal of the GSF is to ensure a minimum amount of green cover in every building lot (Kruuse, 2011), which in practice often meant green roofs. Green roofs form part of the stormwater management system in Augustenborg (Kazmierczak and Carter, 2010), and are also used in the Western Harbour developments (Austin, 2013) and Malmö's largest expansion area, Hyllie (Baetan, 2012).

Implemented projects have exhibited varying degrees of success, particularly on environmental and social fronts. This chapter will focus on possible NBS in two established developments, Augustenborg and the Western Harbour Bo01 development, as well as the currently in-progress Hyllie development, which illustrates trends in urban planning focus in Malmö. Augustenborg represents use of NBS in retrofitting or regeneration of an established neighborhood, while the Western Harbour and Hyllie represent different approaches to incorporation of NBS into planning from the beginning.

4.1 Eco-City Augustenborg

Augustenborg is a residential neighborhood in Malmö originally developed in the 1950s, but by the 1970s degenerating conditions had led to residents moving away. In 1998, the City of Malmö began a partnership with the social housing company MKB to regenerate Augustenborg as an "eco-city," working with residents to create a socially, ecologically, and economically sustainable settlement (Stahre, 2008). This urban renewal effort focused on enhancing green and blue infrastructure, installing NBS (referred to in literature as "ecosystem-based solutions" or "sustainable urban drainage systems") for managing stormwater and waste to mitigate flood risk and enhance biodiversity in the neighborhood, as well as improving waste management and transportation (Granberg, 2001; Kazmierczak and Carter, 2010).

4.1.1 Project Objectives

The Augustenborg neighborhood has historically been vulnerable to floods. Stormwater was handled by a combined sewer system that handled both sewage and runoff, which overloaded in periods of heavy rainfall, causing basement flooding and sewage to enter watercourses (Kazmierczak and Carter 2010; Stahre, 2008). The issue of combined stormwater/sewage runoff and flooding is very common in Sweden, as older systems, many 19th century, cannot handle current capacity during heavy rainfall (Cettner, Söderholm, and Viklander, 2012). Such floods were predicted to grow more frequent as warming climate leads to increased rainfall, adding a climate change component to an annual pressure (Kazmierczak and Carter 2010). Flooding in general is an environmental challenge that is increasingly viewed as one particularly amenable to NBS or ecosystem-based adaptation (van Wesenbeeck et al., 2014).

In addition to this pressing problem, Augustenborg was a declining neighborhood with high tenant turnover and an unemployment rate of 30%, much higher than Malmö's average (Kazmierczak and Carter, 2010).

The overall objectives of the Augustenborg regeneration included (among others) 1) enabling residents to play a role in planning and implementation, 2) implementing a new stormwater

system that would resolve the flooding and waste management problems, 3) demonstrating the potential of green roofs (Granberg, 2001).

4.1.2 Drivers

Malmö had previously implemented smaller open drainage projects: wetlands, ponds, drainage corridors, and identified side benefits such as recreation value, pollution mitigation, and increased biodiversity. In some cases, such as the Toftanäs Wetland Park, an open drainage system was clearly a cheaper option than constructing new pipes. In order to traditionally retrofit Augustenborg, the system would have to be upgraded to a duplicate sewer system with separate pipes for sewage and stormwater (Stahre, 2008). This would have required extensive earthworks and could have created bottleneck problems where the system interfaced with older systems (Kazmierczak and Carter, 2010).

The drivers of the decision to integrate open drainage techniques for an ecological solution were the general poor social and economic situation of the neighborhood and the urgent pressure of flooding and waste management problems. By implementing an open drainage system, planners hoped to both solve the flooding and waste management problem and make the neighborhood more attractive by increasing biodiversity and providing attractive green spaces and water features (Kazmierczak and Carter, 2010; Stahre, 2008).

Several of the stakeholders interviewed also emphasized the importance of key individuals in driving this project, particularly Peter Stahre, who emphasized collaboration between different technical departments in Malmö as well as the public, including before environmental concerns were commonly integrated into urban planning in Sweden (Stahre, 2002; Stahre, 2008).

4.1.3 Implementation

A variety of NBS were used to construct an open drainage system for the Augustenborg neighborhood, which covers approximately 20 hectares (0.2 sq km). The goal was to handle the majority of rainwater via this open system, rather than the existing sewer system, using a network of green spaces, drainage channels, and holding ponds to reduce flooding by 70% and eliminate combined sewer overflow (Kazmierczak and Carter, 2010; Stahre, 2008).

The new open drainage system was constructed to handle as much rainwater as possible near the source via local infiltration on green roofs, lawns, and permeable parking lots. Heavy flows could be detained in ponds and temporary flooded areas and then transported slowly in 6 km of swales, ditches, and canals (Kazmierczak and Carter, 2010; Stahre, 2008). Stahre (2008), one of the key individuals driving the project, divided the system into four parts:

- The 9,500 square meter Augustenborg Botanical Roof Garden
- The central drainage corridor
- The Lönngatan drainage corridor
- Other features such as additional green roofs, permeable parking lots, local detention ponds, and floodable areas (*Figures 4-1, 2, 3*)

The use of wetland plants in canals and ponds provided some water treatment benefits (Stahre, 2008; *Figure 4-1*).

Figure 4-1 A holding pond in Augustenborg

Source: "Augustenborg, Malmö, 2014" (https://commons.wikimedia.org/wiki/File:Augustenborg,_Malm%C3%B6,_2014.jpg) by Jorchr is licensed under CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/).

Figure 4-2 A green roof in Augustenborg

Source: public domain (Niklas Nilsson, 2007)

Figure 4-3 An empty drainage canal in Augustenborg

Source: public domain (Niklas Nilsson, 2007)

4.1.4 Impacts

Augustenborg has been internationally hailed as a success, and its impacts have been evaluated more thoroughly than many other NBS projects in Malmö (*Table 4-1*). Unlike other high-profile, expensive developments, Augustenborg remains a more economically accessible neighborhood for Malmö, with 1,600 out of 1,800 homes available as rentals and 62% of residents reporting a foreign background in 2007 (Rolfsdotter-Jansson, n.d.).

Table 4-1 Impacts of the Augustenborg Redevelopment Project

Environmental	*Social*	*Economic*
• 90% of stormwater runoff is now directed into the open stormwater system and can be handled locally • The sewage system now handles almost exclusively wastewater • No floods between 2002-2010, even during a 50-year rain event in 2007 • Green roofs absorb ~50% of annual rainfall and provide cooling in summer • Biodiversity increased by 50% • Carbon emissions and waste generation decreased by 20%	• 20% of residents participated in dialogue and/or design • Election participation increased from 54% to 79% • Tenancy turnover decreased	• Unemployment fell from 30% to Malmö's average of 6% • Three local "green" companies were established

Source: Kazmierczak and Carter (2010)

One researcher described Augustenborg as

> "[A] very rare, classic example of using nature-based solutions to solve a technical problem. […] The municipality has to pay for [damages from sewage overflow]. So they were forced to [find a solution]. And then they solved it! They had the alternative to make a huge, huge concrete basin under the street or take care of stormwater on the surface, take out the stormwater fraction from the combined system. That was what they did. And then they used nature, they used soil, plants, green to take care of it. It's just spot-on a nature-based solution to a technical problem. [It was cheaper] and better. It attracted the attention of the world."

During record flooding in 2014, according to planners in the City of Malmö, there was some backwash from the flooded sewer system in basements in Augustenborg, but preliminary field studies indicated that the neighborhood managed flooding better than it would have before the retrofit (Mottaghi, Aspegren, and Jönsson, 2015). One interview subject noted that some at MKB thought the presence of backwash in basements was proof the system didn't work, while others realized that the damage would have been worse without the system in place. Before the system was installed, floods in Augustenborg were annual. Raising awareness of the effectiveness of the new drainage system was a challenge.

Augustenborg demonstrates the benefits of combining different kinds of NBS with green technology. While the green roofs absorb up to 50% of annual rainfall, and make use of previously unused space, they are less effective during stormflow peaks (Kazmierczak and Carter, 2010; Mentens, Raes, and Hermy, 2006). The drainage corridors, retention ponds, and floodable areas are thus essential for handling cloudburst events. Green roofs also offer side benefits, such as temperature regulation and prolonging the life of the roof structure (Stahre and Geldof, 2003).

The success of Augustenborg and previous open drainage projects led to the development of a drainage policy for the city that incorporated open drainage systems, and the widespread implementation of open drainage features in new developments in Malmö (Stahre, 2002). Although the open drainage system concept for handling stormwater is efficient and turns stormwater into a benefit for citizens rather than simply a problem, the planning process for such systems is more complex and requires more cooperation between departments than traditional gray drainage infrastructure (Stahre and Geldof, 2003). Despite Augustenborg's success, retrofitting of older neighborhoods on the same scale has not yet been repeated in Malmö.

4.2 Western Harbour

The Western Harbour (*Västra Hamnen*) was Malmö's first big green development project planned from the beginning. In the late 1990s, the city decided to host an international City of Tomorrow housing exhibition in 2001, locating it in the western part of the former wharf area of the Western Harbour (Stahre, 2008). This ecological district was designated the Bo01 development. The goal was to revitalize this former industrial area by creating a dense, mixed-use neighborhood using sustainable planning and building technologies, with a strong emphasis on aesthetics, open space, and energy efficiency (Austin, 2013; Kruuse af Verchou, 2005). Two additional ecological districts in the western Western Harbour were subsequently developed, building upon lessons learned in Bo01: Bo02 (Flagghusen) and Bo03 (Fullriggaren) (Dalman, Månsson, and Jansson, 2011). A variety of NBS have been incorporated into these developments, including open drainage systems previously

implemented elsewhere in Malmö, as well as habitat biotopes designed to improve biodiversity.

4.2.1 Project Objectives

Unlike Augustenborg, the Western Harbour was not an existing neighborhood facing an obvious pressing environmental problem like flooding. The problem the City of Malmö sought to address by creating Bo01 was the broader problem of socioeconomic decline (Austin, 2013; Holgersen, 2014). Within the development, various GBI projects were implemented to produce benefits such as water management, biodiversity attraction and retention, and recreation areas, as well as to generally improve social wellbeing.

4.2.2 Drivers

The initial decision to include GBI in the Bo01 development could be seen as driven by economic desperation. According to one architect and researcher, the city faced bankruptcy, so the ambitious secretariat in charge of the housing exhibition and city management developed a two-pronged strategy, hinging on bringing a university to Malmö and establishing attractive housing areas. At this point, the city faced problems so severe that perhaps the inertial barriers to trying sustainable solutions on a large scale were reduced, and GBI was integrated into the plan from the beginning. The city's crisis motivated a high-risk experiment with sustainable design (Austin, 2013).

During construction of Bo01, Malmö adopted the Green Space Factor and began developing the Green Points System, in order to mainstream biodiversity concerns into urban planning and enhance the greenness of dense developments. These guidelines drove the implementation of green roofs and other biodiversity features in the Bo02 and Bo03 developments as well, although the exact specifications evolved over the course of development based on prior experience (Kruuse, 2011). An area ecologist was also hired to support the project. An early version of the city's stormwater policy, which included principles such as utilizing stormwater as a positive resource and open solutions being prioritized as much as possible in new developments, was completed in 2000 (Haghighatafshar et al. 2014).

4.2.3 Implementation

As the Western Harbour sits on the edge of the Öresund strait, many of the water management pressures that affect suburbs such as Augustenborg are not relevant. In addition to structural features such as raised land and permeable paving, developers in Bo01 also installed features of an open stormwater drainage system, such as water channels, rain gardens and vegetated courtyards, and holding ponds. Each courtyard has its own stormwater pond. Much of the landscaping consists of native plants in "biotopes" to mimic nature and enhance biodiversity. Water not absorbed by vegetation or through infiltration is carried via channels to a saltwater canal constructed through the middle of Bo01 or directly to the strait (Austin, 2013; Kruuse, 2011; Kruuse af Verchou, 2005).

Unlike in other neighborhoods, developers did not regard the open stormwater drainage system as technically necessary—pipes would have been sufficient. The open system was chosen in part for its aesthetic value and in part as a pilot for such a system in a dense urban development (Kruuse, 2011). Although the system has proved popular with residents, some engineers expressed concerns about the lack of piping, and subsequent development in the Western Harbour did not follow the same approach (Kruuse, 2011; Kruuse af Verchau,

2015; Stahre, 2008). The city's current policy, according to one planner, is to reserve open drainage systems for locations where they are necessary.

Most other NBS in the Western Harbour are landscaping and habitat pilot projects aimed at improving aesthetic value and increasing biodiversity. Many of these were implemented as part of the BiodiverCity program, which seeks to increase biodiversity, enhance ecosystem services, and improve public health, using six categories of project (Miljöförvaltningen, n.d.):

- Urban habitats or biotopes
- Trees in the streets
- Green facades and walls (*Figure 4-4*)
- Green roofs (*Figure 4-5)*
- Mobile plant systems
- Three dimensional greenery (e.g. for shading)

Figure 4-4 Vertical greenery and bird boxes in the Western Harbour

Source: Author (28 May 2016).

Figure 4-5 Green roof on a recycling building in the Western Harbour

Source: Author (28 May 2016).

Initial phases of the project focused on developing new types of GBI, particularly smaller projects that could fit into a dense urban environment, in partnership with private developers, architects, universities, and consultants (Miljöförvaltningen, n.d.). According to the project manager, the latest phase, which began in January 2016, focuses more on commercializing the more successful pilot projects, but new pilot projects will also be developed. One notable aspect of the BiodiverCity project is the development of mobile plant systems or moveable biotopes.

There are also a number of biotopes incorporated into courtyards and parks to encourage biodiversity, such as the miniature alder, beech, and oak groves in Ankarpark (*Figure 4-6*). The saltwater canal was seeded with macroalgae, fish, and other marine organisms (Kruuse af Verchou, 2005).

Figure 4-6 Biotope grove in Ankarpark

Source: Author (28 May 2016).

4.2.4 Impacts

Most study of specific impacts or outcomes of NBS in the Western Harbour has focused on biodiversity measures and resident perception of aesthetics. Interviews with Bo01 residents indicated generally positive feelings about water features such as landscaped ponds and drainage canals, which give a "unique character to the whole settlement" (Stahre, 2008:66). Although residents were willing to pay more for the open drainage system and the general perception was that litter is only a *more visible* problem in an open system rather than a *greater* problem (Stahre, 2008), according to one planner there has been internal debate about the problem of rapid algae growth in the ponds.

In theory, vegetation in ponds and other parts of the open drainage system should improve water quality, but there is probably not enough vegetation to achieve significant water quality improvement (Austin, 2013; Kruuse af Verchou, 2005). This has not been quantitatively measured, and assumptions about water quality impacts of NBS in the Western Harbour are speculative.

Biodiversity outcomes have been mixed at best, although available data is old and primarily limited to Bo01. Published biodiversity evaluation of the Bo01 landscaping is mostly based on surveys conducted shortly after construction, in 2002-2003. Biodiversity in Bo01 was compared with the older seaside development of Ön. Breeding birds were chosen as one measure of biodiversity, as bird abundance and diversity indicates food abundance and varied habitats. Both abundance and diversity in Bo01 were about half of that in Ön. Surveys of the constructed woodlands in Ankarpark found declining plant diversity and colonization by weeds between 2001-2003. Biodiversity of the saltwater canal fared better, and drainage pond vegetation was relatively stable (Kruuse af Verchou, 2005). It is possible that biodiversity indicators improved over the following decade, but data was not available. During site visits in late spring/early summer of 2016, no insect life was observed in the vegetated ponds near the waterfront in Bo01, which were thick with filamentous algae (*Figure 4-7*).

Figure 4-7 Algae and rubbish in Bo01 drainage pond

Source: Author (28 May 2016).

The saltwater canal, which had been seeded with numerous native marine species, also exhibited abundant filamentous algae, but only a few small fish were observed (*Figure 4-8*). While these observations were only casual and would need to be confirmed, they suggest problems with eutrophication, which can cause anoxic conditions that reduce marine biodiversity (Korpinen and Bonsdorff, 2015).

Figure 4-8 Filamentous algae in the Bo01 saltwater canal

Source: Author (28 May 2016).

Despite the relatively low biodiversity values from an ecological point of view, a 2002 survey of residents found a high degree of satisfaction with parks and green areas (4.4 on a 5-point scale) (Kruuse af Verchou, 2005). This may improve social and psychological wellbeing (Kati and Jari, 2016).

In the broad sense, the Western Harbour development has been successful: today the Western Harbour is an attractive neighborhood that serves as a national and international model for sustainable architecture (Austin, 2013). Malmö's economy is no longer in crisis, and many of the NBS first implemented in Augustenborg and the Western Harbour are now part of the planning toolkit in the municipality. The GSF and Green Points Systems developed for Bo01 and refined in Bo02 and Bo03 are now adopted at the municipal level for use in other developments (Austin, 2013; Kruuse, 2011).

On a social level, the initial Western Harbour development was widely criticized for its high prices, lack of rental housing, and social segregation (Austin, 2013; Jansson, 2005). Costs in the Bo01 neighborhood in particular were always high, and doubled between 2001 and 2007 (Austin, 2013). The City of Malmö attempted to address these social sustainability criticisms in the Bo02 and Bo03 developments, which have a much greater percentage of rental housing and which prioritizes affordable housing. Rental apartments in Bo02 in 2011 were priced at approximately 1,400 SEK/square meter annually, which was cheaper than the Western Harbour (1,600 SEK/sq. m./year and higher) but still more expensive than many other neighborhoods in Malmö (Austin, 2013; Dalman, Månsson, and Hansson, 2011; Kruuse, 2011).

It costs two to three times as much to maintain the open drainage system in Bo01 as traditional landscape plantings, mostly in algae and trash removal and cleaning of the drainage canals (Stahre, 2008). The more affordable Bo02 and Bo03 developments did not follow the same open drainage approach. The GSF used in Bo02 was proportional and generally lower, and the Green Points System was altered to focus solely on promoting biodiversity, rather than ecosystem services such as improving stormwater management. Greenery and urban biodiversity were chosen as focuses for environmental goals in part due to the ability to deliver them affordably. However, resident satisfaction with the green spaces in Bo02 was lower. The municipality again adjusted and reweighted the GSF to encourage more and higher quality green spaces (Kruuse, 2011).

Arguably, the greatest impact of the Western Harbour development has been as a testing and demonstration ground for sustainable building, including GBI (some of which may be considered NBS as well), slowly overcoming skepticism and developing tools for development (Kruuse, 2011). The development and refinement of the GSF and Green Points System in the Western Harbour affected city planning policy, mainstreaming some of the concepts (Austin 2013, Kruuse, 2011). Perceptions among researchers and planners of the effectiveness of these policies were mixed. While all agreed that they have quantitatively increased green space and particularly led to broad-scale implementation of green roofs, some were concerned that the goal or narrative of the GSF was unclear and implementation was not always maximally beneficial. For example, under early versions of the GSF, a manicured lawn was viewed as equivalent to a more biodiverse meadow (Kruuse, 2011).

4.3 Hyllie

The Hyllie development currently under construction in Malmö is Malmö's largest area of expansion (Baetan, 2012). Centered around the Hyllie train station, the development aims to become a climate-friendly, energy- and resource-efficient mixed-use city that serves as a new

city center and provides a transition between town and country (City of Malmö, n.d.). After completion, the development will offer 7,000 homes, housing 15,000 people (Baetan, 2012).

4.3.1 Project Objectives

The city of Malmö has a number of goals for the Hyllie development (City of Malmö, VA SYD, and E.ON, n.d.). These include

- Energy efficiency.
- Attracting biodiversity and providing habitat
- Stormwater management.
- Including green spaces and features in a dense development

4.3.2 Drivers

A key driver of many of the implemented and planned green features in Hyllie is the GSF, originally introduced by the City of Malmö during development of the Western Harbour and now incorporated into all new developments in Malmö (Kruuse, 2011). The municipality's commitment to building "dense but green" also serves as a driver for implementing vegetation-based NBS such as green roofs, which can be incorporated into a mixed urban environment.

4.3.3 Implementation

The most notable example of a possible NBS implemented in Hyllie is the green roof garden or park of the Emporia Shopping Center. The roof is one of the world's largest green roofs at 27,000 square meters and is open to the public. It functions as a park, with a mixture of planting and habitat types, including open paved areas, grass, fenced extensive sedum roof, fenced biotopes of mixed plants, and planter beds. Raised areas conceal ventilation and other infrastructure and provide windbreaks (*Figures 4-9, 10*).

Figure 4-9 Roof park on Emporia Shopping Center, Hyllie

Source: Author (19 May 2016).

Figure 4-10 Roof park on Emporia Shopping Center, Hyllie

Source: Author (19 May 2016).

One architect involved in the Hyllie project described the main goal of the roof as being to encourage biodiversity, with rainwater management and recreation as secondary goals, all supporting the commercial side of the shopping center. Most of the roof is planted with sedum, according to the provider of the green roof system there are more than 50 species of plants, including perennials, grasses, and trees (DIADEM, 2012).

4.3.4 Impacts

The Hyllie development is still in a relatively early stage, so little evaluation of the effectiveness of the Emporia green roof or other green elements has been conducted. The Scandinavian Green Roof Association awarded the Emporia roof park the 2013 Green Roof Award, which takes into account biodiversity, rainwater management, recreational value, sustainability, and design in identifying innovative projects (Steen & Ström Sverige AB, 2013; SGRA, n.d.):

> "The roof park at the Emporia shopping center in Malmö is an exciting example of how green roofs can lift our urban environment to new heights. It showcases an impressive variety of green roofing solutions achieved through a unique collaboration between suppliers, the developer, and architects."[2]

Green roofs such as the Emporia roof park can provide temperature regulation, water management, and sound dampening. However, it is unclear to what degree the Emporia roof park delivers these services. Similarly, there does not appear to be any existing data quantifying its use as a recreational space. The main goal of the green roof is to encourage biodiversity, which is not within the scope of NBS in the strict sense.

[2] "Takparken på köpcentret Emporia i Malmö är ett spännande exempel på hur gröna tak kan lyfta våra stadsmiljöer till nya höjder. Den visar upp en imponerande variation av gröna taklösningar som åstadkommits genom ett unikt samarbete mellan leverantörer, byggherre och arkitekter."

There are also some concerns about effectiveness of implementation. One interview subject criticized aspects of implementation of the Emporia roof park, such as the use of expanded clay drainage material instead of soil, and the extensive use of thin sedum blankets (*Figure 4-11)*, and questioned whether the project had optimally taken roof steepness and wind factor into account.

Figure 4-11 Sedum mat on Emporia green roof

Source: Author (19 May 2016).

5 Discussion

This chapter presents a more detailed case for a narrower definition of NBS. It also addresses the research objectives by analyzing impact, drivers, and barriers of the cases presented in chapter 4 in the context of the theoretical framework of practice theory and communities of practices.

5.1 (Re)defining NBS

It became clear in the course of interviewing and document analysis that the literature-based definitions of NBS are difficult to apply. Many stakeholders in Malmö expressed a discomfort or uncertainty when asked to define NBS; it is not a term commonly used in Malmö or in Sweden in general. Stakeholders were more comfortable discussing ES and GBI, but often unclear on where these concepts overlap with and differ from with NBS.

> "To me it doesn't bring anything new, actually. The ecosystem services concept is really good for being able to describe values of nature-based solutions, and also I think the green-blue infrastructure describes what it's all about—that you need an infrastructure, really, working infrastructure, a working ecosystem. Nature-based solutions—no, I don't think so. And I think it's not very long ago that the EU talked about green infrastructure a lot, so I'm surprised that they abandoned that term and started using nature-based solutions."
> –*municipal planner*

> "I'm thinking – and well, tell me if I'm wrong, obviously. […] I'm thinking a lot about sort of in the line of ecosystem services. Different types of ecosystem services that nature provides to deal with problems and stresses."
> –*researcher and planner*

Others saw clear distinctions between NBS, ES, and GBI:

> "I think that the concept of nature-based solutions is kind of the same [as with the ES concept]: that suddenly we have a good word for summarizing the idea that we have been arguing for, that we have tried to establish for [a very] long time and which has been overly hard sometimes to explain. You say 'It's a *nature*-based solution.' 'What's the difference?' 'It's a nature-based solution.' 'Ah, okay. It's not technically based or economically based, it's nature-based.' […] There's a huge difference [from ecosystem services], because the service is what you get out of a nature-based solution. The nature-based solution is what you do, how you do it is nature-based, and the service is the output of the solution. So [for example] this [phone] is a technical solution and calling someone is a service. Nature-based solution and ecosystem services. That's absolutely two good concepts that are—you have to use them [both]."
> –*researcher*

> "They're very similar, but ecosystem services – I'd say nature-based solutions could be used as a problem solver, like more direct[ly]. Because I'm an architect I think of rooms and stuff. Also, going back to the wind problem, you could shape—you could use the trees to create a room, and you would get ecosystem services from that. But with ecosystem services, I think [that]

> the function doesn't have to be as specific. I mean the trees would give you all these services anyway, but with the nature-based solutions they're more targeted to address a problem, a specific problem. But they are very similar, I'd say."
> –*architect*

Similarly, while GBI *may* be implemented in order to solve problems, as in the case of Augustenborg, there are also other reasons to implement GBI. Much of the value of green infrastructure such as parks is framed in terms of desired "benefits" or ES, particularly cultural ES, a capital-based approach rather than a risk-based approach (Matthews, Lo, and Byrne, 2015).

This lack of clarity on definition even within the literature perhaps contributes to the caution stakeholders in Malmö expressed regarding NBS—while most thought it had potential pedagogical or communication ('marketing') value, some were unsure that it would bring functional value beyond current concepts that are already closer to mainstreaming. The appeal of NBS as a concept is its apparent simplicity—but it has been defined in such broad and contradictory terms that it becomes more confusing than clarifying.

Based on the literature review in chapter 2, a revised working definition of NBS in the broad sense might look something like this:

> *Nature-based solutions address environmental, social, and/or economic problems by using nature as a provider of ecosystem services and green and blue infrastructure or by mimicking nature (biomimicry), but not by genetically modifying organisms. NBS are sustainable in the long term and resilient to changing pressures, taking local conditions into account and often enhancing or building upon existing ecosystem services and infrastructure in order to solve problems and deliver some combination of environmental, social, and economic benefits.*

This definition, while it covers the majority of actions defined as NBS in the literature (Balian, Eggermont, and Le Roux, 2014; EC, 2015; Potschin *et al.*, 2014; etc.) and is somewhat narrower than that of, for example, the European Commission (EC, 2015), is still quite complex. It requires further definition of ecosystem services, green and blue infrastructure, and other terms that overlap significantly with NBS in order to remove the ambiguity of understanding revealed in interviews.

The key to narrowing the definition of NBS to something more functionally useful, as briefly outlined in section 3.1, lies in the European Commission's mention of "sustainable alternatives" to human activities that have failed to recognize ecological limitations (EC, 2015:24). However, it does not go far enough.

In order to be meaningful, nature-based solutions must indeed be *alternatives*, but to other kinds of solutions, not to activities. Thus when planners and other actors in the urban context face a problem, they can evaluate a range of potential solutions, of which NBS are one type. The most common type of solution to environmental problems is of course technological; economic or social problems may have political, legal, social, and economic solutions. Under this definition, environmental problems that cannot be solved with non-nature-based solutions are excluded from the field.

For example, if a decline in bat population is identified as a problem, the only way to reverse it is to encourage more bats, e.g. by putting up bat boxes or protecting habitat, or perhaps by

captive breeding. There is currently no technological way to create more bats. These solutions might qualify as an NBS in the broad, literature-based sense, but not in the narrower sense proposed here.

By contrast, if the identified problem is an increase in the biting insect population, this could be addressed 1) technologically, e.g. by pesticide treatment, or 2) by nature-based methods that encourage and enhance natural predation ES such as putting up bat boxes to attract more breeding bats or stocking water bodies with dragonfly larvae. In this case, the second set of approaches would be considered to be NBS in the strict sense.

This narrow definition can be summarized much more simply:

> *Nature-based solutions provide an alternative to conventional, non-nature-based (e.g. technological) solutions to environmental, social, and economic problems. They utilize systems and processes based in nature, such as ecosystems and ecosystem services, organisms, and hydrologic processes, to create resilient, sustainable solutions.*

In general, the planning approach in Malmö for NBS appears to have shifted over the last two decades from a risk-based concept utilizing NBS in the narrow sense as a subset of GBI, as in the case of Augustenborg, to a capital concept more broadly synonymous with GBI in general. Later projects in the Western Harbour and Hyllie prioritize biodiversity, recreation, and more nebulous social health benefits, but do not respond clearly to specific problems, and often aim for ES that are by definition nature-based, such as greater biodiversity. The majority of recent "NBS" projects in Malmö, while beneficial in some respects, thus cannot be considered NBS in the narrow sense, as they are not being used as alternative solutions to specific problems.

5.2 Impacts of NBS in Malmö

Although NBS are highly visible in parts of Malmö and contribute to its international reputation as a "green city," the benefits and drawbacks are often difficult to quantify, both due to a lack of evaluation and to unclear goals and targets. The positive impacts of open stormwater drainage systems are readily apparent, but other NBS projects are more difficult to measure, as is the relationship between NBS projects and potential green gentrification.

5.2.1 Benefits

Malmö's current economic situation owes a great deal to its rebranding in the late 1990s and early 2000s as a "green" city, with a central policy commitment to sustainability driven by near-collapse in the 1980s and 1990s (Holgersen, 2014). High-profile, internationally famous development projects like Augustenborg and the Western Harbour helped make this reconceptualization of the city possible, and NBS played key roles in these developments. Qualitatively, it is easy to see that the Western Harbour is no longer an abandoned post-industrial area, but now a desirable residential and office community, in part thanks to the NBS integrated into the development, although other factors such as Malmö's connection to the Öresund Bridge played a major role in the city's economic revival (Jansson, 2005). The average income of residents in the Western Harbour is higher than Malmö's average, suggesting that it succeeded in retaining or attracting more well-off citizens who previously would have moved away (Holgersen and Malm, 2016). The relatively good performance of Augustenborg's open stormwater drainage system in the 2014 flooding is an obvious benefit, and confirmation of the effectiveness of Malmö's slow mainstreaming of open stormwater drainage (Mottaghi, Aspegren, and Jönsson, 2015; Stahre, 2008). According to one planner,

after the Bo01 development in the Western Harbour, the City of Malmö decided to save open solutions for areas where they were genuinely necessary.

Quantitative evaluation of the benefits of specific NBS projects for Malmö is more difficult. Evaluation of the benefits of the Augustenborg redevelopment included quantitative factors resulting from NBS such as percentage of stormwater handled in the open system, reduced flooding frequency, and percentage of rainfall absorbed by green roofs, as well as factors related to the implementation of NBS as part of the overall redevelopment, such as changes in the unemployment rate (Kazmierczak and Carter, 2010).

After Augustenborg, city planning focus began to shift, and later projects implemented in the Western Harbour and Hyllie were focused more on aesthetic and psychological problems of the urban setting—providing habitat for animals and beautiful green spaces for recreation and enjoyment. These projects, while they can be broadly categorized as NBS in the current sense of the literature, do not meet the narrower definition proposed by this thesis, as many of them do not address problems that have alternate technological solutions, and others lack a clear problem to respond to. In addition, their benefits are vague and poorly understood. For example, evaluation studies were typically based on surveys that asked residents about their subjective perceptions of the open drainage systems and biodiversity features (Stahre, 2008; Kruuse af Verchou, 2005). While citizen satisfaction is worth assessing, the lack of rigorous evaluation is a weakness for the future of Malmö's environmental program. Promotional literature produced by the city, with few exceptions, frames environmental claims for NBS in terms of "should" and "may," based on theory and literature studying previous projects elsewhere. In order to make strong arguments for continuation and expansion of NBS programs, NBS must be demonstrated to achieve solutions to environmental and other problems—as in Augustenborg.

After Bo01, published evaluation of the more quantitative aspects of NBS projects are absent, and even in the case of Bo01, it is unclear how much long-term evaluation was done. For example, Kruuse af Verchou (2005) discusses the results of biodiversity surveys performed in Bo01 2002-2003, shortly after the completion of the Western Harbour, noting that biodiversity was "expected to increase in the future" (Kruuse af Verchou, 2005:178), even though in some areas it had already declined. No basis for these expectations of improvement was provided, and no further reports on biodiversity in Bo01 have been published, although more than 10 years have passed.

The benefits of NBS in Malmö, and sustainable development in general, are also primarily limited to wealthier neighborhoods, where the social and economic problems still facing Malmö are felt less strongly (Holgersen and Malm, 2016). The ongoing process of sustainable development in Malmö, although it is imperfect, has created and disseminated a large body of knowledge about urban ecological and environmental problems and ways to address them, according to interviews and published literature (Kruuse, 2011; Holgersen and Malm, 2016).

5.2.2 Drawbacks

In most cases, there do not seem to have been immediate negative effects or drawbacks to NBS implementation in the areas of Malmö studied. For example, concerns that open stormwater systems might present a safety hazard were dismissed by residents of Bo01 (Stahre, 2008). The majority of problems that arose were problems with implementation, rather than EDS, and can be divided into the categories of

- Maintenance challenges

- Non-ideal implementation
- Fewer benefits than expected
- Additional expense

Maintenance challenges, such as the algae in stormwater retention ponds, can be often addressed by changes in maintenance protocols—in 2008, the city was testing techniques for preventing or limiting rapid algae growth—or by finding ways to modify the system to convert EDS and other drawbacks to natural capital or benefits (Stahre, 2008; Stahre and Geldof, 2003).

Additional expense can be difficult to quantify: for example, while maintenance of GBI in Bo01 may be 2–3 times as expensive as maintaining conventional landscaping, how do open stormwater systems compare over time to conventional piped systems, which also require maintenance? Both initial and operating cost must be taken into account, but ultimately, cost—provided the city has the money—does not seem to be the deciding factor for the city in deciding whether to use NBS or technological solutions. Residents of Bo01 indicated a willingness to pay more for the open stormwater drainage system because they appreciated the aesthetics, something NBS can offer as a side benefit above and beyond the solution to the problem in question (Stahre, 2008). Despite apparent public willingness to fund maintenance of green-blue features, however, there is currently a disconnect between the building and planning process and maintenance, according to discussion at a 2008 workshop on the sustainable urban landscape held in Lund that included city planners, architects, and researchers (Bylander, 2008:11):

> "After 8 years, all the trees are gone. Benches are rotten. Everything is in ruin. You always get great budgets to do things, but small budgets to maintain things. This is the economical reality of the environmental design profession."
> *- Thorbjörn Andersson, professor and landscape architect*

This does not mean there are no broader drawbacks to NBS in Malmö. NBS are an integral and highly visible part of the "greening" of the city, a process not without negative socioeconomic impacts.

Some have argued that Malmö's commitment to sustainability is simply a "green fix," an economic strategy for overcoming a crisis of capital accumulation and maintaining growth that contains elements of greenwashing and may conceal issues of impact at multiple scales through its local focus. What creates a sustainable local society currently requires unsustainable resources from elsewhere (Holgersen, 2014; Holgersen and Malm, 2016). In this sense, NBS are probably the least unsustainable component of the Western Harbour on a broad scale—but they may also produce fewer local benefits, and as obvious aesthetic features they contribute to making the Western Harbour economically out of reach to a large percentage of Malmö residents, increasing social segregation. While NBS do not necessarily have to be technologically complex to implement, making them theoretically suitable for a range of socioeconomic contexts, thus far in Malmö their actual implementation has been largely limited to high-profile prestige projects aimed at attracting wealthy residents, despite the pressures of immigration and the urgent need for affordable housing and regeneration of declining neighborhoods (Baetan, 2012).

5.3 NBS Communities of Practice

The City of Malmö can be conceptualized as having multiple communities of practice relevant to NBS, with memberships drawn from the municipal government (architects, planners, ecologists, engineers, etc.), from private developers, architectural firms, public housing companies, and utilities, from the nonprofit world, and from academia. Key actors in past NBS projects can be seen in *Table 5-1*. It is important to note that responsibilities of departments have combined and split over the years.

Table 5-1 Actors involved in key NBS projects

	Augustenborg	*Western Harbour*	*Hyllie*
Environment Department (*Miljöförvaltning*)	x	x	x
City Planning Office (*Stadsbyggnadskontoret*)	x	x	x
Department for Water and Wastewater / VA SYD (after 2008)	x	x	x
Streets & Parks Department* (*Gatukontoret*)	x	x	x
Service Administration (*Serviceförvaltning*)	x	x	x
MKB (public housing company)	x		
Scandinavian Green Roof Institute	x	x	
Developers/architects		x	x
Independent housing exhibition secretariat		x	
Academia	x	x	?
*Formerly Parks & City Environment			

Sources: Bernstad Saraiva Schott, Aspegren, Bissmott, and la Cour Janson (2013); Rolfsdotter-Jansson, n.d.; Stahre (2008); Stahre and Geldof (2003); interviews.

The open drainage systems implemented from 1989–2008 were in large part driven by collaboration between the Water & Wastewater Department and the then-Parks & City Environment department (Stahre, 2008). In Augustenborg, these departments worked closely with MKB, the public housing company responsible for the apartments in the development (Rolfsdotter-Jansson, n.d.) After 2008, the water and waste management departments of Malmö and the neighboring municipality of Lund were merged into the public utility VA SYD (Bernstad Saraiva Schott et al., 2013), which continues to be a major actor in sustainable urban drainage implementation and maintenance in Malmö.

The collaboration between departments was fruitful because both departments brought specific expertise as well as differing but complementary goals: the Water & Wastewater Department aimed to achieve better management of stormwater, ideally at a lower cost than a traditional pipe system, while the Parks & City Environment Department wished to add value (or ES) to existing or new parks while improving the city environment (Stahre and Geldof, 2003). These departments also worked with the City Planning Office, as well as other departments, depending on the proposed implementation.

Other types of more symbolic NBS focused on delivering biodiversity and generally improving the urban environment implemented in newer developments like the Western

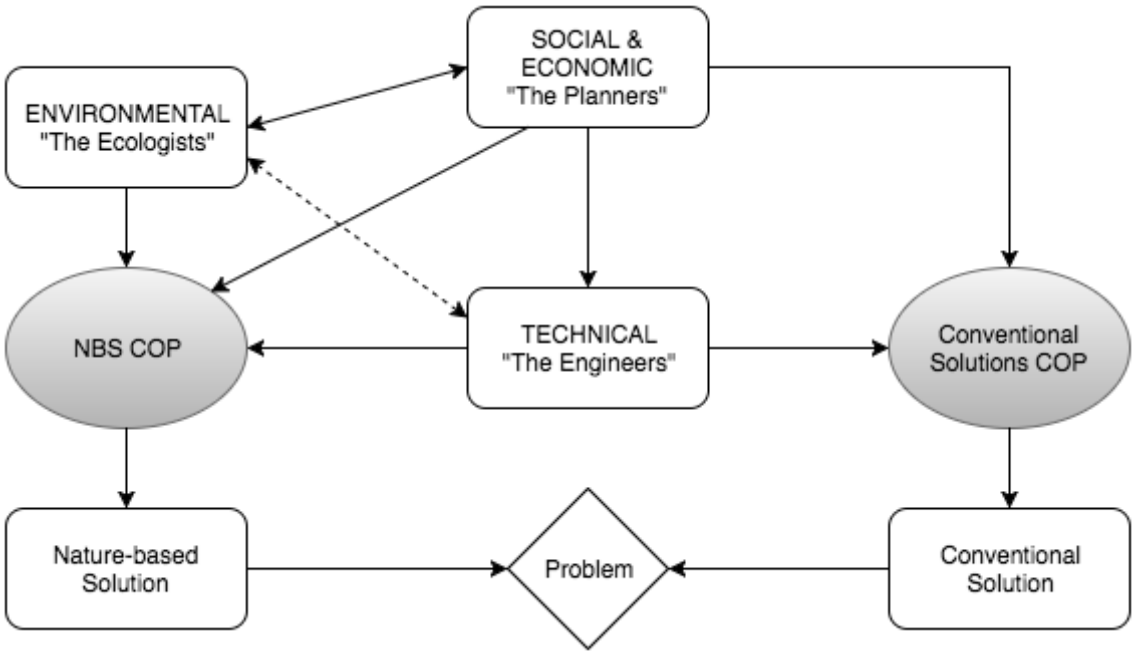
Harbour and Hyllie, by contrast, have been developed in large part by partnerships between the Environment Department and various private developers and companies, with early integration into the planning process through the City Planning Office. For example, the BiodiverCity pilot projects were created in partnership with various companies, which seek to develop them for commercial marketability in the current phase of the project.

In general, these actors can be loosely divided into three groups, which bring different focuses and practice expertise to the NBS COP in Malmö:

1. The "Planners," consisting of planners, architects, and parts of the development community, who bring a focus on social and economic aspects of development.
2. The "Engineers," consisting of those who design and implement solutions to problems and maintain the infrastructure of the city, including the water utility, Parks Department, and parts of the development community focused on the logistics of building. This group focuses on technical aspects of design and implementation.
3. The "Ecologists," primarily from the Environment Department and the academic community, who focus on the ecological and environmental aspects of NBS, including biodiversity, environment and public health, and ES.

The interactions, formal and informal, between these three COPs unite different actors and collectively form the NBS COP in Malmö (*Figure 5-1*).

Figure 5-1 The NBS community of practice in Malmö



Source: Developed by author.

Workers often turn first to coworkers and their larger network for information, rather than to written sources, and individuals are often rich sources of tacit knowledge, which can be difficult to preserve but which can provide shortcuts (Davenport and Prusak, 2000). The discussions and knowledge generated by COPs and the individuals within them are what permits the translation of theory into practice (Duguid, 2005).

The relative mainstreaming of open stormwater drainage systems in Malmö in both policy and practice owes a great deal to the building of cooperative links between previously uncooperative departments (Haghighatafshar et al., 2014). When it comes to other types of NBS in Malmö, these links are weaker, particularly between the Ecologists and the Engineers. This perhaps contributes to the vague goals and minimal evaluation for many of the biodiversity-focused projects. Similarly, although the Planners and Engineers still work closely in implementing drainage projects, the influence of Engineers to drive innovative new types of NBS projects seems to have waned with the loss of key individuals from that community.

The shift in focus from concrete solutions to concrete problems to broadly defined aspirational goals to some extent parallels policy shifts at the national level. Two models of sustainability are simultaneously being used in Malmö and in Sweden: one focused on solving environmental problems and controlling future outcomes, which can readily be operationalized, and one focused on creating flexible systems based on social consensus that can adapt to future conditions (Emmelin and Cherp, 2016). As with national policy, Malmö's approach to NBS has shifted to incorporate emphasis on vague, utopian "landscape" goals that are difficult to measure and operationalize. However, Augustenborg does demonstrate that it is possible to incorporate public consensus into scientific problem-solving goals, although this contributes to the complexity of the process for implementing open drainage systems (Stahre, 2008; Stahre and Geldof, 2003).

5.4 Drivers and Barriers for NBS in Malmö

Drivers and barriers are important factors to understand when seeking to change systems or mainstream new concepts (Hansen et al., 2015; Matthews, Lo, and Byrne, 2015; Wamsler, 2015). Drivers and barriers can be used to identify leverage points, places where changes can have a cascading effect on the entire system (Meadows, 2008). These drivers and barriers also interact with the practice and COP of NBS in Malmö.

The original intent was to discuss drivers and barriers separately. As research progressed, it became clear that they were closely intertwined, and that what some stakeholders perceived as drivers, others perceived as barriers to significant change. Thus, drivers and barriers will be discussed together.

During interviews, stakeholders were asked about the drivers and barriers they perceived to NBS implementation in Sweden, both at the local level in Malmö and the national level. Related concepts such as ES and GBI, which are more integrated into planning and policy in Sweden, were also discussed. Several themes emerged spontaneously in multiple interviews, while others were discussed in response to specific questions. A summary of these results is presented below.

There was little consensus among stakeholders about the most important drivers of NBS implementation, or the incorporation of related concepts such as ES and GBI into policy and planning. The most mentioned drivers were knowledge, although lack of knowledge was mentioned even more frequently as a barrier, and the dedicated efforts of influential individuals. Negative experiences, such as with flood events, were cited as strong motivations for specific projects (such as Augustenborg) and for current directions in city planning. Clearer consensus emerged among stakeholders as to barriers to wider NBS implementation. The three barriers discussed in the strongest terms were the Planning and Building Act, which limits what municipalities can regulate; a pervasive lack of knowledge in many departments; and strong inertia or path-dependency within the municipality. Interview subjects identified a range of drivers and barriers, both historical and current, which can be classified as political, legal, institutional, financial, and technical or knowledge-based (Niven, 2014; *Table 5-2*).

Table 5-2 Stakeholder-identified drivers and barriers for NBS

	Drivers	*Barriers*
Political	• Augustenborg flooding (historical) • Experience with flooding in 2014	• Short-term pressures impede long-term planning
Legal	• GSF/Green Points • National environmental goals	• Planning and Building Act
Institutional	• Dedicated individuals • Incorporation of related concepts into municipal planning policy • Engaged people	• Inertia/path-dependency at municipality level • Silo thinking/lack of cooperation between departments • Lack of prioritization • Over-reliance on points-based systems, e.g. GSF
Financial	• Public/private partnerships • Availability of funding earmarked for environmental projects	• Uncertainty about cost/benefit
Technical/Knowledge	• Communication/knowledge transfer • Pilot projects as examples of what can be done • Cooperation with researchers • Public/private partnerships	• Lack of knowledge • Lack of planning tools

Source: Stakeholder interviews.

5.4.1 Political

Political pressures can act as both drivers and barriers to NBS implementation. The two political pressures—problems so pressing they demand an immediate response—are the need to avoid catastrophic flooding, such as that Augustenborg was once subject to and the damages seen in 2014, and the need to quickly build new affordable housing to accommodate a growing population, much of it foreign-born.

Previous studies in Norway and the U.S. have found that past experience with flooding and other weather extremes is a much stronger driver of adaptation than concern about future climate risk (Reckien et al., 2015). Several of the planners and researchers interviewed mentioned the severe flooding in Malmö in 2014, which caused permanent damage to gray infrastructure such as buildings and service vehicles (Mottaghi, Aspegren, and Jönsson, 2015), in one case describing it as an "eye-opener." Although there was flooding in Copenhagen in 2011 that created a billion euro of damages and prompted a major re-evaluation of stormwater management planning in Copenhagen (Haghighatafshar et al., 2014), Malmö's more extensive open stormwater management system, mostly implemented in the suburbs, provided a buffer until 2014:

> "There was also an incident in the hospital where the generator…they have a generator that was supposed to go in and work, but it was in the basement so […] it was very close to being flooded. It could have been a major disaster; the hospital would have been out of electricity for so many hours. And the

> ambulances and so on couldn't pass through the city, so it was really an eye-opener that this could actually happen. There was an even worse flooding in Copenhagen in 2011, so that was kind of an eye-opener, too, but it wasn't until it really happened here, these terrible damaging effects on infrastructure, [economic] effects…that everyone suddenly woke up and said we have to do something about this."

Open drainage systems are a well-established type of NBS used to address flooding risk in Malmö. For problems where NBS are less established, there is reluctance to take the risk of trying them when conventional solutions are familiar and well-understood. A major barrier to long-term planning throughout Sweden is a perceived need to focus on short-term pressures first—multiple subjects cited the housing crisis and immigration as pressing concerns. While there is a broad consensus that planning for long-term sustainability is desirable, in the short term funding and resources are often directed towards the immediate need for housing, as quickly and cheaply as possible. The 2010 revision to the Planning and Building Act, although it mentioned sustainability, focused in large part on simplifying the building approval process to facilitate construction of new housing, not on giving municipalities tools to facilitate incorporation of sustainable solutions.

This may contribute to the prevalence of NBS in high-profile developments in Malmö, where they can also be argued for on aesthetic grounds, and their relative lack in ordinary neighborhoods. The decision to focus Malmö's "greening" effort on wealthier neighborhoods is deliberate, and in part an international marketing choice (Baetan, 2012). It is unclear how much the possibilities of implementing NBS to address the problems of the neighborhoods facing the greatest challenges have been examined, although Augustenborg demonstrates that there is strong potential. Community-directed projects that are "just green enough" offer one possible strategy for averting green gentrification (Wolch, Byrne, and Newell, 2014).

5.4.2 Legal

A frequently mentioned barrier to NBS implementation in Malmö, particularly on private land, is the current legal framework for spatial planning. Although most spatial planning in Sweden is carried out at the municipality level and municipalities have a great deal of autonomy (Ulfvarson Östlund, 2007; Ptichnikova, 2012), national legislation can still have a strong impact, as it restricts what regulations municipalities can enact. The National Board of Housing, Building and Planning (*Boverket*) is the primary authority for physical planning and building, while the Ministry of the Environment and Energy (*Miljö- och energidepartementet*) oversees legal proposals and directions for spatial planning (Ulfvarson Östlund, 2007). One key piece of legislation relevant to NBS and other sustainability measures in urban planning is the Swedish National Planning and Building Act (*Plan- och bygglagen,* PBL), an extensive and complicated law which regulates planning of land, water, and building; after analysis, a major revision was passed in 2010 (Ulfvarson Östlund, 2007). This revision had the goals of 1) strengthening the PBL as a tool for sustainable development, 2) revising it to meet modern social planning needs, and 3) to better meet the need for efficient planning and building while balancing social and justice concerns (Ulfvarson Östlund, 2007). Another is the Environmental Code, which regulates environmental quality standards for land, water, air, and other aspects of the environment (Ptichnikova, 2012).

Despite the provisions of the Environmental Code and other national acts related to sustainability and the 2010 revisions to the PBL, nearly all Swedish interview subjects, both researchers and those involved directly in urban planning, expressed a consensus that the

PBL in its current form is a major hindrance to incorporating NBS into planning at the municipal level. Although there is a general commitment to sustainability at the national level, reflected in the 2010 revisions to the PBL, the law strongly limits what municipalities can regulate. A landscape architect at Boverket, which provides supporting guidelines to help municipalities interpret the law, noted that the act was originally written before the current need for densification, and assumes building on unexploited land, a description corroborated by planners and researchers in Malmö:

> "The planning legislation…doesn't allow for certain types of regulation or certain types of uses of this land. For example, in a spatial plan you cannot…regulate for example the amount of rainwater that should be contained or kept on a certain property. The legislation doesn't allow it. The legislation only allows…that you can mark space for rainwater management. You can sort of say, 'This needs to be a pond or a dam or something'. But you cannot regulate water flows."

Another researcher with experience in planning for the City of Malmö described the PBL as a strong barrier because "it was developed for buildings, not for ecosystem services," which makes it difficult to work with ES, and by extension, NBS. Common land owned by the municipality is relatively easy to work with, as the municipality has more latitude to set regulations, but the PBL gives municipalities little latitude to require private developers to implement NBS or plan for ES.

One planner who has worked on the Malmö and Ecosystem Services (MEST) project described the current paradigm as expressed in the PBL as being focused on built structures and expanding into unbuilt land, not incorporating green infrastructure, green spaces, or other aspects of NBS which deliver ES into a dense urban environment. The PBL thus presents a barrier to connecting "green" to the built environment. As one architect explained:

> "We can't force private stakeholders to plant trees, for example, that's the main problem. Another problem is that the law is simply to protect values, not to strengthen them. That's another discussion we have to have with Boverket. And the next question is—the discussion right now is to exploit—but second chapter, second paragraph[3] says the land should be used for what it's most convenient for. It's not the discussion right now—it's obvious that the [unbuilt] land should be built. We don't discuss whether it's best for taking care of ecosystem services, for example. […] Malmö is trying to grow. […] If there is a plot not being built in the dense city, the question should be 'Should it be a park here instead of being built?' But that's not the way we use it right now. Perhaps a park is not the best picture right now in terms of ecosystem services, but there could be ecosystem services that should be implemented."

[3] "Planning and assessment of cases regarding permission or advance rulings in accordance to this law are to be made with regard for the land and water areas to be used for that or those purposes to which the areas [in question] are the most suited for, with regards to their characteristics, locations and needs. Priority is to be given to such usage that from a public perspective entails good stewardship. The regulations for stewardship regarding land and water areas as given in 3 and 4, paragraphs 1-8, in the Swedish Environmental Code are to be followed." PBL 2 § 2 (2010:900). Translation courtesy of Gabriella Gomez.

Rather than feeling that the PBL supports their efforts to integrate nature into urban planning, Malmö planners expressed a need to "think around corners all the time" to incorporate NBS and related concepts such as ES into planning. Currently, there is little drive to change the law, as this is a complicated, expensive process and the last major revision was relatively recent. The present focus at Boverket is to revise interpretation guidelines to help municipalities reinterpret the PBL. Reforms since 2010 have made it easier to build in general, but have not dealt much with green areas, GBI, or NBS.

Boverket is working on new supporting documents to help municipalities use the PBL to enhance ecosystem services. Although Boverket is not working directly with the NBS concept, the new guidelines for interpretation do incorporate GBI and ES. There is some possibility of further reforms to the law in the future, but this is not expected to occur soon, so planners must continue to work within (or around) the existing legislation.

One of the implications of the PBL in its current form is that points-based regulatory systems for development like Malmö's implementation of the GSF and the Green Points System in the Western Harbour's Bo01 development and subsequently in later construction projects (Kruuse, 2011) rely to some degree on voluntary compliance. According to several planners and architects, developers were required to provide figures when applying for building permission from the city—the system was in effect treated by the municipality and developers as if legally binding, but in actuality it is not, and the PBL does not permit the municipality to enact legal requirements of that nature. The architect quoted above continued, "Perhaps it's not legal. […] Not everybody [but] almost everybody [acts as if it is]. The main thing about this is that it's not legal—it's legal to protect trees or green spaces, but it's not legal to force someone to make green spaces or plant trees."

The same restrictions of the PBL that put the GSF and Green Points System on questionable legal ground also prevent the municipality from, for example, requiring developers on private land to include NBS to address problems such as stormwater management. This is a significant limit to the tools available to the municipality to encourage NBS implementation and mainstreaming, especially since there has been a trend in Malmö towards selling city-owned land to private developers (Baetan, 2012). However, some questioned whether the regulations like the GSF and Green Points System are the most effective ways to encourage effective NBS implementation (discussed in section 5.4.3).

At the municipal level, NBS in general are not explicitly mentioned in policy at this time, although open stormwater drainage systems are incorporated into Malmö's stormwater management policy and the new cloudburst plan and the GSF has been used in some developments, resulting in widespread implementation of green roofs.

5.4.3 Institutional

Historically, institutional culture in the city government has been strongly influenced by key individuals. Interview subjects in Malmö typically identified Peter Stahre, of the Water Department, as the main individual driving the shift to open stormwater drainage systems in Malmö. The process he describes for planning and implementing these systems is more complex than for conventional piped systems (Stahre, 2008; Stahre and Geldof, 2003), and achieving the current degree of mainstreaming for this type of NBS was a long process that required constant effort from Stahre and other key individuals. This is in part due to institutional inertia, which is connected to the knowledge barriers discussed in section 5.4.5.

According to one researcher, "If you don't want to, it's very easy to find reasons to say no. But if you *want* to—in the Swedish system we have a decentralized power structure, […] so if you want to do something in a Swedish municipality […] at least after a few years, you can. […] You have to get people on all levels of the local organizations to see the point and think this is a good idea. So it deals a lot with attitudes, information of course, also […] mindsets, [seeing] the possibilities."

While individuals can have powerful effects and form the membership of the NBS COP in Malmö, in a fully functioning COP or system, their loss would not result in the stagnation effect seen in Malmö, where the drive for innovation seemed to fade with the loss of key individuals and the weakening of connections between departments. The complexity of planning and implementing NBS may be another factor in the fragility of the COP (Stahre and Geldof, 2003).

The shifts in focus for NBS can be seen as a function of institutional priority: open drainage systems are considered to be established technology, and current sustainability planning focuses strongly on targets such as energy efficiency and renewable energy, problems which are not necessarily perceived as NBS-friendly. Consequently, new NBS have been reduced to the more symbolic, biodiversity-focused projects that lack a clear problem to address; they function primarily as aesthetic features in high-profile developments. These newer projects have also been strongly driven by semi-voluntary regulation within the city, the GSF and Green Points System, as well as by environmental certifications like BREEAM. Some, particularly those outside of the city government were skeptical of these point- and certification-based schemes popular in Sweden, citing Meadows (2008), who classifies standards as one of the weakest leverage points in a system. According to these stakeholders, point systems primarily encourage meeting an arbitrary minimum, rather than encouraging larger changes or paradigm shifts. Even those who were supportive of the GSF expressed concerns such as a lack of clear goal or narrative, poor clarity about outcomes, and a tendency to meet the standard by implementing thin sedum roofs, rather than more beneficial—and expensive—solutions.

5.4.4 Financial

The availability of funding earmarked for environmental projects was noted as a driver for Bo01 in particular, as well as more generally. This funding may come from the national or regional level, and it facilitates the incorporation of NBS into planning.

There are also technical-financial barriers to further mainstreaming of NBS: specifically, the difficulty of conducting cost-benefit analysis comparisons to conventional solutions with current data (discussed in section 5.4.5).

5.4.5 Technical/Knowledge-Based

Although stakeholders considered knowledge to be an important driver of change, e.g. the ability to point to successful pilot projects and understanding of how to implement NBS, lack of knowledge and siloization of knowledge was commonly identified as a major barrier. The MEST project in part seeks to build connections between departments and other actors in the city in order to better integrate and implement ES in planning. Educational efforts such as workshops and seminars, including those aimed at politicians within the city, have increasingly mainstreamed ES and GBI into the dialogue in the city over the past several years, according to city planners. However, they also emphasized the need for substantive

knowledge translated into action. NBS is still a new concept—while planners had heard of it, they were less comfortable describing and working with it than with ES and GBI.

Another challenge identified is the difficulty of calculating and quantifying the costs and impacts of NBS when compared with conventional solutions. According to a local partner, it is much easier for engineers to calculate the costs and water handling capacities of traditional piped drainage systems than to do the same for an open system incorporating green roofs, water bodies, etc. The difficulty of quantifying and predicting ES and costing NBS is a challenge for planners arguing for NBS implementation, although multifunctionality has generally been demonstrated to be a strong argument for design shifts (Matthews, Lo, and Byrne, 2015)—NBS offer both aesthetic and functional qualities that make them appealing.

National environmental goals for ES and GBI influence municipal policy to some degree, but this was perceived as a weak driver by some, and not influential by others. According to one researcher:

> "My personal opinion is that [national strategy] is pretty worthless in practice [as a driver], because it doesn't lead to anything. It's good to have national strategy because people that are active in the local arena, they can use it as an argument, so you have to have it. But [it is] worthless and does not do any work at all unless you have the people on the local level—like in Malmö—all those specific persons having the ideas, having the ambitions. Then they are supported by seed money from different kinds of funds, by regulations, from national strategies, from regional strategies. They have to have it to argue, to make it possible—but strategies don't do anything by themselves. But they are important."

6 Conclusions

The objectives of NBS projects in Malmö can be broadly divided into two categories: those that aim to solve a specific, serious problem (typically flooding), and those which aim to deliver benefits that address more vague, undefined problems. The former clearly fit the definition of NBS, while the latter, which are often biodiversity-focused, are examples of GBI but perhaps should not be considered NBS in the narrow sense proposed in this paper. The outcomes of these projects have been mixed and often unclear. While projects in the first category are measurably successful in addressing the problem of flooding, evaluation of other projects has been minimal, and unclear goals make assessment difficult.

Historically, NBS projects in Malmö have been strongly driven by the vision and dedication of key individuals, working to build interdisciplinary connections, transfer knowledge, and generate creative ideas within an NBS community of practice that connects municipal departments, public utilities, private companies, and academia.

While knowledge is crucial to driving mainstreaming of NBS, lack of knowledge, particularly of the cost-benefit side of NBS, is a major barrier to implementation. This is exacerbated by siloization of departments and weakened links between key communities of practice in Malmö. Although there is wide recognition of a need for NBS and a sustainability paradigm shift, institutional inertia is strong, and has historically been easiest to overcome when the city was faced with severe problems. Experience with major flooding in 2014 may serve as a catalyst for a renaissance of NBS in Malmö.

6.1 Main Findings

The planners and researchers interviewed in Malmö generally expressed positive impressions of nature-based solutions, but wide disagreement on the actual meaning of the concept, frequently conflating it with ecosystem services or GBI. This is understandable, given the broad use of the term in the current literature. In order to be a useful concept, NBS needs to be much more narrowly defined. Significantly, an NBS needs to not only solve a specific problem, but to be an *alternative* to a conventional solution. For example, although many would describe a green roof as an NBS, whether the goal was to manage rainwater or improve biodiversity measures, under this narrower definition the goal matters. For rainwater management, there are alterative conventional solutions available, such as gutters and pipes. For biodiversity, there is no alternative solution, and thus calling a green roof for biodiversity an "NBS" is meaningless. Rather than manipulating language to reframe every goal or desired benefit as a "problem," it seems better to define the NBS concept more narrowly for the use of the planner or engineer facing a genuine problem and wondering which solution to use to address it.

The role of NBS in urban planning in Malmö has shifted since the open drainage projects of the 1990s. These first groundbreaking projects were clear example of NBS in the narrow sense. Not only were they effective, but in some ways they were better than conventional solutions—cheaper to implement, with fewer negative side effects and more positive side benefits, such as encouraging biodiversity, providing additional ecosystem services, and offering recreation and aesthetic value. The results were concrete, tangible, and measurable, and because they were implemented in existing neighborhoods, it was possible to compare values before and after implementation.

In subsequent high-profile projects, the patterns of NBS incorporation have changed. Rather than solving problems, green and blue infrastructural features were implemented in hopes of

producing "benefits," although in most cases these benefits are difficult to quantify and no specific goals were established. Many of these benefits are less tangible, such as aesthetic value, and while important from the point of view of an architect designing a development where people will want to live, are not necessarily important from a sustainability standpoint. The incorporation of NBS into developments such as the Western Harbour and Hyllie became more symbolic than functional, a visible representation of the vaunted "greenness" and "sustainability" of the developments, driven by regulatory codes with unclear argument for their goals, such as the GSF and Green Points System. These later projects, while they fit broadly into the current definitions in the literature, are not meaningful examples of NBS by the narrower definition proposed here. Encouraging biodiversity is a worthwhile goal, but it is nature-based by default. Likewise, GBI is important, but not always an NBS. For all of these concepts to be useful, they must be clearly defined.

This shift appears to coincide with the weakening of links between two communities of practice within the City of Malmö: the community of engineers and service providers that worked with public housing companies to implement open drainage systems in Augustenborg and other neighborhoods and the community of ecologists and environmentally-minded landscape architects who coalesced around the Western Harbour development and currently comprise the Environment Department and City Planning Office. After Peter Stahre died and his colleagues and successors largely left the city, the driving impetus behind innovative NBS to solve pressing problems seems to have faded. While Stahre's legacy has to a reasonable degree mainstreamed open drainage systems as an option into Malmö's urban planning, nothing as successful on all three fronts—environmental, social, and economic—as Augustenborg has been replicated. Most current NBS are implemented in new, "green" developments meant to attract wealthy residents. Even in these developments "NBS" play a largely symbolic role, offering weak and ambiguous benefits rather than concrete solutions to problems. They may have other values for urban planning, but are not good examples of NBS in the narrow sense.

Key drivers of NBS historically in Malmö have been dedicated, visionary individuals and the presence of an urgent problem requiring an innovative response. As the focus has shifted to more symbolic projects, the drivers have become points-based codes, the GSF and Green Points System. While such regulations can form an important part of a functioning system, without a reasoned target their power to effect meaningful paradigmatic change is weak.

At the same time, Malmö faces significant barriers to further implementation of NBS, including national regulation that limits the tools the city has to shape development, compartmentalization within the city that restricts knowledge transfer, institutional inertia, and over-reliance on visionary individuals to drive projects.

Many of the individuals interviewed spoke approvingly of specific people who have driven successful NBS projects, not only in Malmö but in other cities and countries as well. The necessity of visionary individuals for initial innovation cannot be underestimated, but effective mainstreaming of their ideas requires functioning systems that preserve continuity, regardless of the death or departure of individuals from that system. A functioning system facilitates knowledge transfer within and between communities of practice and possesses frameworks and regulations that ensure retention of knowledge and simplify implementation. In Malmö, some of these features are only weakly present, making it difficult for communities to recover from the loss of key individuals and overcome institutional inertia to implement innovative solutions.

The 2014 floods may prove to be a blessing in disguise for Malmö's planners. Historically, crisis conditions have triggered change in response within the city of Malmö, and this is a commonly documented pattern in human systems. In response to the 2014 floods, the city developed a cloudburst plan in 2016 (Udomcharoenchaikit, 2016). At present, most of the established neighborhoods with high percentages of hard surfaces at most risk of flooding are in the central parts of the city, the same neighborhoods that are more likely to be low-income and have high percentages of foreign-born residents (Haghighatafshar et al., 2014). Although they face the greatest environmental and social challenges, they also have the greatest opportunities for utilizing NBS to address these challenges. Perhaps renewed awareness of flood risk and the development of the cloudburst plan will be the impetus required to expand Augustenborg's successes with NBS and citizen participation to other neighborhoods, increasing the equitability of city greening.

6.2 Wider Significance

A key question of interview-based case study research is whether the results can be generalized to other subjects and situations. In fact, this is often considered a marker of validity (Kvale and Brinkmann, 2009).

This case study is designed as an intrinsic case study, undertaken to provide insight into this particular case: the role of NBS in urban planning in Malmö, Sweden. Aspects of this case may also apply to other cases: for example, national planning law and regulations apply to all municipalities, so drivers or barriers at the national level can be expected to affect other municipalities as well. The identified need to work with Boverket on how to apply and perhaps eventually reform the PBL, for example, is likely to be relevant throughout Sweden. The majority of this analysis focuses specifically on Malmö's stakeholder network and communities, policies, and unique situation. Thus it is not necessarily desirable to generalize, although a comparative case study between Malmö and other municipalities to identify common issues and strengths, as well as areas where municipalities could form partnerships and learn from each other, could be valuable.

General, context-independent knowledge is not always more important than concrete, context-dependent knowledge (Flyvbjerg, 2006). Given that NBS solutions are rarely one-size-fits-all and tend to require careful consideration of local ecosystem and building factors (EC, 2015), it may well be that concrete, local knowledge will more useful to this area of research than generalized theories, particularly for understanding the socio-political aspects of implementation.

6.3 Policy Recommendations

In order to facilitate innovation and implementation of NBS in Malmö, the communities of practice responsible for planning and NBS must be strengthened. Stakeholders interviewed identified a number of general drivers and barriers to NBS and related projects, and many of these can be examined in the context of a practice theory and community of practice framework.

First, the practice of NBS itself can be strengthened, particularly in the first three components: practical understandings, rules, and teleoaffective structure. Enhancement of practical understandings or technical knowledge is widely recognized already within the municipal government as an area for improvement. Technical knowledge can be generated and transferred via

1. Research: evaluation impacts, viability tests of new NBS (pilot projects), etc.
2. Codification: collection of existing knowledge in the form of papers, manuals, etc. so that individual knowledge is retained and accessible.
3. Publication: validation and sharing of knowledge through formally or informally peer-reviewed publications.
4. Education: sharing of knowledge through workshops, seminars, etc.

Second, in order to implement useful rules, the limits of the national framework must be fully understood. Malmö is already working with Boverket on BEST (*Boverket and Ecosystem Services*), which involves ways to utilize ecosystem services in urban planning within the legal framework of the PBL. This could be expanded to explicitly include NBS. Ultimately, if the PBL as it currently stands proves to be too great an obstacle to sustainable urban planning, municipality planners may need to be prepared to argue for the necessity of revising the law again.

At the local level, extra-legal, voluntary regulations such as the GSF and the Green Points System should be developed in cooperation with other stakeholders, so that they are practical to implement and the reasoning behind them is clear.

Third, the teleoaffective structure for NBS in Malmö is weak due to a lack of clear goals in many cases. The GSF and the Green Points System illustrate this with their vague goals and sometimes-arbitrary weighting of different types of green features. These points systems, as currently implemented, do not encourage NBS in the narrow sense of an alternative solution, and in general fit better into a capital concept (Matthews, Lo, and Byrne, 2015). Of course, it is not necessary to choose between NBS and more general green-blue infrastructure that produces less tangible benefits. Both types of projects will likely play an important role in the sustainable city. However, it is important to be clear about the goals and desired outcomes of an individual project, and to follow-up with assessment in order to build upon the knowledge gained from previous successes and failures. Due in part to 2016 changes in Swedish planning law, the current version of the GSF is expected to retire, although it may be replaced with a new version that incorporates functions rather than simply amount of green space (A. Kruuse, personal communication, August 22).

Finally, while communities of practice often arise organically, it is possible to consciously strengthen or even build them. City planners are already aware of problems with siloization between city departments, and working to build links between them. It is also already common practice to establish working groups or steering committees for specific projects.

These efforts can be expanded by encouraging cross-linking between project groups, using formal or informal meetings, exchanges of reports and other information, and so on. Face-to-face meetings can be particularly productive (McDermott and Archibald, 2010). This strengthens the focus and efficiency of individual project groups, while ensuring that groups do not waste time and resources by simultaneous separate invention. Similarly, interaction can be encouraged between departments and between the City of Malmö and other communities—particularly housing and utility companies, private developers and the research community.

In addition, possibilities for NBS implementation in stressed neighborhoods facing poverty, unemployment, and social segregation should be assessed, and a strong public participation component included whenever possible (Stefansdottir, 2013). NBS have the potential to play an important role in addressing some of Malmö's environmental and social challenges in the

future, but the concept and goals must be clearly defined, and projects implemented equitably and evaluated for effectiveness.

6.4 Suggestions for Future Research

In order to strengthen the case for NBS in Malmö and determine which solutions and implementations are most effective, two areas for further research can be identified: environmental impact evaluation and social aspects. The scope of this thesis is broad, and identification of smaller areas to examine in greater depth is crucial.

6.4.1 Environmental Impact Evaluation

Some NBS solutions in Malmö exhibit established, measurable positive impacts: the widespread implementation of GBI features to handle stormwater management, for example, is clearly effective. There is a need for more quantitative evaluation of environmental outcomes for specific types of NBS, particularly of newer projects that have received less study than Augustenborg and Bo01, such as those in Bo02, Bo03, and Hyllie, and projects not related to stormwater.

Evaluation should include quantitative measures of effectiveness at addressing problems or delivering desired ecosystem services, as well as measures of resident satisfaction. As monitoring can be expensive, this could be done in part by forming partnerships. For example, local bird enthusiasts could be a source of data on nesting birds in neighborhoods of interest. Monitoring biodiversity of the saltwater canal in the Western Harbour or of biotope plantings could be achieved at lower costs by working with students from local schools and universities, offering research experience and educational opportunities in exchange for annual or at least periodic monitoring data collection.

6.4.2 Social and Economic Sustainability

Malmö faces a range of social pressures, some of which may be exacerbated by inequitable implementations of NBS. If NBS are to be implemented equitably and used to address social as well as environmental issues, several areas of the intersections between environmental and social sustainability must be better understood. First, the social impacts of current NBS in Malmö need to be measured in greater depth: do NBS contribute to green gentrification? Are any of the benefits of NBS accessible to marginalized communities?

Second, potential for wider implementation of NBS in marginalized or even typical neighborhoods should be assessed. While the need to build affordable housing quickly to respond to the pressures of immigration-driven growth is pressing, in the long term, if Malmö aims to achieve its sustainability goals, NBS and other sustainable measures must be incorporated into all neighborhoods, not only high-profile flagship developments. This means both retrofitting existing neighborhoods in the model of Augustenborg and incorporating sustainable design into new neighborhoods. Long-term cost-benefit analysis should be conducted, comparing the cost of implementing NBS in new affordable developments now to the cost of building as quickly as possible now and later retrofitting these developments to meet the city's sustainability goals. There is also an identified need for better cost-benefit estimate tools for planners to use for ES and NBS.

The question of why Augustenborg has not been more widely replicated, in terms of both the scale and design of its NBS, which were integrated into an existing neighborhood, and its highly participatory planning process, could form the basis of an entire study.

Finally, social sustainability requires civic participation. It seems likely that part of the success of Augustenborg is due to the high levels of public involvement in all phases of the project, and thus civic investment. Further research into the impacts of public participation on environmental projects and the communities where they are sited, as well as the best ways to incorporate public participation, could improve the social effectiveness and equitability of NBS in Malmö, as well as open avenues for innovation.

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Annex I: Interview Subjects

No.	Organization(s)	Specialty	Date/place of interview
Gary Austin	University of Idaho, Moscow	Landscape architect, professor, wrote case study of Bo01; green infrastructure, biological treatment, planning for biodiversity.	10 May 2016. Via email.
Ulrika Åkerlund	Swedish National Board of Housing, Building and Planning (Boverket)	Landscape architect, involved with developing guidelines for municipalities to work with Planning and Building Act.	25 April 2016. Via Skype.
Anonymous	Lund University/City of Malmö	Landscape ecologist; worked on Malmö project on ecosystem services in urban planning.	18 March 2016. Centre for Environmental and Climate Research, Lund University.
Åke Hesslekrans	City Planning Office, City of Malmö	Architect; city planning; 2002–2005 project leader for Hyllie development.	14 April 2016. Stadshuset, Malmö.
Annika Kruuse	Malmö Environment Department	Original Western Harbour ecologist, environmental strategist in Environment Department; green and blue infrastructure.	13 April 2016. Miljöförvaltning, Malmö.
Juliet Lidgren	Malmö Environment Department	Architect, previously worked in City Planning Office, project coordinator for MEST/BEST; ecosystem services.	17 May 2016. Miljöförvaltning, Malmö.
Anonymous	Scandinavian Green Roof Institute	Anonymous	11 April 2016. Scandinavian Green Roof Institute.
Bengt Persson	Swedish University of Agricultural Sciences, Alnarp	Senior lecturer; extension specialist, urban landscape, cooperation between municipalities and university, involved in concept development for Bo01.	11 April 2016. IIIEE, Lund.
Roland Zinkernagel	Malmö Environment Department/IIIEE	Qualitative indicators for sustainable development; city development and planning; energy.	18 March 2016. IIIEE, Lund.

Annex II: Interview Protocol

1. Can you briefly describe your research or role in your organization?

2. Are you familiar with the concept of nature-based solutions?

3. If so, how would you define them?

   Provide EC definition: "Nature-based solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, for example, mimicking how non-human organisms and communities cope with environmental extremes. […] Nature-based solutions, however, have a distinctive set of premises: (i) some societal challenges stem from human activities that have failed to recognize ecological limitations; (ii) sustainable alternatives to those activities can be found by looking to nature for design and process knowledge." (EC, 2015)

4. Can you think of examples of nature-based solutions already implemented in Malmö or other parts of Sweden? *[Omitted for some interviews.]*

5. Do you think the concept of nature-based solutions brings anything new to sustainability discourse?

6. Who or what do you see driving the integration of nature-based solutions into sustainable urban planning?

7. What barriers, if any, do you see to incorporating nature-based solutions into urban planning in Sweden?

8. Do you know of other researchers working in this area, or planners, green business representatives, etc. in Malmö whom I might contact? *[Omitted for some interviews.]*