# Management and restoration of eelgrass in Sweden

- Ecological, legal and economic background

The Swedish Agency for Marine and Water Management's Report 2016: 8

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# *Preface*

The state of the coastal and marine environment needs to be improved. A large number of international and national commitments and decisions raise demands for measures to reduce impact and strain, as well as for restoration of the coastal and marine environment; primarily the framework directive for water, the marine environment directive, the species and habitat directive, the environmental quality objective Sea in balance (Hav i Balans) and the living coast and archipelago. An important prerequisite for the restoration work is a well-functioning toolbox, with scientifically based methods.

This report provides a background and description of the ecological and legal situation for eelgrass management in Sweden today. The focus is on descriptions of how ecological restoration and compensation of eelgrass can contribute to the development of better management of eelgrass ecosystems and other habitats in shallow coastal areas in Sweden. The report forms part of the action program for the Marine Environment Directive (measures 29.30 and 31; Swedish Agency for Marine and Water Management Report 2015: 30). The report is also an important basis for the manual restoration of eelgrass in Sweden (Swedish Agency for Marine and Water Management Report 2016: 9).

Compensation restoration is a complex business where many conditions (e.g. ecological, economic and legal) interact. There are currently few completed restoration projects in coastal environments and case law is not yet particularly developed. It is important to point out that compensation restoration cannot be seen as a precautionary measure among others. Instead, compensation should be used as a way to minimise damage to ecological values when an activity is still considered permissible.

It is the hope of the Swedish Agency for Marine and Water Management that theis report can provide support for the supervisory and reviewing authorities in matters relating to the management and restoration of shallow coastal aquatic environments and eelgrass.

Target groups for the report are primarily environmental officers and managers of marine coastal environments at national authorities, county administrative boards and municipalities that organize and handle eelgrass matters, but also business operators whose activities may adversely affect eelgrass and consultancy companies that may carry out the practical work on eelgrass restoration and monitoring. Another important target group is environmental courts and their technical councils, as well as decision makers at the municipal and regional level. The report can also form the basis for courses at universities and colleges.

The work has been funded by the Swedish Agency for Marine and Water Management (HaV Dnr 2283-14), the research program FORMAS (Dnr 212-2011-758) and the University of Gothenburg (two doctoral students).

A big thank you to all those who contributed with information, data and opinions during the course of the work. The report has been produced by a research group from the University of Gothenburg. The group consists of researchers in marine ecology, environmental law and environmental economics. For the part of the Swedish Agency for Marine and Water Management and the County Administrative Board, the project manager has been Ingemar Andersson and Ingela Isaksson. The authors themselves are responsible for the assessments and conclusions presented in the report and these cannot be relied upon as the position of the Swedish Agency for Marine and Water Management.

Gothenburg May 2016, Björn Sjöberg

Head of the Department of Marine and Water Management

APPENDICES (available digitally at https://www.HAVOCHVATTEN.SE/)

# Summary

Eelgrass beds constitute key habitats in shallow, coastal areas that support high species diversity and provide mankind with several important ecosystem services. Eelgrass habitats have been identified as essential habitats in need of protection by international conventions and EU directives. Along the Swedish northwest coast, more than 60%, approximately 12,500 ha, of the eelgrass beds have vanished since the 1980s as a result of coastal eutrophication and overfishing. Although measures have reduced nutrient pollution and overfishing, and the water quality along the Swedish west coast has improved, no general recovery of eelgrass has been observed. Instead, the loss of eelgrass continues, partly due to an increasing exploitation of Swedish coasts.

The aim of this report is to contribute to the development of an improved management of eelgrass ecosystems in Sweden, in particular regarding the use of eelgrass restoration, but also in relation to licensing and supervision of activities that may affect eelgrass and other coastal habitats. The goal has been to assemble all relevant information in one report, and provide a multidisciplinary background that addresses ecological, legal and economic aspects of management and restoration of eelgrass in Sweden. Another objective has been to analyse the existing management of eelgrass in Sweden, identify possible shortcomings, and provide recommendations on how it could be improved. The report establishes an important basis for the *eelgrass restoration handbook in Sweden* (Moksnes et al. 2016).

Although functional methods and guidelines for eelgrass restoration are now available for Swedish waters, it is important to point out that restoration of eelgrass is very labour intensive, expensive and not possible in all areas. When a large eelgrass bed is lost, the physical and biological environment may change so much that eelgrass can no longer grow in the area. It is therefore critical that environmental managers prioritize the protection and conservation of remaining eelgrass habitats, and restore lost meadows when possible, but only as a last resort using compensatory restoration of eelgrass as a measure to mitigate losses caused by coastal exploitation.

Eelgrass meadows create several important ecosystem functions, which in turn provide society with important ecosystem goods and services. A bioeconomic analysis of three of these services (production of commercial fish and uptake and storage of carbon and nitrogen) estimates their economic value up to approximately SEK 0.5 million per hectare of eelgrass along the Swedish northwest coast. It is important to note that this value did not include several other important ecosystem services (e.g. increasing biodiversity, stabilization of sediment and prevention of beach erosion). The historical losses of eelgrass along the Swedish north-west coast were estimated to have caused a total loss of approximately 8000 tons in cod catches, which is equivalent to the total catch of cod in Swedish waters in 2013. The historical loss of eelgrass was also estimated to have caused a release of 6000 tons of sequestered nitrogen to coastal waters, which is three times larger than the annual river supply to the Swedish northwest coast. A rough estimate of the total economic value of the lost ecosystem services since 1990, including carbon sequestration varies between SEK 4 and 21 billion.

There is no Swedish legislation that protects eelgrass meadows specifically, but a large number of laws and regulations that aim to prevent deterioration or restore deteriorated environments, or regulate what type of influence is allowed in

different areas. However, the exploitation of eelgrass is also allowed in areas where large historical losses have occurred, as well as within marine protected areas, demonstrating that the existing legal protection is insufficient. The situation is not in agreement with the EU water framework directive and the marine strategy framework directive to obtain and maintain good ecological and environmental status, and makes it difficult for Sweden to fulfil international commitments.

The present management of eelgrass in Sweden is impeded by a lack of environmental monitoring and use of eelgrass when assessing the environmental status according to the EU directives. It is therefore important to revise the present indicator for coastal vegetation in Sweden, and to include the distribution of eelgrass in the national monitoring program so that the condition of the eelgrass ecosystems contributes to the classification of the environmental status. Along with a no-net-loss policy, such a change would substantially increase the protection of eelgrass and also clarify the need to carry out large-scale restoration of lost eelgrass meadows.

Compensatory mitigation has been used very little in the marine environment in Sweden, and no compensatory restoration of eelgrass has yet been carried out. Compensatory restoration could constitute a tool to implement the "polluter pays principle", and contribute to preventing net losses of eelgrass habitats caused by coastal exploitation. In contrast to the current use of economic fees to offset fishery when an eelgrass bed is damaged, all ecosystem services would be compensated for after successful compensatory restoration. However, compensatory mitigation is not unproblematic, and it is critical that compensation does not affect the permitting process, but that it is only used as a last resort after all possibilities to avoid and minimise the damage have been exhausted. This is particularly important in the southern part of the Swedish northwest coast where studies have shown that there are areas where restoration is not possible. Moreover, due to the large historic losses of eelgrass in this region, most areas where compensatory restoration could be attempted consist of bottoms where eelgrass was growing in the 1980s. Restoration in those areas would only compensate for the historic losses, but not for the eelgrass harmed by exploitation, resulting in a net loss of habitat.

In Swedish legislation there are several alternative sections of law that could be used to demand compensatory mitigation when eelgrass is adversely affected by an activity. The best support for demanding full compensation is in the Swedish environmental code chapter 16, section 9. Until recently, the lack of established practice has constituted a challenge to demand compensatory mitigation in the marine environment. However, this is about to change as land and environmental courts have started to demand compensation. It is recommended to increase the use of "biotope protected areas" for eelgrass habitats as this protection would increase the possibility of demand compensatory mitigation for eelgrass and, more importantly, increase demand to avoid and minimise damage to eelgrass habitats. .

Experience from the USA, where compensatory restoration of eelgrass has been used as a management tool since the 1970s, has shown the value of developing state-wide policies regarding what methods should be used during restoration, how the extent of restoration should be calculated, and how the success of the restoration should be determined. A national *eelgrass mitigation policy* would facilitate the use and chances of success for compensatory restoration in Sweden, and this report presents a detailed description of how such a policy could be designed.

# 1. Introduction

## 1.1. Background

### 1.1.1. Eelgrass fulfils many important functions

Seagrass meadows are one of the world's most valuable and productive ecosystems, providing man with many important ecosystem functions and services. Their ability to grow on the soft bottom allows them to provide a physical structure and habitat for many different organisms, which increases species richness and production in the area. Eelgrass is the dominant seagrass in Sweden and forms the basis for very rich biotopes with high primary and secondary production, and serves as important growth environments for a large number of fish and crustacean species. Eelgrass also absorbs nutrients and carbon dioxide from the water, which is largely bound in the sediment, which is why eelgrass meadows reduce eutrophication and the greenhouse effect. Eelgrass meadow leaves suppress currents and wave energy, and rhizomes and roots stabilise the seabed, which reduces resuspension and erosion of sediment and provides clearer water locally. All in all, this means that eelgrass meadows are unique habitats whose ecosystem functions cannot be replaced by other habitats, e.g. a bed of macroalgae or mussels.

### 1.1.2. Endangered environments

Eelgrass meadows are threatened ecosystems whose distribution has declined dramatically over the Northern Hemisphere over the past 30 years. In Bohuslän, more than 60% of all eelgrass has disappeared since the 1980s, which represents an estimated loss of around 12,500 ha. An important cause of the losses is considered to be eutrophication. Eelgrass is adapted to living in clear and nutrient-poor seas and is at risk of being outcompeted by fast-growing algae at high levels of nutrients in the water. Overfishing and loss of large predatory fish in coastal ecosystems are also considered to have contributed to increased occurrence of fast-growing algae. Although measures have been put in place to reduce eutrophication and the water quality has improved in the North Sea over the past 10 years, no general recovery of eelgrass has been seen. Instead, a slow loss of the remaining eelgrass meadows continues as a result of increasing exploitation pressure on shallow coastal areas.

### 1.1.3. Deficiencies in today's protection of eelgrass

Although awareness among both managers and the public has increased about the importance and need for protection of eelgrass, and a more restrictive attitude is seen in the decision on activities that may affect eelgrass, many activities that cause eelgrass meadows to directly or indirectly be destroyed or damaged is still permitted. This is especially true for smaller activities such as the construction of jetties, marinas and other construction in shallow soft-bottom coastal areas, i.e. in areas where eelgrass has its most important habitats.

Today, a significant proportion of shallow subtidal areas along the west coast have been exploited, and the proportion continues to increase. In 2008, the County Administrative Board conducted an inventory of this small-scale exploitation in the North Sea and found a total of approximately 7000 ports and 600 marinas between Strömstad and Malmö, where the number had increased by 200 ports and 9 ports during the last 5 years (Figure 1.1; Pettersson 2011). Also, in areas where the number of new marinas and ports does not increase, the growing popularity of larger motorised boats means that many docks and ports are expanded with more and larger docks, and that fairways are made deeper. In many areas, older paved bridges are also replaced by floating bridges, which give significantly less light transmission and thus greater negative effects on underlying eelgrass (Eriander et al. *In manuscript*). In total, this small-scale exploitation means that available living space for eelgrass is continuously decreasing. It also indicates that the legal protection for eelgrass does not work satisfactorily and that Sweden can therefore not live up to Swedish and international environmental goals of not deteriorating the state of the marine environment. Preliminary results from a recent study of around 150 cases concerning applications for exemptions from the beach protection and notification of water activities for construction of jetties in Bohuslän between 2011 and 2015 showed that only about 25% of the jetty cases were stopped. Even when the cases were in marine protected areas, less than half of the jetties were stopped. The presence of eelgrass was considered to a very small extent in the investigated cases. The proportion of cases stopped was even lower in areas with eelgrass (20%) than in areas without vegetation (Eriander et al. *In manuscript*).

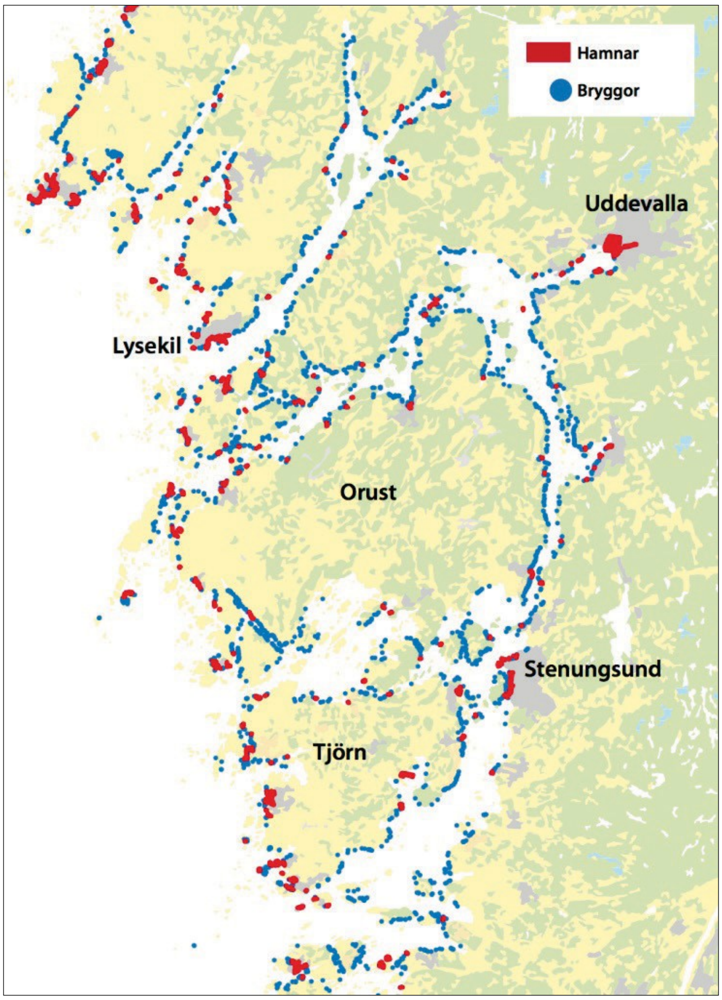


Figure 1.1 The map shows a section of the coast in Västra Götaland County, where ports larger than 0.25 ha are shown as red areas and occasional bridges as blue points. The documentation was developed by Metria on behalf of the Swedish Environmental Protection Agency (*Lantmäteriet, no. 106-2004 / 188; from* Pettersson 2011).

### 1.1.4. Need for new measures

Until recently, seagrass and eelgrass meadows have been relatively unknown habitats to the public. Environmental monitoring and management of the habitat has been neglected in many countries, including in Sweden that lacks a functioning national monitoring framework for eelgrass and other shallow soft bottom habitats. Over the past decade, however, this has begun to change as work on protecting marine environments internationally and within the EU has intensified. Among other things, eelgrass has been included on OSPAR's list of threatened species and habitats, which means that the member states are committed to monitor the propagation and recovery of this habitat. Today, eelgrass is used as an environmental indicator in many countries to assess ecological status under the EU Water Framework Directive (hereafter referred to as the Water Directive), and eelgrass has also been proposed as an indicator for several of the descriptors for the Marine Environment Directive. These EU directives, together with the Habitats Directive set, among other things, a demand on Sweden to achieve good environmental status / favorable conservation status and to not allow further deterioration, and this is an important driving force for national work.

In Sweden, the management of eelgrass has primarily been about including eelgrass in different types of marine protected areas. However, measures to strengthen judicial protection outside protected areas have been lacking. Furthermore, there have been no effective measures to reverse the negative trend of declining eelgrass stocks that are still ongoing in parts of Bohuslän. Today, however, work is ongoing at regional and national authorities to try to improve mapping, monitoring and protection of eelgrass, as well as exploring opportunities for measures to improve its environmental status. Among other things, the *action program for threatened species* for eelgrass meadows is being developed in 2016, which is a national strategy to facilitate coordination of various measures and management of eelgrass at regional and national level.

Over the past 10 years, the interest of both managers and operators has increased to use eelgrass restoration as a possible measure to reduce historical habitat loss or as a compensatory measure when eelgrass is destroyed during exploitation (Moksnes 2009). *Organic compensation* has been highlighted as an important tool in recent years to stop losses of biodiversity and ecosystem services both at EU level in the work of biodiversity and *No Net Loss* initiatives (European Commission 2011), and nationally as a way to achieve the environmental quality objectives (Prop. 2013/12: 141). However, in the marine environment, no ecological compensation has yet been carried out, both because the legal possibilities for claiming compensation have been unclear (Naturvårdsverketet 2016), and because proven methods are lacking. In recent years, however, effective methods for restoring eelgrass in the North Sea have been developed (Moksnes et al. 2016). Therefore, eelgrass restoration is today a possible tool for the cultivation, which is also reflected in new management decisions and judgments. The Swedish Agency for Marine and Water Management decided in 2015 within its *action program for the marine environment,* in accordance with the Marine Environment Directive, to implement large-scale restoration measures for eelgrass in the North Sea (Sea and Water Authority 2015). In the same year, for the first time in Sweden, a judgment was also issued where restoration of eelgrass was required as compensation for losses of eelgrass, caused by an expansion of the port of Gothenburg (Case no. M 4523-13, Vänersborg District Court). To successfully manage eelgrass meadows and use restoration and ecological compensation in the right way requires a great deal of knowledge about eelgrass ecology, legislation and rules relating to eelgrass management, as well as financial aspects of ecological restoration and compensation, which has been lacking.

This report is the result of an interdisciplinary work carried out by researchers at the University of Gothenburg within the research program Zorro (www.gu.se.zorro) in collaboration with the County Administrative Board of Västra Götaland County and the Swedish Agency for Marine and Water Management. The aim of the report is to compile up-to-date information relevant to the management and restoration of eelgrass, as well as to identify deficiencies and make recommendations on how management can be improved. It is hoped that this report will improve the state of knowledge and the possibilities to use the restoration of eelgrass as a measure to reduce loss of this habitat.

## 1.2. Purpose and delimitations

The purpose of the report is to make a contribution to the development of better management of eelgrass ecosystems and other habitats in shallow coastal areas in Sweden, in particular when it comes to using restoration as a management measure, but also with regard to testing and supervision of operations and other measures that may affect eelgrass ecosystems and other coastal habitats. This report provides a multidisciplinary background for the management and restoration of eelgrass ecosystems in Sweden, which covers the ecological, legal and economic aspects.

The aim has been to gather all current information relevant to the management and restoration of eelgrass in Sweden in one place, as well as to analyse any deficiencies in current management, and try to make recommendations on how it could be improved. **This report is also an important basis for the handbook on restoration of eelgrass in Sweden** (Moksnes et al. 2016; The Swedish Agency for Marine and Water Management report 2016: 9), which describes all the steps in the restoration process.

Target groups for the report are primarily environmental officers and managers of marine coastal environments at national authorities, county administrative boards and municipalities that organize and handle eelgrass matters, but also business practitioners who may have a negative impact on eelgrass and consultancy companies that will carry out the practical work on eelgrass and monitoring. Another important target group is environmental courts and their technical councils, as well as decision makers at the municipal and regional level. Parts of the report may also be of public interest, and could constitute a basis for teaching in schools and universities.

The report only deals with eelgrass habitat and focuses mainly on ecosystems in Bohuslän in the North Sea, because this is where large losses of eelgrass have occurred and measures need to be taken, and because the scientific basis is primarily based on studies in this area. However, much of the advice and recommendations given in this report are general and can be used in other parts of Sweden as well as for other coastal habitats, especially for other angiosperm plants, but also for example, perennial macroalgae, mussel banks and oyster reefs.

## 1.3. Reading instructions

The report consists of 9 chapters that provide a description and analysis of the ecological and legal situation for eelgrass management and restoration in Sweden today. Since the main purpose of the report is to support the use of restoration as a management tool, the report begins with a background and definition of different types of restoration in Chapter 2. Subsequently, in chapters 3 to 5, a background description of eelgrass ecology, its economic value and how eelgrass is managed today is given. Chapters 6 and 7 then provide a legal description and analysis of Swedish eelgrass management and restoration, after which recommendations and method descriptions for compensatory restoration of eelgrass are given in chapters 8 and 9.

A description of each chapter is given in detail below.

**Chapter 2** provides a background and explanation for the difference between ecological restoration and ecological compensation. Here we discuss, among other things, opportunities, limitations and risks with compensatory restoration.

**Chapter 3** gives a background of eelgrass ecology in Swedish water and a description of eelgrass ecosystem functions. Here, historical changes are also described and estimated of the distribution of eelgrass in Sweden, where the calculations are reported in **Appendix 1**. Last, probable causes of observed losses and lack of natural recovery are discussed.

**Chapter 4** provides a brief background on the valuation of ecosystem services, after which a quantitative estimate of eelgrass ecosystem functions in the North Sea and the economic value of their ecosystem services are reported. It also estimates the total loss of ecosystem functions and services caused by the sharp decline of eelgrass in Bohuslän since the 1980s.

**Chapter 5** gives a brief description of the monitoring and mapping of eelgrass that exists in Sweden today, as well as how eelgrass is included in various forms of protected areas. A short analysis is also made of Swedish environmental monitoring of eelgrass where proposals are given on how it could be improved.

**Chapter 6** describes the legal preventive protection of marine habitats, and in particular eelgrass, through international conventions, EU legislation and the Swedish Environmental Code. Here an analysis of shortcomings in today's judicial administration is also provided.

**Chapter 7** describes the legal basis for ecological restoration and compensation requirements at international as well as within the EU and at national level. Here, too, a summary analysis of the conditions for claiming compensation is made.

**Chapter 8** gives a description of how the use of ecological compensation in marine environments, and in particular how the use of compensation restoration looks in Sweden today. This chapter also describes how ecological compensation of eelgrass was successfully organised in California, where detailed recommendations for eelgrass restoration are used in all matters. The last section discusses how similar recommendations could be used for the restoration of eelgrass in Sweden, where a proposal for guidance is presented in **Appendix 2**. The Swedish Agency for Marine and Water Management intends to issue Appendix 2 of the report as a digital guide.

**Chapter 9** provides a more detailed description of methods for calculating the extent of a compensation restoration so that net losses of ecosystem services can be avoided.

# 2. Ecological restoration and ecological compensation

## 2.1. Ecological restoration

### 2.1.1. Background

**Restoration ecology** is the name of the scientific field that includes studies on how to recreate damaged or lost ecosystems through human intervention. It is the experimental scientific foundation that underlies the techniques and practicalities of ecological restoration. It is a relatively young scientific discipline that was formally coined during the late 1980s. Restoration involves trying to recreate an ecosystem or alternatively accelerate or initiate a recovery of an ecosystem that has been damaged by being disrupted. These disturbances are usually an effect of human activities such as direct effects of emissions or exploitation or indirect effects such as climate change. Restoration can look different, for example, it can aim to recreate an ecosystem as it has historically or to create a whole new ecosystem in an area where it has never existed before.

In recent decades, restoration ecology has become a robust and independent scientific discipline where the number of published articles with results from restoration studies and commercial applications of ecological restoration has increased exponentially in recent years. At present, there are a large number of non-governmental organisations devoted to nature conservation, conservation ecology and restoration work (Choi 2004; Young et al. 2005). There is also a discussion about the need to adapt the restoration ecology to climate change among other things, so that the restored ecosystems can withstand future environmental conditions (Choi 2007, Choi et al. 2008). Most of the literature and concepts in this science come from research on terrestrial environments and freshwater systems, and it is not until later years that knowledge of restoration of various marine environments has improved, especially coastal systems. However, the knowledge is still inadequate when it comes to restoration of open marine systems (Elliott et al. 2007).

Defining what is meant by different types of restoration is important from a scientific as well as from a legal perspective, and the definition also defines the goals that are intended to be achieved through a restoration measure (see fact box 2.1 and figure 2.1 for definition of various types of measures that occur with a view to improving a degraded environment).

### Fact Box 2.1. Terms in restoration ecology and compensation

Below is a description and definition of ecological restoration and other types of measures that are in place to improve a damaged environment or to offset intrusion into an environment.

**Ecological restoration** can be said to be the "true" type of restoration where the goal is to restore the entire ecosystem and all its structural and functional properties to a state similar to the one that existed before it was disturbed (Figure 2.1.). Thus, in ecological restoration, the goal is for a damaged ecosystem to return to a historical state, which must be clearly defined before the project's goals are set.

Like restoration, **rehabilitation** has a focus on a historical state of the ecosystem, with the difference that rehabilitation focuses more on the processes and ecosystem services that the ecosystem provides (SER 2004). In simple terms, a rehabilitative measure does not place as high demands on achieving an original condition as on ecological restoration (Bradshaw 1995, Figure 2.1).

**Replacement or reclamation**
In this type of action, one does not necessarily strive to regain the original ecosystem that has been degraded or lost, but rather to seek a more useful condition than is currently in place (Bradshaw 1995). Thus, the focus is not on the overall picture, but the aim is to improve the function of the system, for example the ability to absorb carbon dioxide or nutrients (Figure 2.1.). An example of this could be planting seagrass to reduce erosion, or planting wetlands to increase nitrogen uptake.

**Mitigation** is a word commonly used in restoration. However, this has no real connection to restoration as the term only means performing mitigating or dampening actions against an ecosystem damaged by human activity (Bradshaw 1995).

**Ecological compensation (in English "Offsetting" or "Compensatory mitigation")** is a term used in the event of damage or loss of natural values, for example, exploitation where a well-known business operator is responsible for recreating lost natural resources. Ecological compensation can be set as a requirement after court decisions or made voluntarily and aims to compensate for all natural resources and ecosystem services lost so that no net losses occur. This is achieved by adding new ecological values, for example through innovation (see above), protection and maintenance or through restoration.

**Compensatory restoration** is a type of ecological compensation, where compensation is done through restoration of the damaged or lost habitat where the extent of the restoration corresponds to the loss of ecosystem services caused by the damage in time and space. Compensatory restoration is therefore a term that refers to a specific type of restoration in which the goal is to compensate for damage that an identified operator is responsible for, often based on a court decision.

**The injury mitigation hierarchy** is a method that should be used in all cases where ecological compensation is relevant, which means that damage should be avoided in the first place, secondarily minimised and remedied, and only as a last resort compensated.

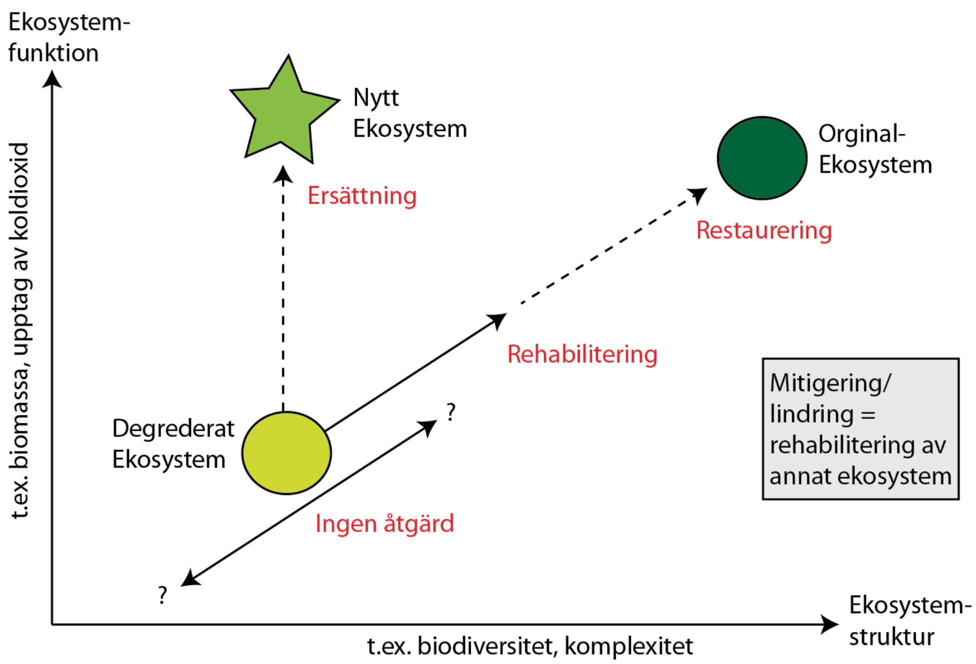


Figure 2.1. The graph illustrates ecosystem structure and function of a degraded (damaged) ecosystem and the meaning behind various types of improvement measures that can be applied to the damaged ecosystem (the image is based on an illustration from Bradshaw (1984)).

### 2.1.2. A multidisciplinary business

In order for restoration to be carried out in an efficient and successful way, in addition to ecological competence and understanding of how different habitats or ecosystems work, people with other knowledge and skills are also required to be involved in the process, from planning, financing and execution.

It is usually stated that there is a need to consider five main components when performing a restoration (Jackson et al. 1995; Aronson 2010):

- **ecology -** information about patterns and processes in nature that are collected through historical, analytical and experimental studies
- **society's formal and informal norms -** information on political goals and requirements and groups' acceptance of these norms
- **culture** such as traditional use of an area or a resource
- **economy -** what type of areas are considered worth restoring. Often, areas that offer a clear value to human beings are favoured, but the cost of the actual execution can also have an impact on the scope of the restoration measure.
- **politics -** what goals, values and requirements is there political will to drive and counter

# 2.2. Ecological compensation and compensatory restoration

## 2.2.1. Background

**Ecological compensation** means that those who will damage natural environments that constitute general resources, such as species, habitat types, ecosystem functions and experience values, must compensate for this by adding new values with the ambition that no net loss will remain (SOU 2013: 68).
The terminology in English for various forms of compensation may be a bit unclear where the terms " *environmental mitigation* " or " *compensatory mitigation* " are used by US authorities for ecological compensation, while the term " *offsetting* " is used within the EU to describe ecological compensation, where " *compensation*” has a broader significance that also includes compensation that does not fully outweigh the impact (see fact box 2.1.).

Ecological compensation is based on the international principle within environmental politics that the polluter pays (in English *polluters pay principle*, PPP), which is also an important principle in Swedish environmental legislation. Ecological compensation can be seen as a tool to put the principle into practice. Two important factors for ecological compensation to meet the requirements for counteracting net losses are *additionality* and *longevity*, which means that the measures intended to be carried out within the compensation would not otherwise have been carried out, and that the compensation obligation is set in relation to how long a disturbance is expected to last (SOU 2013: 68).

Interest in ecological compensation has increased in recent years through, among other things, The EU's strategy for biodiversity and the goal of no deterioration of the environment (the so-called *No Net Loss* initiative), where ecological compensation is highlighted as one of the tools to stop biodiversity and ecosystem services losses (European Commission 2011). The strategy mentions, among other things, to maintain and improve ecosystems and ecosystem services by 2020 by introducing "green infrastructure" and restoring at least 15% of damaged ecosystems. In Sweden, ecological compensation is discussed as a possible tool for achieving the environmental quality goals, including by integrating the value of ecosystem services into the decision-making process (Prop. 2013/12: 141). Although there is room to claim compensation for the negative impact on ecosystem services in the exploitation of land and water areas according to the Environmental Code (see section 7), the use of legal obscurity is currently hampered (SOU 2013: 68). The Swedish Environmental Protection Agency has therefore produced a guide on the provisions of the Environmental Code regarding compensation as a support for supervisory and reviewing authorities (the Swedish Environmental Protection Agency 2016). Increased use of the environmental bar's compensation rules also increases the knowledge and experience of compensation restoration.

Ecological compensation can be designed in several ways where it is the choice of unit of measure to describe the consequences of an injury that determines the design. This may involve measures in the form of **nature conservation** or safeguarding of **nature protection**, or measures in the form of **innovation** of nature in an area that is largely devoid of natural values. It may also involve **restoration** of lost natural values and ecosystem services in an area that has low natural values (SOU 2013: 68; see fact box 2.1.). Compensation can also take different forms in terms of the damaged and the compensated environment is of the same habitat (so-called "in-kind" in English), in the same place ("on-site"), or where a resource is to be replaced by another type of resource (so-called "out-of-kind"), or at another site (so-called "off-site").

**Compensation restoration** is thus a special form of ecological compensation where damage to the environment is compensated by restoring a habitat (see fact box 2.1.). This report focuses on the restoration of eelgrass, i.e. when damage to an eelgrass habitat is compensated by restoring eelgrass in the same place or in another area.

### 2.2.2. Difference between compensatory and ecological restoration

Although the restoration methods in a compensatory restoration may be the same as in an ecological restoration, there are important differences in goals, responsibilities and legal basis for the two types of restoration, which is why we describe them separately in this report. Compensatory restoration is a specific type of restoration that constitutes ecological compensation in a case where a well-known operator caused damage to a habitat. The restoration is often done because claims have been made for compensation after the operation has been tested in accordance with the Environmental Code. The goal of the restoration is to compensate for the damage by restoring a specific area of the habitat that corresponds to the losses in ecosystem services caused by the damage in time and space. Most restorations of this type are normally relatively small in scope (0.1 to around 10 ha).

In ecological restoration, the aim is to recover historical losses from an important habitat where it is often about restoring large areas (10 to 100 ha). Often the causes of the losses are unclear, and a responsible operator is missing. The driving forces behind the restoration can instead be commitments to international conventions, EU directives and Swedish environmental quality objectives, and it is normally carried out by authorities at national or regional level.

### 2.2.3. Opportunities and risks of ecological compensation

Effective ecological compensation can be a useful tool for applying the polluter pays principle and achieving environmental goals linked to biodiversity and ecosystem services. At best, it can help counteract a gradual degradation of biodiversity and ecosystem services as a result of exploitation by ensuring that no net losses from habitats and other environmental resources occur.

Increased application of ecological compensation also involves risks, e.g. that exploits in sensitive areas increase in order to lower the requirements for a business because there is a will or opportunity to compensate. Therefore, the Swedish Environmental Protection Agency's starting point is that **compensation commitments must not lead to lower requirements in an admissions test** or result in the acceptance of a more harmful location (the Swedish Environmental Protection Agency 2016). Therefore, it is very important that the so-called *damage mitigation hierarchy* is used in all cases where ecological compensation is relevant, which means that **damage should *be avoided* in the first place, secondary *minimised* and *remedied* and only *compensated* in the last instance**. This means that damage during exploitation should be avoided primarily through good planning, and secondly, consideration should be given to the design of the business to minimise the damage from exploitation

while at the same time follow-up and other remedial measures should be carried out on site to mitigate the negative effects that occur. It is only if damage can be expected to remain even though all these measures have been taken as compensation may be relevant (the Swedish Environmental Protection Agency 2016). In connection with the decision on compensation measures, it is also necessary to ensure that the measures really compensate for the damage without net losses and that they function in the long term.
In the **compensatory restoration of seagrass,** there is also a problem that many compensation projects have historically failed, which is why net losses of seagrass habitat have occurred. Because there are often no suitable sites around an exploited area that allows seagrass growth, this type of restoration fails more often than ecological restorations. Furthermore, it has been common to plant only the same (equally large) surface of seagrass that is exploited. But since survival is often much lower than 100%, even "successful" projects of this type also result in a net loss of seagrass (Fonseca et al. 1998). It is therefore very important that the extent of the compensation is designed so that losses in both time and space are compensated, and where the likelihood of success of the compensation is weighed in such a way that the risk of net loss of habitat and ecosystem services is minimised (see section 9.4).

Finally, there is also a serious problem around compensatory restoration **if planting occurs at a site that has lost seagrass due to a different impact, as this results in a net loss of seagrass habitat overall.** This problem has often not been noticed because the focus is on the individual case without taking historical losses into account (Fonseca et al. 1998). In Bohuslän, where eutrophication and overfishing are considered to have caused large losses of eelgrass, and in virtually all potential areas where compensatory restoration could be carried out are bottoms where eelgrass grew in the 1980s (see section 2.3.2), this constitutes a real problem. If an eelgrass habitat is permanently destroyed at e.g. construction of a harbour, and replaced by the restoration of eelgrass at a site where the habitat was lost due to e.g. eutrophication, only one restoration has been done by the historic meadow, but no compensation has been made for the construction of the harbour. Thus, it is important to have a long-term historical perspective when analysing losses and offsetting habitat, and to realise that **in most cases compensatory restoration of eelgrass in Swedish waters would only be a way to finance and accelerate the compensation of historical losses; but lead to a net loss of eelgrass habitat.** It is therefore important to primarily avoid and minimise damage to eelgrass, and only as a last resort to allow exploitation that results in losses of eelgrass meadows, even if a compensation restoration is performed.

# 3. Ecological background for eelgrass ecosystems in Swedish waters

## 3.1. Eelgrass ecology

Seagrass is the term for flowering plants that have adapted to a life below sea level. This ecological group of plants is relatively young and is believed to have evolved around 100 million years ago. Other groups of plants have also developed a certain salt tolerance, such as mangroves and salt meadows, but seagrass is the only group of land plants that have adapted to live entirely in a marine environment. Globally, there are about 60 species of seagrass, all of which have developed special properties to grow and reproduce underwater in a marine environment (Arber 1920). Despite the low diversity of seagrass species (0.02% of the world's flowering plants), seagrass has a great ability to adapt to different marine environments and grows along all continents except Antarctica. This makes seagrass meadows unique among important marine ecosystems, which are often limited to certain latitudes, such as coral reefs around the equator or kelp forests in temperate areas. The diversity of seagrass species is highest in the eastern parts of the Indian Ocean where 12–15 species are found. For more information about marine grass species and its global reach, see Green & Short (2003).

### 3.1.1. Swedish seagrass species and distribution

In Sweden, four seagrass species occur (Green & Short 2003, Borum et al. 2004). Eelgrass (*Zostera marina* L.) is the most common and largest species in Swedish waters and dominates completely on the west coast. Dwarf grass (*Z. noltii*) is a smaller species that is common in tidal areas in northern Europe, but which is very rare in Sweden and is found only on some 30 known sites in Västra Götaland and Halland counties. The species is distinguished from the eelgrass by its smaller size, narrower leaves (1–2 mm) which have a groove at the top, and seeds that are smooth unlike the eelgrass rifled seeds (Mossberg & Stenberg 2005). Narrow eelgrass (*Z. angustifolia*) is also found along the west coast, but as there is uncertainty about its taxonomic status (it is considered by many to be a smaller and narrower variant of *Z. marina;* World Register of Marine Species 2016) it is not included here as a species of its own. Two seagrass species found in more delicate environments are beaked tasselweed (*Ruppia maritima*) and spiral tasselweed (*R. cirrhosa*), which differ from eelgrass species in that they have a more bush-like structure with thread-shaped pointed leaves. These are common on the west coast in areas affected by freshwater outflows and in the brackish waters of the Baltic Sea. However, there is some disagreement as to whether tasselweed should be considered true seagrass as they do not grow in environments with full salinity.

In the brackish waters of the Baltic Sea, seagrass often grows in mixed stocks together with freshwater live seed plants such as clasping-leaved pondweed (*Potamogeton perfoliatus*), slender-leaved pondweed (*P. filiformis*), fennel pondweed (*Stuckenia pectinatus*; *syn. P. pectinatus*), horned pondweed (*Zannichellia* spp.) spiny water nymph (*Najas marina)*, three species of watermilfoil (*Myriophyllum* spp.) and a large number of species of coral algae.

In this report, "eelgrass" refers to *Z. marina* and all recommendations apply only to this seagrass species. The older term "band of seaweed", which is often found in flora, is misleading as the plant is not an algae and should therefore be avoided. Nor is the name "eelgrass" quite accurate as the plant does not belong to the family grass (*Poaceae*), but just like other seagrass species is a monocotyledonous seed within the swelling *scheme* (*Alismatales*). However, the name eelgrass is now well established and dominant in scientific literature and in the administration both in Sweden and internationally (e.g. Norwegian: *ålegras*, Danish: *ålegræs*, English: *eelgrass*).

Eelgrass is the dominant seagrass species in temperate areas in the Northern Hemisphere as well as in Swedish waters and grows both in the North Sea and the Baltic. The eelgrass is the main seagrass species in the world that is best studied both in basic science and from a management perspective where it is used in a variety of restoration projects in both the United States and Europe (Fonseca et al. 1998, Borum et al. 2004).

The eelgrass is the dominant species of seagrass in Swedish water and is often found in shallow bays (0.5–10 m in unaffected areas) with low to moderate wave exposure and muddy to sandy sediments (Figure 3.1). Along the coast of Sweden, eelgrass is perennial and grows in depth where it is almost never exposed to air. The shape of the eelgrass (morphology) differs depending on the physical conditions in which they grow and they also have the ability to change shape as shoots are moved from one environment to another. Generally, blade length, width and density of shoots depend on light conditions and wave exposure at the sites where the width and length of the leaves increase and shoot density decreases with depth and with reduced exposure (Borum et al. 2004, Boström m. fl. 2014). In deeper (> 4 m), sheltered sites on the Swedish west coast, the leaf length may be over 1 m, while eelgrass growing in shallow (1 m) more exposed sites may have a leaf length of about 20 cm (Figure 3.2).

The eelgrass anchors in the sediment by means of rhizomes and roots, which allows them to grow from relatively exposed sites with sandy sediment to protected sites where the sediment has a high organic content and high water content. In addition to serving as an anchor, the rootstocks and roots are used for nutrient uptake and starch storage that the plant can use during periods of poor lighting conditions. The eelgrass absorbs nutrients both from the sediment using the roots and through the leaf surface and is adapted to live in environments with relatively nutrient-poor water. In nutrient-poor environments, eelgrass therefore has a strong competitiveness in comparison with e.g. phytoplankton that requires 4 times as much nitrogen and phosphorus (Borum et al. 2004). However, eelgrass and other seagrass species have a much higher light requirement than for example, algae, which is due, among other things to the need to support a large non-photosynthesising biomass (rhizome and roots), and to continuously oxygenate the root zone to avoid negative effects of oxygen deficiency. The eelgrass requires an average of 20% of the amount of light at the surface to survive and grow, while phytoplankton and epiphytic algae require only about 1% (Dennison et al. 1993). This means that the eelgrass can be out-competed by algae in over-fertilized environments with high nutrient levels and poor lighting conditions. The eelgrass is particularly sensitive to poor lighting conditions in sheltered environments where the sediment has a high organic content and is often oxygen-free with high levels of toxic hydrogen sulfide. In these environments good light supply and oxygen are required to prevent hydrogen sulfide from entering the plant through the roots, which can quickly kill the eelgrass (Holmer & Bondegaard 2001; Holmer & Laursen 2002). This sensitivity to deteriorated light conditions makes the eelgrass a good indicator of the light supply in the water. The depth distribution of the eelgrass can therefore be used as an indicator for changes in water quality over longer periods of time (Krause-Jensen et al. 2008).


Figure 3.1 Eelgrass meadow (*Zostera marina*) in the Gullmarsfjord with the growth of ascidian and sea anemones. *Photo: P. Moksnes.*

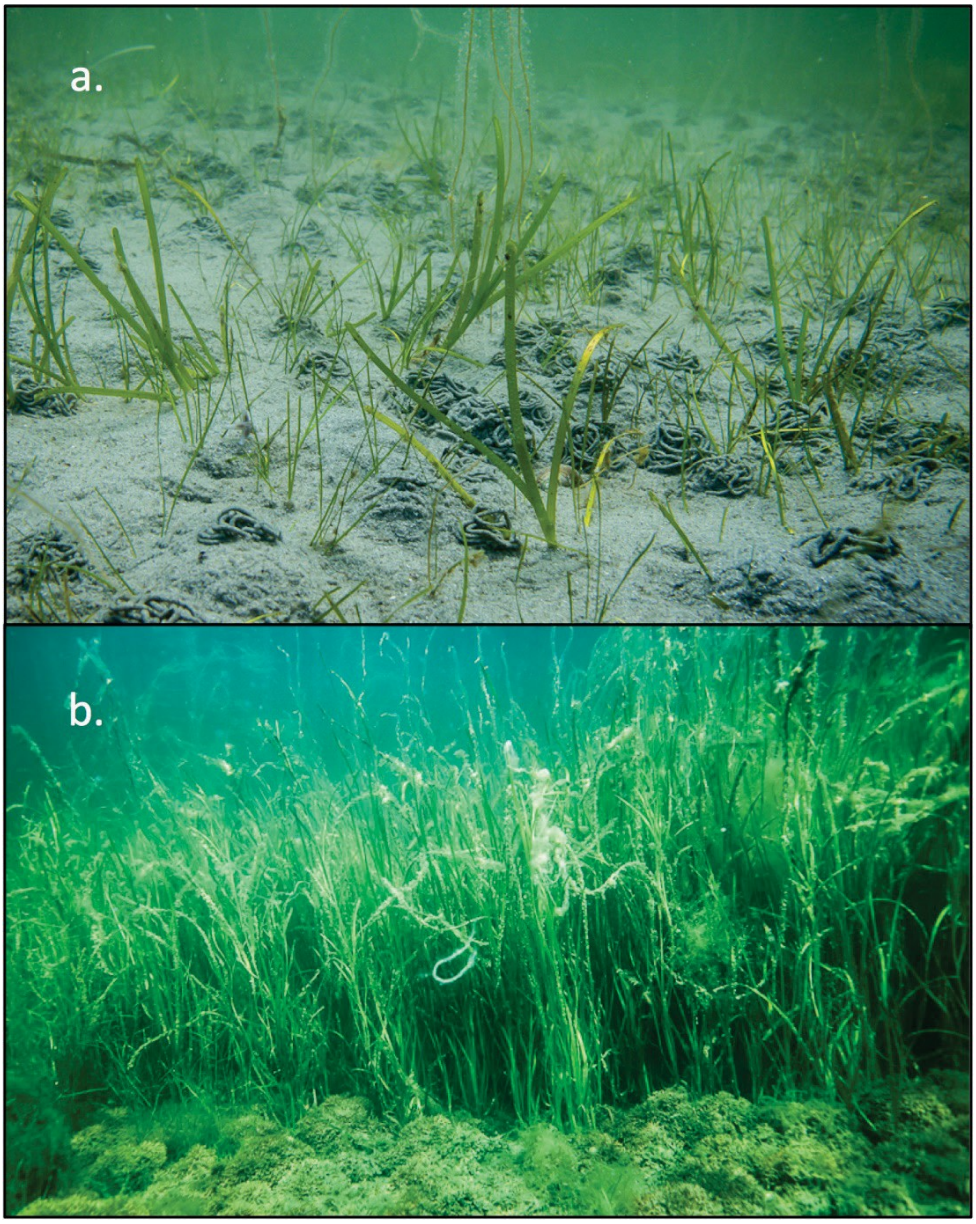


Figure 3.2. The shape of the eelgrass varies greatly depending on wave exposure and light supply. In shallow, exposed sites (a), the leaves are often less than 30 cm (the broad leaves are eelgrass; the thin ones are tasselweed *Ruppia* sp.), While the leaves are up to one meter long in deep, light-poor environments (b). *Photo: E. Infantes.*

The distribution of eelgrass along the coast of Sweden extends from the Norwegian border on the west coast (salinity 20-30) to Stockholm's northern archipelago (salinity approximately 5) in the Baltic Sea (see Boström et al. 2014 for a detailed description of the distribution of eelgrass in Scandinavia). In the North Sea, the seagrass population is made up almost entirely of eelgrass, although tasselweed (*Ruppia* spp.) are often found in shallower, more vulnerable areas (Figure 3.2a). In Bohuslän, prosperous eelgrass stocks are found close to estuaries where salinity varies between 0 and 19 (average 6; see Table 2.1 in Moksnes et al. 2016), which shows that eelgrass is tolerant to large variations in salinity. Here, eelgrass generally grows in sheltered bays with sandy to muddy sediment with high content of organic matter and water (up to 25 and 85%; Table 2.1 in Moksnes et al. 2016) and usually at a depth between 0.5- 4 m. In Kattegat large stocks of eelgrass are found from Gothenburg down to Kungsbacka fjord in Halland, while few eelgrass meadows are found in the central, more exposed parts of the Swedish Kattegat coast. In southern Kattegat, eelgrass is found in the Gulf of Laholms Bay and

Skäldersviken, while large, well-developed meadows are found in Östersund at depths up to 6–7 m. Along the southern coast of Skåne, large meadows are found in more sheltered areas, including at Trelleborg, Ystad and in the northern parts of Hanö Bay. Large meadows are also found in Blekinge, Kalmarsund and Gotland, while the occurrence is poorly investigated along the Swedish east coast north of Öland.

In the Baltic Sea, eelgrass generally grows in more exposed sites on gravel and sandy substrates with lower organic content (0.5–1.5%), at a depth between 1.5–6 m (Baden & Pihl 1984, Baden & Boström 2001, Boström et al. 2003, Boström et al. 2014). The reason for the difference in depth and substrate of the distribution of eelgrass between the West Coast and the Swedish Baltic coast is not fully known but may be due to competition from other species of freshwater seed plants and wreath algae that dominate the shallow and sheltered soft bottoms in the Baltic Sea.

### 3.1.2. Growth, reproduction and spread

The eelgrass propagates and spreads both asexually (vegetatively) through branches along the root of the soil, where new shoots shoot up, and sexually through seeds formed on reproductive flower shoots. Vegetative propagation occurs by the main shoot forming new leaves and dropping old as the rootstock grows. Each time an old leaf withers and falls off, a scar is formed on the rhizome (a node). The life of a leaf is 33–164 days, depending on, for instance temperature (Borum et al. 2004). Approximately after every fifth node, a branch is formed on the rhizome, but the interval depends on the environment in which the shoot grows. At shallow depths with good light supply most of the energy is invested in high branching rhizome growth so that a complex mat of lateral shoots is formed. However, at greater depths with poor light supply, most of the energy is used for vertical growth, which gives long shots, but low rhizome growth with few branches (Bintz and Nixon 2001; Ochieng et al. 2010; Eriander et al. 2016).

In Danish waters, eelgrass meadows spread horizontally by an average of 16 cm per year (Olesen and Sand-Jensen 1994), in warmer water the rate of propagation is slightly faster (22–31 cm per year; Borum et al. 2004). However, planting studies in Bohuslän show that a vegetative shoot with a 5 cm long rhizome that is planted at shallow depth can grow to over a meter in rhizome length in 14 months (see Figure 6.3 in Moksnes et al. 2016). A similar growth can also be obtained from a seed shoot after 14 months. This rapid growth indicates that eelgrass shoots planted separately from other shoots and potential competition may exhibit significantly higher growth than shoots in natural meadows.

Sexual reproduction occurs through seed formation on special reproductive shoots. These flowering shoots are generally longer than the vegetative shoots in the meadow and can thus be easily discerned. They also have a branched structure with a round stem in the middle (Figure 3.3). At the branches there are floral holsters where the seeds will eventually develop. Eelgrass plants have both male and female flowers in each holster, but these mature at different times to avoid self-fertilization. Wire pollen is released from male flowers and transported by streams through the waterbody, where they are captured by mature female flowers on another plant. The female flower pistil has two filaments that fall off after fertilization, which makes it possible to see if a flower has been fertilized or not. The seeds develop in the holster until they are fully ripe when they release from the flower shoot and sink to the bottom due to their negative buoyancy. A shoot that blooms dies after seedling, which is why flowering represents an end stage in the shoot's life history. The average life expectancy of an eelgrass shoot is around 1.5 years (DeCock 1980, Borum et al. 2004). However, seedling studies in Bohuslän show that some seed shoots can produce reproductive shoots as soon as 3–4 months after they have germinated (Infantes et al. 2016).

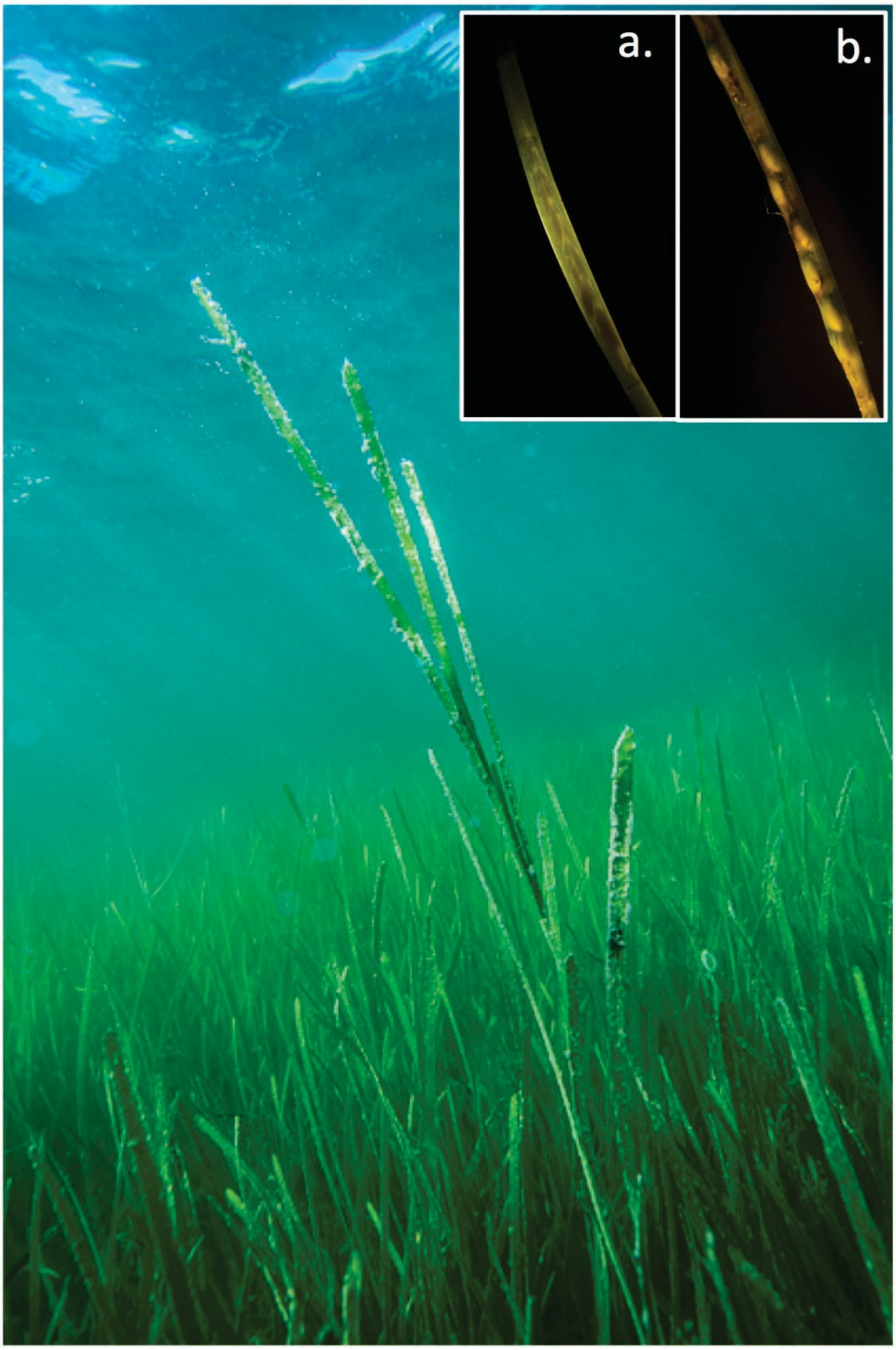


Figure 3.3. Reproductive flower shoot of eelgrass that protrudes half a meter longer than the vegetative shoots. The inset image shows a floral holster in early development with unfertilized flowers (a) and a holster in late development with mature eelgrass seeds (b). *Photo: E. Infantes.*

The number of seeds produced by a meadow often varies between site and year, but can amount to large quantities. In eelgrass meadows in Denmark, densities of seeds between 3 400–17 600 seeds per square meter have been measured (Olesen 1999). As the seeds quickly fall to the bottom, most end up in the meadow or just a few meters away (Orth et al. 1994), and the density of seeds in the sediment outside meadows is generally very low (Olesen & Sand-Jensen 1994, Olesen 1999). Due to the fact that most of the seeds that grow are located in the meadow, competition for light is great from established plants, which means that only a few seedlings survive. Despite getting seeds established, this seed bank serves as an important reserve should anything happen to the existing meadow. For example, if the vegetative shoots are knocked out by extreme temperature conditions during late summer or by ice scraping during the winter, the surface can be recolonized by seeds that can lie in the sediment up to one year before they grow (Orth et al. 2000).

Although experiments have shown that 80% of eelgrass seeds are retained within 5 m of the site they were released (Orth et al. 1994), seeds can be spread far longer via floating inflorescences with seeds. Studies in Bohuslän show that the eelgrass reproductive shoots easily detach when the seeds are ripe and that they have positive buoyancy for at least 26 days, which would provide a potential spread up to 150 km with the help of wind-driven surface currents (Källström et al. 2008). However, only a small number of seeds with inflorescences are spread (Harwell & Orth 2001), so although this dispersal mechanism is important from a genetic perspective (Reusch 2002), it is normally a very slow mechanism for the re-establishment of lost eelgrass stocks.

Eelgrass along the coast of Sweden propagates both sexually and asexually. Vegetative growth is the most common form of eelgrass propagation, and in the northern parts of Bohuslän new shoots account for about 65% of asexual growth and 35% of seed growth (Källström et al. 2008). In Bohuslän, reproductive flower shoots are normally found from May to October with maximum densities of flower shoots (around 6 shoots per square meter) from mid-July to early September. Pollination normally starts at the end of June and lasts until September.
Ripe seeds can be found from late July to late September, but large variations are found between years, sites and depth (E. Infantes, unpublished data). As temperature affects the development, mature seeds are usually found earlier in the year in shallow compared to deep areas within the same meadow, and since the pods develop from below and upwards on the shoots, it is also normal to find pods at different development stages within the same shoot. In Scandinavian waters, seeds do not germinate in the fall, but rest in sediment over winter until they germinate in April – May (Olesen 1999, Infantes et al. 2016). Studies in Bohuslän show that the loss of seeds during this period is very high and in average less than one percent of seeds grow to seed shoots in the spring (Infantes et al. 2016).

However, in the Baltic Sea, and in more exposed environments, it is less common for eelgrass to bloom and the few seedlings that are formed often find it difficult to survive the winter due to the lower growth in the low salinity (Baden & Boström 2001, Boström et al. 2003). Therefore, growth occurs mainly through asexual propagation in the Baltic Sea, and entire meadows can consist of one and the same clone, i.e. all individuals have the same inheritance mass.

The growth and distribution of eelgrass varies over the year and between years due to e.g. differences in temperature, light conditions, nutrition and ice effect. Generally, the largest biomass of eelgrass is reached during the late summer (August-September) in Bohuslän, whereupon the shoots begin to drop leaves during October-December (Baden & Pihl 1984). As the light supply decreases with depth, eelgrass that grows in deep or cloudy water has a shorter growth season (see figure 2.5 in Moksnes et al. 2016), which means that eelgrass in these environments can start dropping leaves as early as August (Eriander et al. 2016). However, in Sweden where the eelgrass is perennial, a meadow does not drop all leaves during the winter, but a relatively large number of shoots with leaves are found at all depths also during the cold season. Sampling in two meadows in the Gullmarsfjord in March showed that the bulk density was around 50% of the bulk density in September at 1–2 m depth, but only about 25% of the density at 3–4 m depth (PO. Moksnes, unpublished data). Most shoots and overwintering rhizomes without leaves produce new shoots in the spring when light supply increases again. However, observation of shoots that suddenly emerge from the rhizome in mid-summer suggests that some rhizomes are dormant for a longer period. This may possibly be an explanation for the large variation in eelgrass distribution from year to year reported in some studies (Nyqvist et al. 2009). It is therefore recommended that inventory of eelgrass is made during the period July – September.

## 3.2. Eelgrass ecosystem functions

Eelgrass is an "ecosystem engineer" because its leaf shoots and rootstocks affect both the physical, chemical and biological environment in which they grow and form the structural foundation for very rich and productive ecosystems.
Because eelgrass, unlike macro algae, can grow and form large meadows on the soft bottom, it provides a range of unique ecosystem features that cannot be replaced by other habitats.

### 3.2.1. Habitat for plants and animals

Perhaps the most important feature is that the eelgrass leaves form habitats for a wide range of plants and animals, which means that biodiversity is many times higher in comparison to a bottom without vegetation. Studies in the Skagerrak have found over 40 different fish species (Pihl and Wennhage 2002, Wennhage and Pihl 2002), 125 species of trapped animals and 72 species of trapped macroalgae in eelgrass meadows (Fredriksen et al. 2005). Comparative studies in Bohuslän showed that the biodiversity of fish was 32% higher and the amount of fish in weight 57% higher in eelgrass meadows compared to areas without vegetation where eelgrass disappeared. Juveniles of different cod fish species, wrasse (labridae) and pipefish were found almost exclusively in eelgrass meadows where their numbers were up to 138 times higher than on the bottom without vegetation (Pihl et al. 2006).

Studies show that primary production of seagrass and epiphytic algae in seagrass meadows is higher than in many cultivated systems on land, and three to eight times higher than for macroalgae and plankton communities (Green and Short 2003; Orth et al. 2006). The high production of epiphytic micro- and macro-algae on eelgrass leaves is the basis for highly productive ecosystems that generate a high secondary production of small vertebrates, which in turn constitute food for fish. The high production of food and the protective function provided by the habitat make eelgrass meadows a very important breeding habitat for many Swedish fish species such as juvenile cod, saithe, whiting, eel and sea trout. In addition, it is also an important food area for a large number of fish species. The importance of eelgrass meadows for cod production in the North Sea is well documented today (Lilley and Unsworth 2014), and in Bohuslän, on average, 14 times higher densities of juvenile cod are found in eelgrass than on soft bottom without vegetation (Pihl et al. 2006).

### 3.2.2. Attenuation of currents and stabilisation of benthos

Another important ecosystem function for the local environment is that the eelgrass meadow absorbs wave energy and attenuates the speed of currents. This causes the sedimentation of particles to increase, which reduces the turbidity and nutrient content in the water. In addition, the rhizome and roots of the eelgrass stabilise the bottom, reducing the resuspension of sediment and erosion of the substrate. All in all, this filtering and stabilising effect can have great positive effects on the water quality in the local area when eelgrass meadows are large. Studies in the US showed that both turbidity and chlorophyll content in the water decreased dramatically after a large eelgrass meadow was restored in one area (Orth et al. 2012). In Bohuslän, studies show that the depth of view has deteriorated by over a meter in areas where large eelgrass meadows (10-30 ha) have disappeared, probably as a result of increased resuspension of seabed sediments (Moksnes, unpublished data; see Moksnes et al. 2016, section 2.5 .5). The positive effect of eelgrass meadows on water quality can have positive effects on the production of plants and small animals in the immediate area by increasing the depth distribution and extent of microalgae and larger plants that constitute food and habitat for plants and animals. It also makes it easier for predatory fish who need clear water to find food in the area.

### 3.2.3. Accumulation and long term storage of organic material

One result of increasing sedimentation and reduced resuspension is that organic material accumulates in eelgrass meadows. Carbon and nutrients are also taken up by eelgrass and epiphytic algae, which also accumulate in the sediment in the form of rhizomes and roots, or at the bottom when the leaves are dropped and the algae die. Some of this material is converted, but much is buried in the sediment where oxygen-free conditions prevent further mineralization (Hendriks et al. 2008, Duarte et al. 2013). Therefore, seagrass meadows have a remarkable capacity to collect organic material. It is estimated that a meadow can bury carbon at a rate of around 1.7 tonnes per hectare per year, which is 30-50 times higher than that found in forest environments on land (Kennedy et al. 2010, Duarte et al. 2013). This means that large amounts of carbon, nitrogen and phosphorus are removed from the water and accumulated in the sediment over time, where it is stored for long periods of time (100-1000 years) in meter-thick layers that can contain around 140 tonnes of carbon per hectare (Fourqurean et al. 2012 , Duarte et al. 2013). Uptake and storage of nutrients in seagrass meadows is less studied, but studies of restored eelgrass meadows in the United States indicate that at least 12 kg of nitrogen per hectare per year is stored in the sediment (McGlathery et al. 2012).

Uptake and long-term storage of carbon and nutrients are still poorly studied in Swedish eelgrass meadows, but studies in Bohuslän show that meadows in protected areas may have over meter-thick sediment layers with high levels of organic matter (> 10%; PO. Moksnes, unpublished data), which indicates a high accumulation rate. Eelgrass meadows, especially large meadows in protected areas, therefore constitute important hollows for carbon and nutrients. This ecosystem function thus reduces the availability of these substances and therefore contributes to reducing the climate effects of carbon dioxide emissions and negative effects of eutrophication.

# 3.3. Changes in the extent of eelgrass

## 3.3.1. Changes in the North Sea since the 1880s

In Sweden, there is no historical data on eelgrass distribution before the 1980s, but Denmark, which has a long history of both mapping and research on eelgrass, has data from the late 1800s. Since the environment in which the eelgrass grows in the Danish Kattegat is similar to the one on the Swedish west coast, historical events and ecological processes in Sweden have probably been comparable to those in Denmark.

The distribution of eelgrass in the Danish coastal waters has been mapped for more than 100 years and shows that today's distribution is only 20–25% of that at the beginning of the 20th century (Frederiksen et al. 2004). In the 1930s, most of the eelgrass in Denmark disappeared in what is believed to be an infection of a mucus fungus in combination with high temperatures (Rasmussen 1977; see section 3.4.3.). The eelgrass then re-colonized the area until the 1960s, but the eelgrass never fully resumed its former extent, possibly because some suitable substrate had eroded away. After the 1960s, the spread of eelgrass again decreased, probably mainly due to eutrophication and reduced light supply. Compared to eelgrass stocks in the 1930s, the depth distribution has been halved in today's stocks, from a maximum depth distribution of around 5–7 m inside fjords and 8–10 m in open water in the Kattegat in the 1930s, to 2–3 m, respectively. 4–5 m today (Boström et al. 2003). New analyses of data from Danish scientist Petersen's expeditions in the Kattegat from the late 1800s show that the eelgrass in the northwestern Kattegat was regularly found at depths around 15 m in the 1880s, indicating that a dramatic change in the underwater visibility in the Kattegat, and eelgrass historically may have grown over large parts of western Kattegat where they are not found today (Loo 2015).

## 3.3.2. Changes in Bohuslän since the 1980s

In the 1980s, monitoring of shallow sea areas was carried out in five municipalities in Bohuslän (Strömstad, Lysekil, Uddevalla, Stenungsund and Kungälv) when, among other things, the distribution of eelgrass was carefully invented. In the year 2000, Baden et al. repeated (2003) inventory, and in 2003 and 2004 Nyqvist et al. performed the (2009) same inventory when it was found that 62% of the eelgrass has disappeared since the 1980s on average. In the 1980s, a total of 1,825 ha of eelgrass was found in inventive areas, where almost half were found in Kungälv municipality. During the 2000s, 1,124 eelgrasses had disappeared, but the degree of loss varied widely between different areas. In Kungälv, on average, 87% of the eelgrass in the invented areas had disappeared, which corresponds to more than half of the total loss in Bohuslän. On the contrary, the prevalence in the municipality of Stenungssund had only decreased by 13%.

The losses of eelgrass in Bohuslän since the 1980s do not consist of reduced depth distribution, but the changes are mainly due to loss of whole eelgrass meadows or in some areas the shallower parts of the meadow. The losses coincide with an increased prevalence of fine-threaded algae mats (fast-growing, often fine-threaded macroalgae that form thick mats), which during the 1990s covered 30–50% of all shallow soft bottom areas in Bohuslän in the summer (Pihl et al. 1999). These carpets now cover many eelgrass meadows in the North Sea and can cause oxygen deficiency in the groundwater as the eelgrass can be quickly eliminated (Greve et al. 2005), and is considered a major cause of the eelgrass losses. The reason for the dramatic increase in fast-growing algae are considered today to be due to a combination of eutrophication and overfishing that has reduced the presence of algae-eating crustaceans (Moksnes et al. 2008, Baden et al. 2010, Baden et al. 2012; see section 3.4.4. for details).

### 3.3.3. New changes since 2004

Preliminary results of field mapping of eelgrass in Kungälv municipality and in the adjoining Hakefjord in Stenungssund municipality in the summer of 2015 in collaboration with the County Administrative Board of Västra Götaland County show that large losses of eelgrass have again occurred in the area. In total, the distribution of eelgrass has decreased by about 80% (corresponding to about 290 ha) since the inventories in 2000–2004, and today only smaller, fragmented meadows remain in the area (Figure 3.4). The losses of eelgrass over the past 10 years have been greatest in the already severely affected municipality of Kungälv where over 90% of the remaining meadows have disappeared since 2004, especially in the area around Nordön (Figure 3.4). In total, today, less than 2% (about 13 ha) of the 770 ha of eelgrass found in the invented area in Kungälv Municipality remains in the early 1980s. In addition, most of these meadows are severely fragmented and consist of meter-sized "patches" of eelgrass. Large losses of eelgrass have also occurred in the eastern parts of the Hakefjord in the municipality of Stengungsund since 2004, where approximately 62 ha of eelgrass remain today (77% loss since the 1980s). The losses have mainly occurred in the southern parts of the fjord, which is adjacent to Kungälv municipality where very little eelgrass is found today. Larger areas of eelgrass are still found in the northern parts of the Hakefjord, but these meadows are currently severely fragmented (Moksnes et al. Unpublished data; Figure 3.4).

These new losses in southern Bohuslän do not appear to represent a new general decline in eelgrass in Bohuslän, but appear to be isolated to the areas described. No inventory has been carried out in other areas mapped in the 1980s and 2000–2004, but mapping of eelgrass in Natura 2000 areas and field inventories in connection with remote analysis of eelgrass conducted by the County Administrative Board in Västra Götaland County seems to show prosperous meadows in the other parts of the county. In the area around the Gullmarsfjorden where test plantings have been carried out for the last 5 years, the depth distribution of eelgrass has increased by about 0.5 m since the experiments started, and a recovery in distribution appears to have occurred on the southern parts of Gåsö which has lost about 40% of the eelgrass since the 1980s (see Figure 2.3 in Moksnes et al. 2016). In Kungälv municipality, the new losses appear to be associated with a degraded water quality that can be attributed to an increased resuspension (scaling up) of sediments from areas that have lost eelgrass (Moksnes' unpublished data, figure 3.5). Even large occurrences of drifting perennial algal mats on the bottom can be a partial explanation for the new decline (see sections 2.3 and section 2.5.6 in Moksnes et al. 2016 for more information).

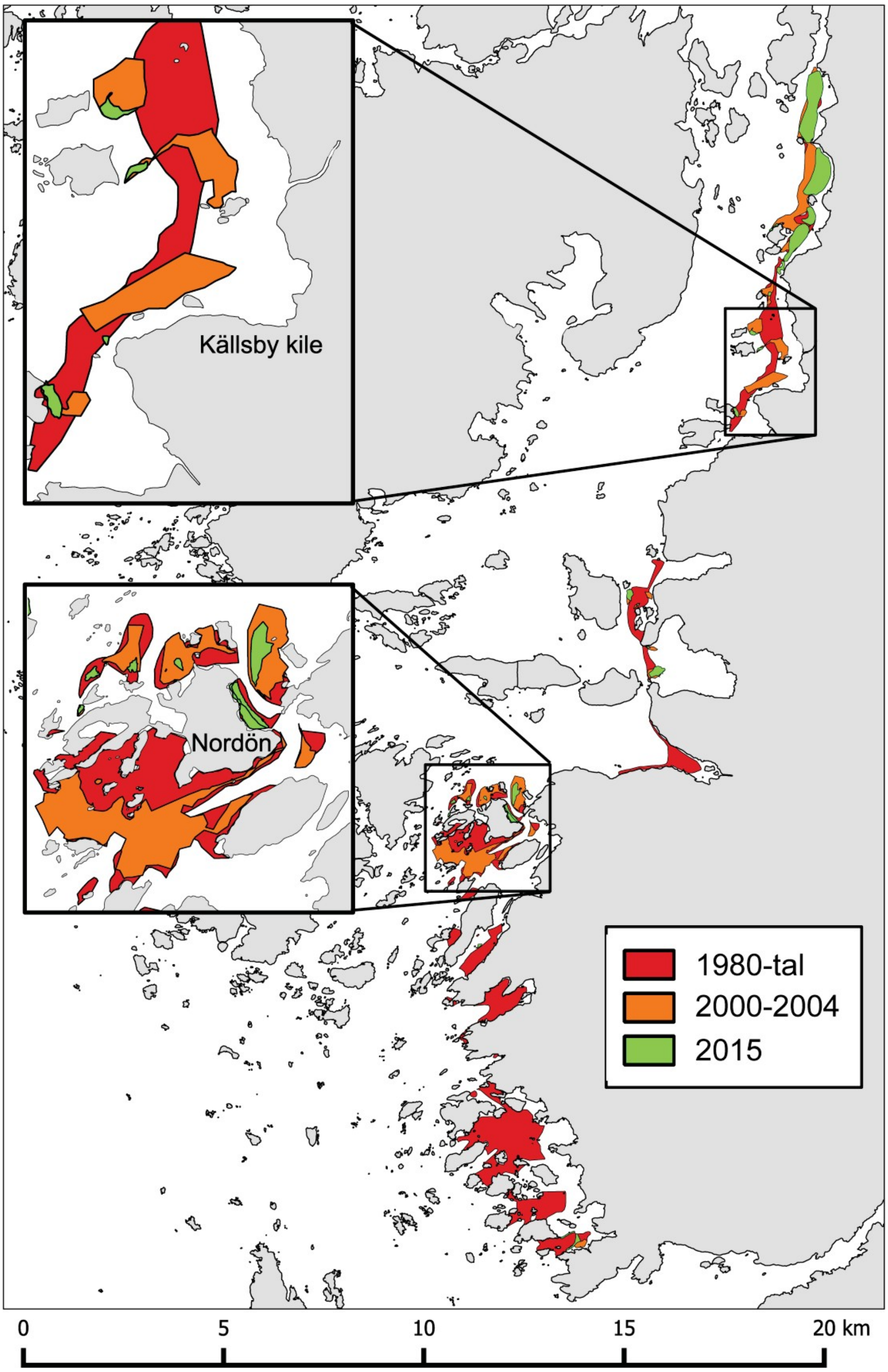


Figure 3.4. Changes in the distribution of eelgrass in 1981–2015 in southern Bohuslän. The map shows the distribution of eelgrass from the Norde Älv outlet in the south to Stengunsund in the north, which was invented on the mainland side in Kungälv municipality and in the eastern parts of the Hakefjord in Stenungsund municipality in the early 1980s, 2000–2004 (Baden et al. 2003, Nyqvist et al. 2009) and 2015 (Moksnes et al. Unpublished data). Coloured areas show the presence of eelgrass with a coverage ratio> 5% where distribution from recent years has been placed above the elderly. In all areas, the distribution in 2015 overlaps with the distribution in the 1980s and 2000–2004, and in most areas, the distribution overlaps in 2000–2004 with that in the 1980s. The pictures below show an enlargement of the area around Källsby wedge in the Hakefjord and around Nordön, before Marstrand, where the largest losses of eelgrass have occurred since 2000–2004.

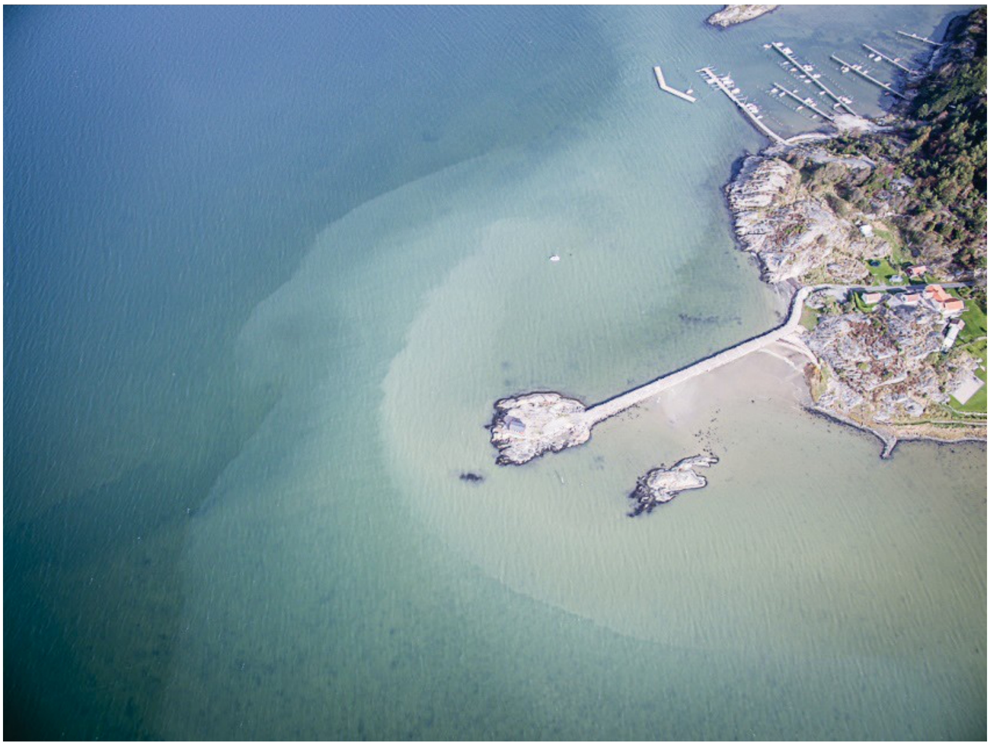

Figure 3.5. Wave-driven resuspension of sediment in the Hakefjord. The picture shows Källsby headland in Hakefjorden in the fall of 2015 where a westerly wind of around 5 meters per second causes local upwelling of the bottom sediment. In the 1980s, a continuous, approximately 8 km long eelgrass meadow stretched from Källsby headland up to Stenungsund along the eastern side of the Hakefjord. Inventory of eelgrass in 2015 shows that large losses have occurred in the southern parts of the meadow during the last 10 years where today only small fragments of eelgrass remain (see Figure 3.4). At the site, the eelgrass is today replaced by clay bottom without vegetation, where the bottom sediment is mixed with fine-grained, glacial clay that is very easily moved by waves on shallow water, which is seen as a grey plume closest to land in the picture. The depth of sight in the water when the picture is taken is <0.5 m. Light measurements and test plantings show that eelgrass can no longer survive at depths where it grew in the early 2000s due to poor lighting conditions. (Photo: E. Infantes.)

### 3.3.4. Estimation of agricultural losses and need of restoration in Bohuslän

Using estimates of today's distribution of eelgrass in Västra Götaland County based on empirical field studies from 2002–2003 (Stål & Pihl 2007) and on satellite image-based remote analysis from 2008–2014 (Lawett et al. 2013, E. Lawett unpublished data), For example, the areal loss of eelgrass in the county since the 1980s can be roughly estimated at 10,000-15,000 ha. This estimate is based on the assumption that the losses documented from the five areas included in the municipal inventories of the 1980s are representative of the whole of Västra Götaland County (see Appendix 1 for details on data and calculations). If the limit for *good environmental status* according to the Marine Environment *Directive* is set at 75% of the arable distribution of eelgrass during the 1980s (the Swedish Agency for Marine and Water Management 2012), between 6,000 and 13,000 must be restored to achieve *good environmental status* for eelgrass.

Restoring this extent of eelgrass by transplanting shoots or seeds presents a tremendous challenge. The largest area of eelgrass that has so far been successfully restored is a total of 1,700 ha over an 11-year period in the north-eastern United States (Orth et al. 2012). Thus, although it is possible to restore 1000's of hectares of eelgrass, it requires good environmental conditions for growth. As the water quality in southern Bohuslän makes it difficult to restore eelgrass there today, it may require measures to improve water quality and remove other factors that counteract growth of eelgrass before restoration can successfully start (see appendix 2 to Moksnes et.al 2016 for more information).

### 3.3.5. Changes in other parts of Sweden

There is no historical data on the arable distribution of eelgrass from other parts of the country, so it is difficult to evaluate whether any losses have occurred. However, there are no indications that similar losses observed in Bohus county since the 1980s should have occurred in some other part of the country. The limited regional monitoring of eelgrass, which is mainly found in southern Sweden (see section 5.3), indicates no losses. However, interview studies with an elderly person indicate that there have historically been large eelgrass meadows along the east coast of Öland, which is largely absent today where drifting carpets of red algae now dominate (*personal communication* RB Jönsson, County Administrative Board in Kalmar County, 2016). It can also be assumed that the decrease in sieve depth of almost 4 m between 1914 and 1991, documented in the actual Baltic Sea (Sandén and Håkansson 1996), has led to reduced depth distribution of eelgrass to the same extent, and probably also led to large negative effects on the extent of eelgrass in shallow areas.

## 3.4. Causes of changes in the distribution of eelgrass

### 3.4.1. Background

Large losses of seagrass have occurred globally as a result of direct and indirect human impact, and over 29% of known seagrass propagation has disappeared in the last 140 years with a continued loss of around 7% annually (Waycott et al. 2009). Mass mortality and loss of seagrass populations, including eelgrass, have been reported from e.g. Sweden (Baden et al. 2003), Denmark (Frederiksen 2004), Germany (Munkes 2005), The Netherlands (Giesen et al. 1990), Poland (Kruk-Dowgiallo 1991) Australia (Walker et al. 2006) and from all coasts around the United States (Fonseca 1998) where human activities are believed to be the main cause of the problems (Short & Wyllie-Echeverria 1996, Green & Short 2003, Borum et al. 2004). This loss is expected to accelerate with the exponentially growing population growth in the world's coastal areas, unless measures are taken swiftly to improve water quality and protect seagrass environments from exploitation and other human activities, for example with the help of marine protected areas (Orth et al. 2006).

The high light requirements of seagrass force them to grow in shallow, coastal areas where human impact is also strongest, and losses can often be correlated to deterioration of light conditions and / or increased sedimentation of particles on seagrass leaves, as well as activities that cause direct damage in the meadows (Larkum et al. 2007). Activities and processes that can cause impaired access to light and thus negatively affect the seagrass are, for example, eutrophication, land drainage, dredging, fish farming and boat activities (Green & Short 2003, Borum et al. 2004, Erftemeijer & Lewis 2006, Orth et al. 2006). Coastal area deployment, together with indirect impacts on water quality from eutrophication, are considered to be two of the leading causes of the global decline (Short & Wyllie-Echeverria 1996, Waycott 2009).

In Swedish sea areas, eutrophication in combination with overfishing is considered to be the main cause of observed eelgrass losses in the North Sea and continue to pose the greatest threats to eelgrass today. In addition, coastal exploitation and boat activities, dumping of mud masses, as well as possible land runoff and climate change are also considered serious threats (see fact box 3.1 for a summary). Below we discuss natural and man-made reasons why eelgrass meadows are lost and do not recover.

### Fact Box 3.1. Threats to eelgrass in Sweden

Below is a summary of the most important threats to eelgrass in Sweden today, their effects on eelgrass and possible management measures.

**Over fertilization**
*Effects*: Increased occurrence of phytoplankton and fast-growing algae, reduced depth distribution and loss of eelgrass meadows in areas where algae mats accumulate. Increased incidence of oxygen deficiency.
*Actions*: Reduced supply of nutrients locally and regionally. Local algal removal and nutrient-saturated sediment removal. Restoration of eelgrass, cultivation of mussels and sea urchins, etc. that absorb nutrients.

**Reduced stock of predatory fish along the coast**
*Effects*: Trophic chain reactions can increase the number of small predatory fish, reduce the presence of algae-grazing animals and increase the amount of fast-growing algae mats. Increased occurrence of beach crabs eating eelgrass seeds and destroying plants.
*Actions*: Reduced fishing pressure or support measures to increase the population of predatory fish along the coast. Directed fishing on small predatory fish and shore crabs.

**Coastal Development**
*Effects*: Loss of environments where eelgrass grows as a result of construction of bridges, ports, marinas, housing, dredging, etc. Shading from bridges, dredging, impaired water circulation due to road banks, etc.
*Actions*: Increased legal protection for eelgrass meadows and shallow soft bottom areas (e.g. by establishing biotope protection for eelgrass). Stricter application of shoreline protection in water areas. Increased use of boat ramps and boat storage on land instead of own docking place. Restoration of old ports, opening of road banks, etc.

**Dumping of mud pulp**
*Effects*: Impaired light supply of eelgrass caused by turbid water, sedimentation on leaves and resuspension of loose sediment.
*Actions*: Prohibition (and no dispensary) of dumping of mud pulp inshore.

**Land drainage**
*Effects*: Sedimentation and impaired light supply for eelgrass caused by outflow of turbid water from watercourses, increased supply of humus substances and nutrients that cause eutrophication.
*Actions*: Reduced erosion from forest and agricultural land and increased retention of nutrients by e.g. increased vegetation around streams, planting of wetlands, catch crops around agricultural land, etc.

**Climate Effects**
*Effects*: May cause lower salinity in the Baltic Sea with reduced northern spread of eelgrass as a result. Higher water temperature, rising sea level and erosion can also have negative effects on eelgrass.
*Actions*: Reduced greenhouse gas emissions. Protection and restoration of vegetation that absorbs carbon dioxide.

### 3.4.2. Natural variation

The environmental conditions prevailing in coastal areas are very variable with large fluctuations in, for example, temperature and salinity. These shallow areas are also more susceptible to disturbances and impacts from various weather phenomena such as storms and ice formation, which causes eelgrass meadows and other coastal habitats to vary widely in their distribution and growth. This is strongly linked to the frequency and magnitude of the physical disturbances to which the area is exposed (e.g. Kendrick et al. 1999). These disorders can be caused by, for example, erosion, fauna, storms and diseases (Larkum et al. 2007). Disturbances from storms, for example, have been shown to cause patchy mortality in meadows and, in some cases, to cause whole meadows to be eliminated (Orth & Moore 1983; Borum et al. 2004). Disturbances are a natural part of most ecosystems and often they can recover on their own. The ability to recover (resilience) in an ecosystem allows it to eventually return to the stable state that existed before the damage.

Inventories carried out in 2003 and 2004 by eelgrass meadows in Västra Götaland County showed significant changes in the distribution between years, both in meadows and in municipalities (Nyqvist et al. 2009). Some meadows that largely disappeared in 2003 were well grown the following year, and some sites where previously unobserved eelgrass showed meadows. In Denmark, it has been found that seed banks in the sediment can explain rapid recovery of large populations from one year to the next as growth conditions improve (Greve et al. 2005). This type of large variation in distribution in both time and space has been observed for many seagrass species and has several important consequences for managers (Fonseca et al. 1998), i.e. eelgrass occurrence inventories must be carried out for more than one year to confirm that eelgrass does not grow on site.

### 3.4.3. Diseases

The most serious mass mortality of eelgrass observed was in the 1930s when "wasting disease" knocked out around 90% of eelgrass on both sides of the Atlantic (Ralph & Short 2002). The immediate cause of the loss is considered to be an infection by the protist *Labyrinthula zosterae*, a type of mucus that causes black necrosis damage to the leaves, which spread and cause the leaves and whole plants to die within a few weeks. Some researchers believe that the high infection rate and mortality rate in the 1930s may have been related to unusually high water temperatures during this period that made the eelgrass stressed and more susceptible to the infection (Ralph & Short 2002; Borum et al. 2004). In Northern Europe, different areas were affected to varying degrees. Along the Dutch coast, almost all eelgrass meadows were knocked out and have not yet recovered (Bockelman et al. 2012). In Denmark, over 90% of all eelgrass disappeared during the 1930s which was mainly discovered after the outbreak of the disease, in areas with lower salinity in the southern Kattegat and in exposed fjord areas. Eelgrass has today recolonized most shallow (<5 m) areas in Denmark, even in the northern parts of the Kattegat, but the area of eelgrass today constitutes only about 25% of the area in the early 1900s (Boström et al. 2003) . Unlike other parts of northern Europe, eelgrass in the Baltic Sea is considered to have been relatively unaffected by the infection (Short et al. 1988). It is not known how the eelgrass in Swedish waters was affected by the disease, but it can be assumed that the distribution along the West Coast decreased to a similar extent to that in Denmark during the 1930s, while populations in the Baltic Sea were probably less affected.

After the epidemic in the 1930s, no more mass outbreaks of *Labyrinthula* have been reported, although minor epidemics in which meadows have been eliminated are documented even today (Hily et al. 2002). Recent studies using molecular methods have shown that *Labyrinthula* today is common in most eelgrass populations in northern Europe where up to 89% of plants in a meadow can carry the infection without the majority of plants showing typical black damage to leaves or signs of increased mortality. A low concentration of *labyrinthine* cells in the infected plants indicates that the infection is chronic, but not pathogenic (Bockelman et al. 2013). However, there are some concerns that increased temperatures due to climate change may increase the risk of new epidemics, as high temperatures could increase *Labyrinthula's* ability to induce disease or increase susceptibility to eelgrass. Recent studies show that optimal conditions for *labyrinthine* growth are a temperature of around 25 ° C and a salinity of around 25 (McKone and Tanner 2009). Studies in the Wadden Sea and in the south-western Baltic show that the presence of *Labyrinthula* reaches a peak in late summer and then almost completely disappears during winter (Bockelman et al. 2013).

Studies in Bohuslän in the summer of 2011 showed very low levels of infection in all populations studied (0–17% prevalence) where the infection rate in the Gullmarfjord and in Kungälv municipality was 6% and 8% (Bockelman et al. 2013, Bockelman and Moksnes, unpublished data; see table 2.1 in Moksnes et al 2016 for details). No outbreaks with high frequency of black damage to eelgrass leaves have been observed in southern Bohuslän during 2010–2015 where about 10 meadows have been visited regularly (Moksnes unpublished data). Therefore, there are no indications that *Labyrinth cave* infections would be involved in the large losses of eelgrass that have occurred in Kungälv Municipality and Hakefjorden over the past 10 years, or explain the large-scale losses in Bohuslän since the 1980s.

### 3.4.4. Eutrophication and overfishing

Eutrophication is considered by many researchers to be one of the greatest threats to seagrass as it negatively affects them in several ways (Short & Wyllie-Echeverria 1996, Borum et al. 2004). Increased population around the coasts and changes in agriculture and forestry have led to greater emissions of nutrients to coastal waters where nitrogen and phosphorus are the primary nutrients that cause eutrophication. Eutrophication indirectly leads to deteriorated lighting conditions by stimulating the growth of both phytoplankton and algae. Micro- and macroalgae can either grow on seagrass leaves as epiphytes, or form thick algal mats, and reduce the amount of light and oxygen that reaches the seagrass.

Eutrophication is considered to be one of the most serious threats to shallow coastal ecosystems and eelgrass meadows in Sweden as well (Rosenberg et al. 1990, Pihl et al. 1999, Baden et al. 2003). Plant plankton and annual micro- and macroalgae have much faster growth than seagrass at high nutritional conditions and can survive in much poorer light conditions (<1% of surface light) compared to seagrass (10-20% of surface light), therefore seagrass can be competed out (Duarte 1995, Valiela and others 1997). High levels of nutrients in the water can also have a direct toxic effect on the seagrass (Burkholder et al. 1992, van katwijk et al. 1997).

The increased amount of phytoplankton and reduced light supply is believed to be a major reason for the maximum propagation depth of seagrasses being reduced dramatically in coastal areas in many places in the world (Short & Wyllie-Echeverria 1996, Green & Short 2003). Similarly, the increased amount of flowering algae and floating mats of fine-threaded macro algae is believed to be a major cause of seagrass disappearing from large areas at shallower depths. An increased amount of algae not only reduces the light supply, but also increases the supply of organic material to seagrass meadows when algae die and sink to the bottom. When this organic material is decomposed, the oxygen deficiency and the level of hydrogen sulfide in the sediment increases, which in combination with poor lighting conditions can contribute to the removal of seagrass (Figure 3.6; Short & Wyllie-Echeverria 1996, Greve et al. 2005). In many places in the world, seagrass beds can be covered by thick mats of macroalgae that also cause oxygen deficiency around seagrass leaves and knock out seagrass locally (Holmer & Nielsen 2007). In Denmark, several such cases of mass death have been observed in recent decades in which entire populations of eelgrass have been eliminated from one area in one case. This usually occurs during the late summer when calm and warm weather can cause rapid growth and degradation of macroalgae mats, with the resultant lack of oxygen in the bottom water, which is believed to be a contributing cause of the mass death (Greve et al. 2005).

Figure 3.6. Fine-threaded algae mats. The picture shows an eelgrass meadow in a confined cove in the Gullmarsfjorden which is covered by a rotting carpet of fine-threaded brown algae. The picture was taken in March, the days after the ice disappeared from the bay. In the spring, bare patches without eelgrass were found in the area. *Photo: E. Infantes.*

The problems of eutrophication can also be exacerbated if small animals that graze on bottom-living and planktonic algae are reduced in coastal areas. This can occur as an indirect effect of overfishing, if the amount of small predators (e.g. small fish, crabs and shrimp) increases as a result of reduced numbers of large predators, which in turn increases the predation on algal organisms (Heck et al. 2000, Moksnes et al. 2008, Baaden et al. 2012). New compilations of experimental studies of coastal eelgrass and seaweed ecosystems in the North Atlantic show that reduced populations of large predatory fish in coastal waters, and increased numbers of small predatory fish have as strong effects on fast-growing algae biomass as increased nutrients (Östman and others *in press*). To reduce problems with algal mats in shallow coastal areas measures to increase the presence of large predatory fish along the coast can be as effective as measures that reduce the nutrient strain.

### *Effects of eutrophication and overfishing in Bohuslän*

The main causes of the extensive losses of eelgrass that have occurred in Bohuslän since the 1980s (see section 3.3.2) are today considered to be a combination of eutrophication and overfishing that favour the emergence of fine-grained algal mats, which in turn have a negative impact on eelgrass. The nutritional load to the North Sea has increased 4–8 times since the 1930s, which has resulted in major ecological effects, among other things reduced depth of macro vegetation (Rosenberg et al. 1990).

Eutrophication has therefore been seen as a main explanation for the increased prevalence of fine-threaded algal mats in Bohuslän (Pihl et al. 1999). The algal mats are dominated by fine-grained green algae, which are favoured by increased levels of nutrients (Moksnes et al. 2008, Baden et al. 2010). The increase in algal mats has occurred during the same period as the eelgrass has decreased and the carpets cover many eelgrass meadows during the summer and are considered to be a major cause of the eelgrass recession (Baden et al. 2003; see section 2.5.6. In Moksnes et al.). fl. 2016).

Although fine-grained algae benefit from eutrophication, more and more studies show that the increased distribution of algae mats also has a clear link to overfishing, which has reduced the biomass of cod in the North Sea by 90% since the 1980s (Svedäng & Bardon 2003, Moksnes et al. 2011). At the same time as the cod has been reduced in Bohuslän eelgrass meadows, the biomass of small predatory fish that the cod eat (especially gobiidae and three-spined stickleback) has increased by between 200 and 700 per cent. During the same period, small algae-eating crustaceans (amphipod and marine isopod) have almost completely disappeared (Baden et al. 2012). These crustaceans have been found to be very important in counteracting the emergence of filamentous algae mats and thus also important in counteracting eutrophication effects in coastal ecosystems. Experimental studies have shown that algae-eating crustaceans in eelgrass meadows can control the growth of filamentous algae, even at high levels of nutrients, if they are not subjected to high predation. The same studies also show that small predatory fish, crabs and shrimp are now so numerous in Bohuslän that they eat up over 95% of all algae-eating crustaceans in eelgrass meadows, which allows filamentous algae to grow unhindered. (Moksnes et al. 2008, Persson et al. 2008, Baden et al. 2010).

Increasingly, therefore, there is evidence that overfishing of large predatory fish has caused a trophic chain reaction in the coastal ecosystem. Reduced predation has caused the small predators to increase, algae grazing decreased, and fast-growing algae increased. Today, therefore, most researchers agree that the overfishing of cod and other large predatory fish in the North Sea has contributed to the vegetation changes that have taken place along the Swedish west coast. **Therefore, in order to address the negative changes in coastal vegetation, measures are needed both against nutrient discharges *and* measures to regain healthy populations of large predatory fish** (Moksnes et al. 2011).

### 3.4.5. Land drainage

Drainage from land is often linked to increased nutrient load in the drainage area, but also sediment that is discharged into the coastal water can have an equally harmful effect on the seagrass. Sediments transported from land lead to an increased amount of particles in the water (turbidity), which reduces the clarity of the water and increases the sedimentation of particles on the seagrass (Holt et al. 1997). Large losses of seagrass have been reported from several parts of the world as a result of increased sediment supply from land runoff (Borum et al. 2004). Once the particles have entered the system, they can continue to be resuspended and sedimented over time (Koch 1999) and the problem may persist, especially in bounded bays or estuaries that are relatively closed systems, with little opportunity for the sediment to flush out. Poor methods for usage of fields, where vegetation is removed, have led to increased soil erosion on land, which has increased sediment transport by rivers into the coastal waters. The drainage water can also contain a wide range of other substances that can adversely affect the seagrass, such as heavy metals, pesticides and herbicides (Larkum et al. 2007). However, it is not known whether herbicides can have negative effects on eelgrass in Swedish waters. In addition to the application of environmental toxins, land runoff can also lead to large fluctuations in salt content, which can lead to further stress for the plants. Increased land runoff is in many countries considered to be the main cause of eelgrass losses, but has not received much attention in Sweden, and its possible role in the losses observed in the North Sea has been poorly investigated.

### 3.4.6. Coastal exploitation

Human development and exploitation of coastal areas is another important stress factor for the marine environment and another factor that can have a negative impact on seagrass populations. The negative effects have increased as the population and human use of the coastal zone for transport, recreation and food production have increased (Duarte 2002, Lotze et al. 2006). The development of structures such as marinas, bridges and breakwaters has therefore had a significant impact on a variety of levels in coastal ecosystems.

Exploitation of the coastal zone often occurs in areas that are protected from wave exposure, which affects the eelgrass extra hard because it is precisely in these protected environments that the eelgrass can grow. The construction of marinas and the expansion of existing marinas along the coast are often associated with dredging activities, which means a direct loss of seagrass ecosystems (Erftemeijer & Lewis 2006). Another direct loss of eelgrass may occur in connection with the construction of new terminal areas within ports where basic areas with eelgrass stocks are filled. Dredging of the seabed often occurs to increase the water depth and allow larger boats to enter the area. This removal of sediment and seagrass results in altered biological, chemical and physical conditions on the bottom (Borum et al. 2004), which may mean that the seagrass cannot recolonize the area after the intervention. The construction of a jetty also means a permanent shading of the bottom, which, depending on the construction of the jetty, can mean full-scale losses of seagrass directly below and some distance from the jetty (Burdick & Short 1999). Increased boat activities in one area also create a greater risk of damage from, for example, anchoring or propeller dredging. In addition to these direct effects, dredging often leads to degraded water quality due to increased turbidity and an increased probability of sediment retention (Onuf 1994, Schoellhamer 1996, Erftemeijer & Lewis 2006). If dumping of mud pellets takes place inside, it can also cause a serious deterioration in water quality. This means that even meadows that are far from the exploited area can be adversely affected by degraded water quality or sedimenting particles.

Increased exploitation around the coast also increases the fragmentation of habitats, which can have negative effects on the organisms living in the environment (Layman et al. 2007). It can also change species composition through the creation of new habitats (e.g. breakwaters) and altered dispersal capacity (Bulleri & Chapman 2010). Changing the coastline through exploitation (fillings, dredging, etc.) also affects the flow dynamics of the water, which can lead to changes in the velocity and direction of currents and wave energy (Barnard & Davis 1999, Dallas & Barnard 2011), which can change the environment's suitability for seagrass propagation.

Today, a significant proportion of shallow soft bottom areas along the Swedish coast have been exploited by, among other things, docks, marinas and ports (see section 1.1.3), but the effect of this exploitation on eelgrass is currently poorly studied. However, recent studies in Bohuslän show that the overall effect of small-scale exploitation is significant. Based on measured shading effects on eelgrass from jetties, and the distribution of eelgrass as well as piers and marinas, it is estimated that the exposure has caused a loss of almost 60 ha of eelgrass and reduced the coverage rate of eelgrass by 50% for an additional 420 ha in Western Götaland county (Eriander et al. *in manuscript*). The area of eelgrass that is adversely affected by bridges accounts for over 7% of all eelgrass in the county today (approximately 6300 ha according to remote analysis; E. Lawett, County Administrative Board of Västra Götaland County, unpublished data), which is why this small-scale exploitation must be seen as a significant threat to eelgrass. This is especially true in areas where large losses of eelgrass have occurred such as e.g. in Kungälv municipality in Bohuslän, where there are currently only about 13 ha of eelgrass in the developed area (see section 3.3.3).

### 3.4.7. Climate change

Climate change as a result of the greenhouse effect is also expected to affect the sea grass. The climate changes that are expected to have the greatest impact on seagrass propagation and growth are global warming, sea level rise, increased carbon dioxide in the atmosphere (and the sea) and increased strength and frequency of storms (Duarte 2002, Orth et al. 2006). The consequence of these changes can be difficult to foresee, especially when they occur in combination with other human impacts such as eutrophication, overfishing and exploitation of the coastal zone (Carr et al. 2012). In addition, climate change at present can be difficult to distinguish from natural changes that occur in dynamic coastal ecosystems.

The effect of an increased carbon dioxide content in the atmosphere may have positive effects on seagrass photosynthesis, but the negative effects of climate change are expected to outweigh the positive. The rise in sea level, together with an increased frequency of storms, is expected to accelerate coastal erosion, which may lead to poorer water quality in the future (Orth et al. 2006). An increased storm rate can also lead to increased losses as plants and entire meadows are washed away, which can also make restoration work difficult, as planted seagrass shoots are more sensitive before rooting properly in the sediment. Although sea level rise may create new areas for seagrass growth, the total area covered by seagrass will probably not increase as water quality is expected to deteriorate, which may cause the spread to shift only upwards (Duarte 2002). In many places along the coast, the propagation towards land is also prevented by sea level elevation of human constructions (e.g. breakwaters and ports) which changed the nature of the seabed. The predicted increase in average temperature is also expected to be able to knock out seagrass populations in areas where temperatures during the summer are close to what the species is capable of, such as at the southern limit of eelgrass along the US East Coast (Carr et al. 2012). The warming of the earth's atmosphere can also lead to large-scale changes in water flows and circulation patterns, which can lead to changes in the distribution of different seagrass species. Precipitation and runoff from land are also expected to increase in some areas, which may lead to changes in the salinity regime along parts of the coast. For example, the salinity gradients in the Baltic Sea are expected to shift southward, which would have major effects on the northern distribution of eelgrass in the Baltic Sea.

### 3.4.8. Ecosystem shifts

Losses of seagrass not only affect the organisms that reside there but can also lead to changes in the physical environment at a site. As previously mentioned, disturbances are a natural part of the dynamics that many ecosystems exhibit, and the ecosystem's resilience to these disturbances often leads them to return to the state in which they were before the disturbance. However, if the damage or disturbance is greater, or prolonged, the ecosystem may reach a threshold level where the mechanisms that previously steered the system toward a recovery are changed or replaced so that the new mechanisms instead steer the system toward a faster change to a new and often undesirable environmental state. Such rapid changes of ecosystems from one stable state to another are usually called *regime shifts* or *ecosystem shifts* as the new ecological mechanisms retain the ecosystem in the new state, even though the disturbance that caused the shift has diminished or disappeared (Scheffer and Carpenter 2003; Figure 3.7).

For eelgrass ecosystems, the stabilising effect of eelgrass on the seabed and positive effect on water quality (see section 3.2.2.) is an important self-generating mechanism that improves the growth conditions for eelgrass and helps the system to recover after a disturbance. If, on the other hand, the disturbance is so severe that the eelgrass stabilising effect on the bottom decreases, increased resuspension of the soil sediment can lead to deteriorated light environment and growth conditions for the eelgrass, so that its biomass and distribution decrease and the resuspension increases in a downward spiral until the eelgrass meadow collapses (Duffy et al. 2014). When the meadow is lost completely, other mechanisms can reinforce the new condition. Lost seagrass systems are often replaced by phytoplankton and fine-grained algal mats that can grow and dominate in low-light environments (Duarte 1995; Valiela et al. 1997), which further deteriorates the environmental conditions and seagrass opportunities to recover naturally. It can therefore be very difficult for an eelgrass meadow to re-establish itself in an area after the loss has occurred (Troell et al. 2005).

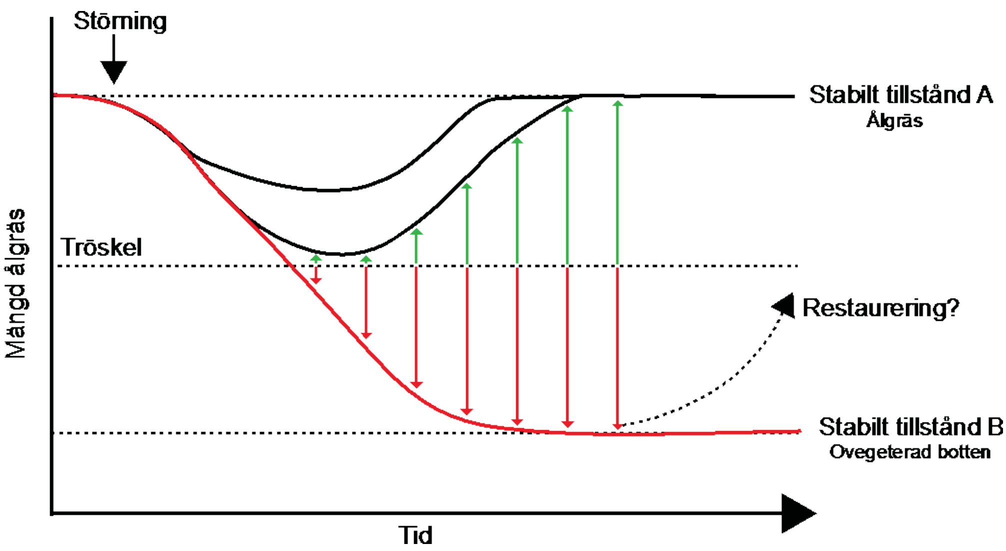


Figure 3.7. Regime shifts. The figure shows what happens to an eelgrass ecosystem when it is disturbed and transitions from a stable state to another, in this case illustrated by a soft bottom with or without eelgrass. Condition A has a large and relatively stable eelgrass meadow. In the case of minor disturbances, the eelgrass meadow can usually return to its original state. The recovery is facilitated by self-generating mechanisms (*positive feedback mechanisms* in English) which become stronger the larger the meadow and favour growth (illustrated by green arrows in the figure). For eelgrass, such a mechanism could be the meadow's positive effect on water quality by stabilising the bottom and "filtering" the water. If the disturbance is large (or prolonged) it can cause the ecosystem to reach a threshold level (horizontal dashed line). In this amount of eelgrass, the mechanisms that facilitate the growth are replaced by self-generating mechanisms that disadvantage the eelgrass, which become stronger the smaller the meadow (red arrows) and cause a collapse of the eelgrass meadow when a new stable condition B occurs without vegetation. These mechanisms could be increased resuspension of sediment and degraded water quality, as well as increased occurrence of drifting algae mats on the soil that shade the eelgrass.

This type of ecosystem change is considered to have occurred both in the Dutch Wadden Sea (van Katwijk et al. 2000, van der Heide et al. 2007) and in the Greifwalder estuary in Germany (Munkes 2005) where huge eelgrass areas have disappeared. Although the nutrient load (and salinity) has decreased in the areas, light supply has not improved, and the eelgrass has not returned despite restoration efforts. Heavy resuspension of sediment and growth of algal mats that reuse nutrients accumulated in the sediment are considered to be the causes of non-recovery (Duffy et al. 2014). The same mechanisms may be the explanation for the degraded water quality and the failure to recover eelgrass in certain areas in Bohuslän.

### *Local regime change in Bohuslän*

Since the 1990s, the supply and levels of nitrogen to the North Sea have decreased. This has led to reduced levels of phytoplankton and water quality in many areas, so that most environmental variables that indicate eutrophication today show good or high status in coastal waters (Anno. 2016, Moksnes et al. 2015). Despite this, few positive changes are found in shallow coastal areas in Bohuslän, where the prevalence of drifting algae mats is still high and no general recovery of eelgrass can be discerned (Sea and Water Authority 2012, Anno. 2016). This is especially true in areas in the municipality of Kungälv where the largest losses of eelgrass have occurred and continue even today (see section 3.3.3).

Studies in this area show that eelgrass can no longer survive in the depths where large eelgrass meadows were found in the 1980s, mainly as a result of degraded water quality, which is likely the result of increased resuspension of sediment when the eelgrass meadow no longer stabilises the seabed (see section 3.2.2). Today, the seabed is covered by drifting perennial algal mats, which further complicates both natural recovery and restoration. Despite four years of attempts to plant shoots and seeds in these areas, very few eelgrass plantations have survived (see sections 4. and Tables 4.1 and 4.2 in Moksnes et al. 2016). Therefore, in areas that have lost large eelgrass meadows, very costly, large-scale measures may be required that will change the environmental conditions in the area before a natural recovery or restoration of eelgrass is possible (see Appendix 2 to Moksnes et al. 2016 for more information).

It is therefore not possible to expect that it will always be possible to restore a lost eelgrass meadow. It is therefore very important for coastal environment managers to detect and remedy human disturbances long before loss of eelgrass occurs. It is also important to protect the remaining eelgrass habitat, especially in these areas, and only as a final measure to allow compensation restoration as a solution in exploitation.

# 4. Economic evaluation of eelgrass ecosystem services in Sweden

## 4.1. Introduction

The *Millennium Ecosystem Assessment* (MEA 2005) research report initiated by the UN identified and categorised numerous benefits that nature provides to society. Focusing on these benefits, also called ecosystem services, has made it easier to highlight how important nature's services are to people's well-being. The classification of ecosystem services, which in the MEA report was mainly based on ecologists' assessments, has since been followed up by the efforts of economists to enable the value of the services to be determined (TEEB 2010, TEEB 2012). The use of the ecosystem service concept, including the monetary values associated with these benefits (see Box 4.1), has attracted increased attention in recent years, both in Europe and in Sweden (TEEB 2012, SOU, 2013: 68). The concept of ecosystem services contributes with a strong theoretical basis for economic evaluation of nature's benefits, and thus contributes useful information in policy decisions. One approach and framework for evaluating these benefits and which has gained in popularity lately is the so-called " *Ecosystem Service Valuation (ESV) framework"* , which has also resulted in an increasing number of reports and articles published on the topic that can support decision makers on issues related to environmental resources (see below).

This chapter focuses on the evaluation of ecosystem services and final economic goods generated by seagrass, which have recently received increased attention, both globally (Short et al. 2000, Barbier et al. 2011) and within Sweden (Rönnbäck et al. 1998, Steel et al. 2008, Tanner 2014). Below we first provide a background for valuing ecosystem services and discuss different methods and challenges with this type of valuation. We then present an attempt to estimate part of the economic value that an eelgrass meadow generates on Sweden's west coast based on three of the eelgrass's many different ecosystem services. These results are largely based on a multidisciplinary valuation study (Cole and Moksnes 2016), but are also supplemented here with new calculations.

To emphasise the uncertainty of this type of valuation, results from both low and high estimates of the values of ecosystem services are presented. We conclude this study with a discussion of limitations and discuss other methods and how new studies could increase knowledge about the value of ecosystem services. Definitions of eco-economic terms used in the text can be found in fact box 4.1.

**Fact box 4.1. Environmental economic terms**

Below is a list of terms used in Chapter 3 which among others is based on the terminology used in the UK NEA (Bateman et al. 2013).

***Monetary values*** are values related to money.

***Instrumental values*** measure the contribution of certain objects (e.g. nature) to human well-being and are based on a world perspective where man is put in the centre. These values are based on what an individual is willing to give up in order to obtain something else of value and is used in welfare economics.

***Inherent values*** mean that nature can have a value in itself, regardless of its contribution to human welfare (a so-called biocentric perspective on the world).

***Direct user values*** capture (instrumental) values of a product or service that provide direct benefits to an individual (e.g. having the opportunity to fish).

***Indirect user values*** capture (instrumental) values of a product or service that provide indirect benefits to an individual (e.g. carbon dioxide uptake leading to reduced climate change).

***Non-user values*** capture (instrumental) values of a commodity or service that an individual has never used and does not plan to use in the future, but which nevertheless delivers benefits to the individual (e.g., existence or heritage values that are often associated with a national park far from where an individual lives).

***Monetary valuation*** measures instrumental values based on monetary considerations (for example, how much money an individual is willing to pay to obtain a valuable environmental improvement).

***Non-monetary valuation*** measures instrumental values based on other considerations, such as how much an individual is willing to give up of one hectare of valuable living environment to obtain one hectare of restored habitat at another location.

**Marginal changes** in e.g. ecosystem services represent small, incremental changes. When assessing ecosystem services, changes in the supply of organic products must be estimated, which are small marginal changes rather than major changes (such as the value "with and without" the ecosystem service).

***Ecosystem function*** is a function that, for example, maintains a habitat in an ecosystem (e.g. growing habitat for fish, nutrient uptake) that lays the foundation for an ecosystem service.

***Ecosystem service*** is the result of an ecosystem function or process that can benefit society.

***Ecological endpoint (ecological end product)*** is the link between an ecological model that measures changes in the environment with an economic model that evaluates how that change affects welfare. For example, kg of fish produced for a professional angler and tonnes of carbon dioxide taken up can be valued by an economic model.

***Economic goods (economic end product)*** is a product or service from the ecosystem that generates benefits to society that can be valued in monetary terms (e.g. commercial fish, improved bathing experience, reduced economic damage from climate change).

***Intermediate ecosystem service or commodity*** is an intermediate product of ecosystem function (e.g. production of juvenile fish, reduced production of phytoplankton). To avoid double counting, economic models avoid valuing such services and instead focus on the final economic goods.

***Discounting*** is when one calculates the present value of a service or commodity that will not accrue to society until the future, when it is often taken into account that society values these future values lower than if the resource had been received today. Discount rate is the interest value used to count down the future value.

***Present value*** is the present value of a commodity or service that has already been delivered or is to be delivered in the future, taking into account the time period that has passed or will come, and the discount rate is used to calculate the value.

***The nominal value*** is the present value of a product or service on an annual basis for a selected period. This measure includes discounting and valuing goods and services delivered or lost more closely in the present day than goods and services found later in the future.

***Nominal value*** is the total value of e.g. a product or service (e.g., an ecosystem service) at a particular time, e.g. at the time of delivery, which does not take into account changes in value over time, and does not include discounting.

# 4.2. Background to the valuation of ecosystem services

## 4.2.1. Why should ecosystem services be evaluated?

Economic valuation of nature's ecosystem services can fulfil several important functions that increase the public's awareness of the value of nature and facilitate decision-makers to make the right considerations in environmental matters. First, a valuation can help raise public awareness and decision-makers of how society is dependent on nature by clearly linking ecological functions to economic goods and services that contribute to the economic well-being of society.
Valuation can also help motivate and improve the use of ecological compensation as a tool for achieving "*no degradation of the environment"* (*no- net-loss*). Resource valuation information is also crucial for implementing the polluter pays principle (see section 2.2.1), which is the basis for most of the EU's environmental policy. Furthermore, an assessment of ecosystem services is a prerequisite for the so-called " *Payments for Ecosystem Services (PES) system"*, which can be described as a policy instrument that relies on markets to improve the supply of ecosystem services (Cole et al. 2012), for example, where sewage treatment plants pay mussel growers to reduce nutrients in the water. Most importantly, information about for example, the economic value of eelgrass can be used to improve society's use of limited resources, e.g. environmental measures.
For example, a valuation may provide support for establishing marine protected areas when the value of the benefits of such a measure is greater than the cost.

There are also risks in valuing the benefits of ecosystem services in monetary terms. Firstly, usually only a small number of an ecosystem services of an environment can be valued economically, which leads to an underestimation of the value or to important values that cannot be economically valued, e.g. non-user values (see fact box 4.1.) are omitted from the decision process. If an economic estimate that has omitted several important values is then used for balancing environmental issues or for estimating the extent of compensation, it can lead to inaccurate decisions (such as poor compensation). The use of only one monetary measure can also imply false precision, which can lead to underestimation of uncertainties and thus lead to decision-makers misinterpreting the nuances and limitations of these, often rather rough estimates. Furthermore, the current state of knowledge means that we must simplify complex ecological systems into individual economic goods and services that we can evaluate. If valuation fails to capture the intrinsic complexity of ecosystems, such as sudden changes in the delivery of ecosystem features via threshold effects and ecosystem shifts (see section 3.4.8), the valuation can be misleading. Nevertheless, the inevitable trade-offs between different goals that decision makers face with an evaluation of ecosystem services, either *explicitly* through monetary measures, or *indirectly* through laws or cultural norms (implied rules and expectations), will constitute an important basis for decisions relating to environmental issues.

## 4.2.2. Methods for valuing ecosystem services

Although there are many different types of values in economics (US EPA, 2009; UK NEA, 2011), this chapter focuses primarily on economic environmental values that measure the contribution of certain objects (e.g., nature) to human well-being.

(i.e. anthropocentric values). These values are based on what an individual is willing to give up to obtain something else of value and is the preferred method of welfare economics. There are two approaches to measuring these economic considerations: *monetary valuation* that can be based, for example, on how much money an individual is willing to pay to obtain a valuable environmental improvement, while *non-monetary valuation* can be based on, for example, how much an individual is willing to give up of a resource to obtain the same resource in another location (see fact box 4.1.). Economic values from nature can capture *user* values directly (e.g. having the opportunity to fish) or indirectly (carbon dioxide uptake leading to reduced climate change) or *non-user* values (e.g. existence or heritage values).

This framework is often called *Total Economic Value* (TEV; Freeman 2014).

When assessing ecosystem services, marginal changes are usually evaluated by the provision of a resource (i.e. relatively small incremental changes; see fact box 4.1.) rather than the total value of "having a resource or not having a resource in a large geographical area". This is because major changes can affect the price and the valuation method, which makes it more difficult to estimate the value correctly. Instead, decision-makers are often faced with decisions about whether to allow partial influence on e.g. eelgrass (from, for example, exploitation of a smaller meadow within a larger coastal area). Although a marginal analysis can be challenging as it requires information about the current and future reference state of a resource, how a specific activity or decision can affect this over time, and how spatial variables affect the value, this type of analysis provides the most credible estimation of value (Turner et al. 2003).

Some ecosystem services lead to economic goods sold in a market (e.g. fish) where the price gives an estimate of the economic value. In other cases, methods that are not based on market valuation are required. Decision-makers are primarily interested in value rather than price, since the latter only captures some of the underlying value realised in a market (Fischer et al. 2011). For example, the price of drinking water may be low, but it is nevertheless very valuable. Factors that can affect value are e.g. scarcity, the interchangeability of the product, the time of consumption, geographical location, etc.

The first step in valuing ecosystem services is to develop a conceptual framework that provides a structure for mapping, modelling, quantifying and calculating an economic value of nature's benefits in monetary terms. Figure 4.1 shows a structure used to evaluate eelgrass ecosystem services in Sweden, which follows the latest recommendations in the valuation literature (see e.g. Keeler et al. 2012). This type of valuation framework (*Ecosystem Services Valuation*, ESV) consists of three steps:

1. Identify biological and physical changes in ecosystem functions expected to occur, e.g. a change in habitat distribution.
2. Identify how these changes affect the flow of ecosystem services (see arrow 1 in Figure 4.1) and the flow of the final economic commodity (arrow 2).
3. Calculate the value of these changes (arrow 4), taking into account if other human efforts (so-called external contributions and goods) have been needed to produce the final economic commodity (arrow 3).

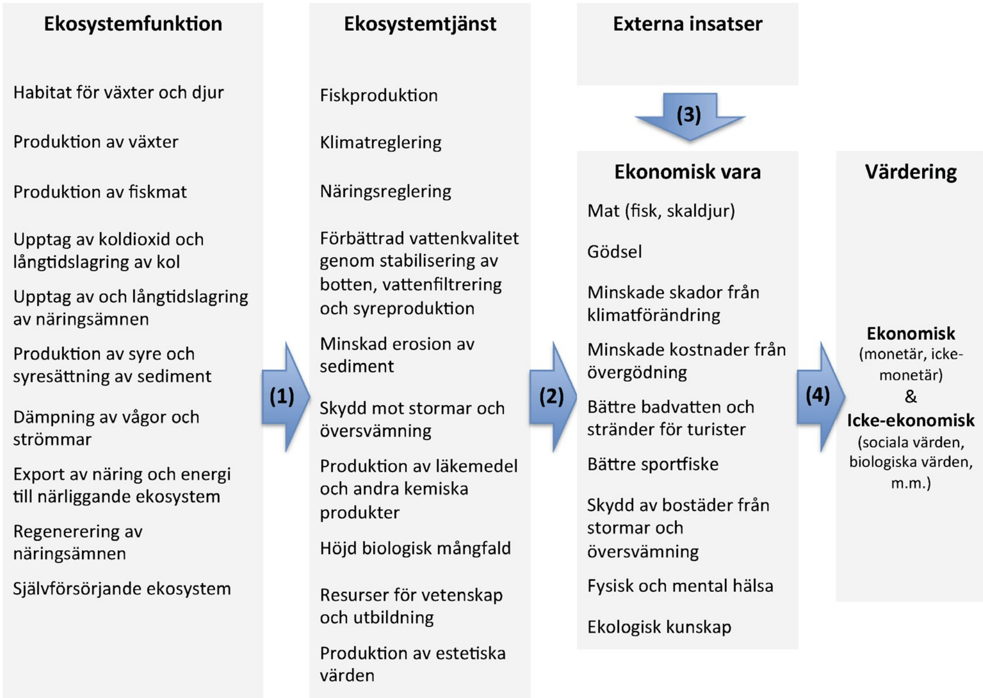


Figure 4.1. Framework for valuing ecosystem services. An assessment of economic benefits provided by a habitat starts by identifying which *ecosystem functions* that habitat generates (e.g., growing habitat for fish and wave energy suppression) and how these functions are affected by a *marginal change* in habitat (quantity and / or quality). In the next step, the connection between these functions and specific *ecosystem services* that are of benefit to society (e.g. production of cod and reduced beach erosion) is identified, as well as how a change in ecosystem functions affects the flow of these ecosystem services (arrow 1). To be able to evaluate these ecosystem services, we identify *ecological end products, or "ecological endpoints"* (ex. Number of fishable cod) and *final economic goods* (ex. Number of kg filleted cod) (arrow 2). For certain economic goods, external intervention is needed (e.g. fishing boat, fisherman, etc.) to get the *economic product* (arrow 3). Finally, the economic commodity can be valued using appropriate valuation methods (e.g. market-based, willingness-to-pay methods, or non-monetary methods; arrow 4).

To calculate the value of the final economic commodity, an appropriate economic valuation method must be selected. The valuation literature presents a number of methods and applications that are briefly described in fact box 4.2. These methods have different advantages and disadvantages, and different methods often need to be used for different types of services.

Despite high demands on both ecological and economic data, the ESV method has gained popularity in recent years as it provides a clear link between various ecosystem functions and their ecological and economic end products (see fact box 4.1.). This reduces the risk of valuing the same final product more than once (so-called double count; see fact box 4.3.) And gives decision-makers a nuanced picture of the variables that can affect the economic value (SAB 2009, Mace and Bateman 2011, Guerry 2015, Olander et al. 2015). The disadvantage of the ESV method today is that the lack of relevant data (both ecological and economic) often means that only a limited number of ecosystem services can be included in the analysis, which underestimates the total economic value. However, this disadvantage is expected to decrease as more and better data becomes available.

**Fact Box 4.2. Economic methods for valuing ecosystem services**

Below, we briefly present some common methods for evaluating ecosystem services as well as examples of studies where the methods have been used. The English names of the methods are indicated in bold italics.

**Scenario evaluation methods (*Stated Preference*).** Since ecosystem services are not sold directly in a market, we cannot evaluate them by observing individuals' willingness to pay for them. One method used to get around this is to ask individuals to consider a hypothetical change in a resource and then ask how much they would be prepared to pay for that change (so-called willingness to pay survey).
*As an example, Söderqvist and Scharin (2000) estimated Swedish citizens' willingness to pay for an increase in the depth of view from 1m to 2m in the Stockholm archipelago.*
**Actual Market Behaviour (*Revealed Preference*).** Some ecosystem services generate values that can be interpreted by observing consumer behaviour in relevant markets.
*As an example, Sandström (1998) examined Swedish beach visitors' travel expenses and found evidence that these had a higher willingness to pay to visit beaches with better visibility depth.*
**Market-based methods.** Some markets sell goods or services that depend on ecosystem services (e.g. fish, timber, raw materials), which allows us to estimate the value using the price.
*For example, Blandon and Zu Ermgassen (2014) estimated the value of seagrass meadows' contribution to fish production for the commercial fish industry in terms of growing environments, shelter and food.*
***Replacement cost approaches.*** An alternative way of directly assessing environmental changes is to use costs to counteract deterioration as a measure of value, which is not an optimal method from a welfare economic perspective. With this method, the value of ecosystem services is estimated by using the costs incurred to avoid damage or to replace the services with different substitutes. A basic assumption for the method is that ecosystem services should be worth at least as much as individuals paid to replace them or to avoid damage that would occur if they were lost.
*Notte et al. (2012) investigated the cost of nitrogen reduction measures to evaluate water quality improvements* (*see a more detailed discussion of this in Cole and Moksnes 2016*).
**Social costs of carbon dioxide emissions (*Social Cost of Carbon*; SCC).** This approach assesses economic damage that results from climate change in monetary terms, and can be used to estimate ecosystem function carbon uptake. The economic calculations for SCC, which are produced by special models (*Integrated Assessment Models*), are based on how carbon dioxide emissions can affect the climate and cause damage to well-being (e.g. increased risks of drought, floods, increased sea levels, etc.). Unlike the compensation cost method, this method is thus based on the lost values of society.
*See, for example, Tol (2008) and Johnson and Hope (2012).*
**Value transfer (*Benefits transfer*).** The method means that values already obtained from primary studies (derived for a specific study site using one of the methods mentioned above) are transferred to the place of interest. The locations should have similar characteristics, but the values can be adjusted for minor differences.
*More information on values and socio-economic analyses can be found on the Swedish Environmental Protection Agency's website*
http://www.naturvardsverket.se/Miljoarbete-i-samhallet/Miljoarbete-i-Sweden/Uppdelat- efter-omrade/Miljoekonomi/Samhallsekonomiska-analyser/

**Fact Box 4.3. Double counting issues when evaluating ecosystem services**

Because ecosystems consist of complex, interactive processes that can affect the same ecosystem service or economic commodity, there is a risk that the same economic end product is valued more than once, so-called double counting, which gives an overestimation of values (Turner et al., 2010). Below are some examples of situations where double counting may be a problem relevant to the valuation of economic goods from eelgrass meadows.

**1. Valuation of both intermediate and final goods**. If an ecosystem function is evaluated both for an intermediate ecosystem product (e.g. reduced nutrient content in the water) and then again when the final economic product is evaluated (ex. Recreational value), a double count is made. An example from society would be to evaluate rubber and steel separately in GDP calculations (intermediate goods) and then again when car production is valued (final product).

**2. Valuation of ecosystem services that provide various economic goods.**
When one and the same ecosystem service contributes to several economic goods that are valued separately and then added, there is a risk of double counting if the valuation methods overlap. This creates a challenge to identify and combine appropriate valuation methods in order to be able to evaluate, for example, nutritional regulation in a correct way (Farber et al. 2006) because nutritional uptake can provide various economic goods for recreation (clearer bathwater, cleaner beaches, improved recreational fishing) and food (increased fish production).

**3. Transfer of values from other studies.**
When a so-called *value transfer* is used as a method for valuing a resource (i.e. when valuation performed at another location is used at a new room; see fact box 4.2.), there is a risk of double-counting (or even underestimation) if the valuation situation differs between the studies. This is especially a risk for ecosystem services that generate more than one economic commodity (see above). For example, if a valuation study of nutritional uptake based on willingness to pay for clearer water and smaller algae mats on the beaches (and thus improved bathing possibilities) is used at another location is available to evaluate e.g. the eelgrass stabilising effect of the sediment (which also provides clearer water) there is at risk of overestimation.

### 4.2.3. Valuation of effects that arise over time

The above-mentioned valuation methods estimate the value of an ecosystem service in connection with a change in an organic end product (a so-called *nominal value*; see fact box 4.1.). An important part of the valuation process is to estimate how *time* affects how society perceives value, i.e. *how do we value a change that affects e.g. an ecosystem service today and 20 years into the future?* Alternatively*, how do we value a change that has taken place 20 years ago?* Such questions are relevant to e.g. decide how much money should be invested *today* to avoid (or achieve) an outcome that will happen far into the future. To be able to take into account how values are affected by *when* an effect occurs, economists use assumptions about how society values this time aspect. A **discount rate** includes this time aspect when calculating a so-called *present value* that standardises future and past effects to the present value (see fact box 4.1.). The starting point with a (positive) discount rate of e.g. 4% is that individuals (and by extension, society) are impatient and value a product or (ecosystem) service higher if it is received today than in the future. This means that a future event is adjusted to what it is worth today, so that values that arise at different periods can be compared correctly. In practice, this means that a future value is reduced by an annual percentage compared to the current value (see sections 9.4 and 9.5 for more information).

Although the use of a discount rate is normal in financial valuation analyses, it is important to also point out some limitations:

4. The choice of discount rate is subjective and varies in the literature (normally 1–5%; Mangi et al. 2010), which contributes to uncertainty in valuations.
5. The choice of discount rate can have a major impact on earnings. For example, 4% discount rate reduces the value of an ecosystem service by 55% over a 50-year period compared to if no discount was used.
6. A positive discount rate values an effect on the future generation lower than if the same effect would fall on today's generation. This has been criticised as incompatible with sustainable development (Mangi et al. 2010), while others argue that a future generation can handle such changes better in part because they will be richer than we are today (Dasgupta 2008).

In Sweden, The Swedish Environmental Protection Agency (2003) and SIKA (2009) proposed that a discount rate of 4% should be used in valuation studies.

In addition to choosing the discount rate, economists must consider the **time horizon** of the analysis, i.e. over how long can the effects of an ecosystem change be credibly assessed? Just as for discount rates, this is a subjective choice that is often limited by uncertainties associated with making ecological and economic assumptions for cases far in the future. In economic analyses, it is common to use a 20-year period. However, it is common for longer periods of time to be used for the estimation of carbon uptake (50–100 years) because its effects and benefits for society are considered persistent (Cole & Moksnes 2016).

Below, the ESV method has been used to estimate the economic value of three ecosystem services that eelgrass meadows in Bohuslän provide to society. Since there are uncertainties in the size of ecological end products, prices and costs that underlie the valuation, both conservative, low estimates of ecosystem services' values (based on Cole & Moksnes 2016) and higher values based on alternative valuation methods and assumptions are presented. Ecosystem services have been estimated over two different time periods (20 and 50 years) with a discount rate of 4%.

## 4.3. Economic evaluation of eelgrass ecosystems in Bohuslän

### 4.3.1. Methods

In the study by Cole and Moksnes, published ecological and economic data were used to calculate the total economic value of three eelgrass ecosystem services for an average hectare of eelgrass along the Swedish coast in Bohuslän. The study used a valuation scenario where it was assumed that one hectare of an eelgrass meadow with all ecosystem functions fully developed is permanently lost and replaced by an unpopulated soft bottom. This scenario assesses the eelgrass meadow benefits as a loss based on the difference in ecosystem functions between these two habitats. In the scenario, the loss of eelgrass is seen as a *marginal change* from a coastal area with many eelgrass meadows. In order to estimate how much this area of eelgrass contributes to the welfare of society and is worth in economic terms, we first quantified the expected biological and physical change (so-called ecological final product) that occurs when one hectare of eelgrass is lost by comparing one eelgrass meadow with a bare, soft seabed in the North Sea. Subsequently, it is identified how these changes affect the financial well-being of society through economic valuation methods (Figure 4.1., Box 4.1). The valuation was based on three of the eelgrass ecosystem functions where available data allowed a calculation: (1) habitat for fish, (2) and (3) uptake and storage of carbon and nitrogen. It is important to point out that the eelgrass meadows contributes to many more ecosystem functions and services (see Section 3.2 and Figure 4.1), and that the study therefore only measured a subset of these (see 4.3.3 for discussions).

## Valuation of fish products

The eelgrass function as a fish habitat gives rise to increased production of fish that can affect several different ecosystem services. Among other things, it can provide increased catch of commercial fish species and more attractive sport fishing, but it can also lead to increased biodiversity of fish and perhaps more attractive snorkelling and diving, better conditions for education and possibly increased aesthetic values. A Swedish study has recently shown that recreational fishing can generate a higher economic value than commercial fishing for coastal species (Paulrud 2006). However, due to limitations in available ecological and economic data, only the production of fish could be valued as increased catch in the commercial fishery in the study by Cole & Moksnes (2016), which is likely to give an underestimate value. In order to include a higher estimate, an alternative method is also presented where the cost of fry compensation is used to calculate the value of increased production of fish in eelgrass meadows. It is unclear how the value based on this method relates to a value based on recreational fishing.

### *Production of commercial fish*

Studies in Bohuslän have shown that eelgrass meadows are an important habitat for over 40 different species of fish (see section 3.2.1). However, due to the absence of an economic market, and the lack of biological and economic evidence to calculate the increase in production and the commercial value, only five of these species could be included in the study (cod, whiting, saithe, goldsinny wrasse and corkwing wrasse; Cole & Moksnes 2016). The latter two fin fish have been included as there is a market for them in Norwegian salmon farming where they are used to remove parasites (salmon lice). Data on densities of these species in eelgrass meadows and in areas that have lost their meadows and today lack vegetation (Pihl et al. 2006) was used to estimate the effect of eelgrass on fish production. In these calculations, it was assumed that the difference in density reflected the difference in production. To calculate how the density of juvenile cod in eelgrass meadows affected the commercial fish's landings of adult fish, estimates of age-specific growth, natural mortality and fishing mortality were used (see Cole and Moksnes 2016 for details). *Market-based methods* were used to calculate the economic value of the production of commercial fish (see fact box 4.2.). There, the lost value for commercial fishing was estimated by multiplying the reduced quantity of fish by the consumer price at the retail level of fish. In these calculations it was assumed that price and costs were not affected by the marginal change in production (see Cole and Moksnes 2016 for details).

### *Valuation of fish based on fry compensation*

An alternative way to evaluate fish production in eelgrass meadows is to calculate *juvenile compensation cost* based on the purchase cost of fish fry from commercial growers for the fish species whose young stages are adversely affected if an eelgrass meadow disappears. In recent years, this method has been used to calculate fishing fees for activities such as damaged eelgrass or other important habitats for fish when examining water activities in the environmental court (e.g. Larsson 2013; see section 7.5 for more information). Although fry compensation has been used as a compensatory measure for salmon by hydropower companies that adversely affects play areas, the method has never been used in practice as a compensatory measure for damage to eelgrass meadows or other marine habitats, but only as a basis for estimating the level of fishing fees. As a valuation method, *fry compensation cost* is therefore a little special, as it is based on *compensation costs* (see fact box 4.2.), but unlike the valuation of e.g. nutritional uptake based on the cost of actual measures taken (see below), this method is based on hypothetical costs. From an economic valuation perspective, this makes the method less robust, as actual, performed costs normally constitute an important criterion when using compensation costs as a valuation method.

However, the method also has clear advantages, especially that it does not impose the same requirements on biological and economic data (e.g. data on juvenile growth and mortality, a commercial market, etc.) needed for the market-based method. To calculate a *juvenile compensation cost*, only data on juvenile densities in relevant habitat is required, as well as the cost of purchasing or producing fish fry. Because this method values the juvenile stage and not the adult commercial fish, the value of the high juvenile mortality rate is not affected, which means that the value of fish production becomes higher than with the market-based method used in the study above.

In the report, we have included value calculations of fish production based on fry compensation as an alternative (and in this case, less conservative) method for estimating the value of fish production from eelgrass meadows. In addition to applying the method to cod, we have also included juvenile eel and juvenile sea trout, where we received information on cultivation costs for cod fish, eel and sea trout (13, 4 and 20 SEK per juvenile) from the County Administrative Board in Västra Götaland County (*personal communication* Fredrik Larson).

## Uptake and storage of carbon and nitrogen

To estimate the amount of carbon that is absorbed and stored in eelgrass biomass and in the sediment in eelgrass meadows (see section 3.2.3), data from a study in the northwestern United States where carbon and nitrogen storage is compared between a restored eelgrass meadow and an area without vegetation (McGlathery et al. 2012). This study was the most representative of Swedish conditions available in the literature. The largest amount of carbon and nitrogen in an eelgrass meadow is not in the plants but in the sediment where it can accumulate in meter-thick layers in protected areas (see section 3.2.3). However, there are currently uncertainties regarding the amount of nitrogen found in the sediment in Swedish eelgrass meadows, and how much of the sediment erodes when an eelgrass meadow is lost, which gives uncertainty in these estimates. To include this uncertainty in the estimation, the calculations are based on two different scenarios, where nitrogen accumulates and erodes down to about 5 or 25 cm deep in the sediment.

The economic value of carbon uptake was estimated using values of *social costs for carbon dioxide emissions* (SCC; see fact box 4.2.). In the literature, SCC values vary greatly (from, for example, SEK 37 to over SEK 2,300 per tonne of carbon). To include this uncertainty, calculations were performed with both a relatively low but credible value (SEK 948 per tonne of carbon) and a higher value (SEK 1,303 per tonne of carbon) found in the literature.

To estimate the economic value of nitrogen uptake, the method of *reimbursement was used* (see fact box 4.2), where local costs of measures implemented to reduce the supply of nutrients to the coast (e.g. catch crops around fields, increased nitrogen treatment in wastewater treatment plants) is used as an estimate of the value. The study used an average value of costs for measures used in various water bodies in Bohuslän (SEK 193 per kg of nitrogen; VISS 2015; see Cole & Moksnes 2016 for details).

## Valuation of historical losses

The study also conducted an attempt to estimate the consequences of the historical losses of eelgrass that have been documented in Bohuslän since the 1980s (see section 3.3.2; Appendix 1), both in terms of losses in fish production as well as carbon and nitrogen storage. To calculate an approximate economic value of these losses, estimates were made of the total loss of eelgrass in Bohuslän (8,000-15,000 ha, Appendix 1), an estimate of the loss on average 25 years ago

(1990–2015 ), as well as prices for ecosystem products today where the estimated *annual values* of the annual loss (see Table 4.2) were used. To calculate the present value of the historical loss, a discount rate of 4% was used. As there are major uncertainties in estimating both the extent of ecological loss and the prices of different ecosystem products, the value was calculated in two different scenarios that reflect the lowest and highest scenario used in the analysis above (see Table 4.2).

### 4.3.2. Results

Results from the study show that if one hectare of eelgrass meadow is permanently lost and replaced by a bare, soft seabed, it results in an annual loss of about 415 juvenile cod fish, which corresponds to a loss of around 31 kg commercial fish per year. In addition, around 2,000 juvenile eels and 23 young trout are lost for every hectare of eelgrass. The loss of eelgrass also leads to a reduction in fin fish production of about 340 fish per year. Over a year, one hectare of eelgrass disappears, approximately 4.3–15.4 tonnes of carbon and 220–868 kg of nitrogen stored in eelgrass biomass and in the eroded surface sediment are released (based on about 5 to 25 cm of sediment being washed away). In addition, an annual intake of approximately 1.6 tonnes of carbon and 12.3 kg of nitrogen is lost (Table 4.1).

Table 4.1. Organic end products from one hectare of eelgrass. Estimated losses of ecological end products produced from ecosystem functions *habitat for fish*, as well as the *uptake and storage of carbon and nitrogen*, and lost when an eelgrass meadow disappears and is replaced by soft sediment without vegetation. Estimates of fish are based on field studies that compare densities of fish in eelgrass and areas without vegetation where eelgrass has disappeared since the 1980s (not veg) in Bohuslän (Pihl et al. 2006), except for eel that is based on unpublished data from the County Administrative Board of Västra Götaland County. The losses of juvenile fish occur every year as the meadow is missing, while the loss of fin fish is calculated every other year (taking into account the generation time of the fish). Estimates of uptake and storage of carbon and nitrogen are based on comparative studies between a restored meadow and an area without vegetation (McGlathery 2012). The losses of carbon and nitrogen in eelgrass biomass and the 5–25 cm of sediment are a one-off loss that occurs when the meadow disappears, while the annual carbon and nitrogen uptake is a loss that occurs every year the meadow is missing. See Cole and Moksnes (2016) for details.

| Ecosystem Function / variable | Eelgrass | No way. | Loss | Unit |
|---|---|---|---|---|
| **Habitat for fish** | | | | |
| Cod (juveniles) | 365 | 30 | 26.6 * | kg ha$^{-1}$ years$^{-1}$ |
| Whiting (juveniles) | 40 | 0 | 4.4 * | kg ha$^{-1}$ years$^{-1}$ |
| Saithe (juveniles) | 10 | 0 | 0.3 * | kg ha$^{-1}$ years$^{-1}$ |
| Eel (juveniles) ** | 2000 | 2 | 2000 | Nr. ha$^{-1}$ years$^{-1}$ |
| Trout (juveniles) ** | 23 | 10 | 13 | Nr. ha$^{-1}$ years$^{-1}$ |
| Goldsinny wrasse (adult) | 680 | 5 | 675 | Nr. ha$^{-1}$ 2 years$^{-1}$ |
| Corkwing wrasse (Adults) | 10 | 0 | 10 | Nr. ha$^{-1}$ 2 years$^{-1}$ |
| **Carbon uptake and storage** | | | | |
| Carbon in eelgrass biomass | 1.49 | 0 | 1.49 | tonnes ha$^{-1}$ |
| Carbon in sediment (5-25 cm) | 2.8 to 14.0 | - | 2.8 to 14.0 | tonnes ha$^{-1}$ |
| Carbon sequestration | 1.66 | - | 1.66 | tonnes ha$^{-1}$ years$^{-1}$ |
| **Uptake and storage nitrogen** | | | | |
| Nitrogen in eelgrass biomass | 58 | 0 | 58 | kg ha$^{-1}$ |
| Nitrogen in sediment (5–25 cm) | 162-810 | - | 162-810 | kg ha$^{-1}$ |
| Nitrogen uptake | 12.3 | - | 12.3 | kg ha$^{-1}$ years$^{-1}$ |

* Estimated loss of biomass adult fish in commercial fishing (see Cole & Moksnes 2016 for details)
** Not included in the market based valuation of commercial fish due to insufficient substrate kg ha$^{-1}$ years$^{-1}$ = kg per hectare per year
Nr. ha$^{-1}$ 2 years$^{-1}$ = number per hectare every two years

As there are major uncertainties regarding, among other things, the size of the final organic products and the prices on which the valuation was based were calculated as both the lowest and the highest values for each ecosystem service, which are presented in Table 4.2. Based on these calculations, it is estimated that the total marginal value in 2015 for the three studied ecosystem services generated from one hectare eelgrass in Bohuslän over a 20-50 year period varies between about SEK 169,000 up to about SEK 482,000 per hectare.

Table 4.2. Economic value of one hectare of eelgrass in Bohuslän. Compilation of the estimated economic value lost when one hectare of eelgrass disappears based on values associated with 3 different ecosystem services. First, the value of the total loss (*present value*) is presented after 20 years (fish production and nitrogen regulation) or 50 years (climate regulation) where a discount rate of 4% was used. We also present the value of the annual loss calculated as an annual *value*, which takes into account when ecosystem services are lost over time periods and includes the discount rate (see fact box 4.1. for explanation of terms). Since there are uncertainties in the size of ecological end products, prices and costs that underlie the valuation, both conservative, low estimates of ecosystem services' values (based on Cole & Moksnes 2016) and higher values based on alternative valuation methods and assumptions are presented. For fish production, a valuation method based on *fry compensation cost* has been used to estimate the higher value. For climate control, a higher price of the *social cost of carbon* (SCC) from the literature has been used for the higher value, and for nitrogen regulation it has been assumed that a larger amount of sediment with nitrogen erodes at the higher value (see text for details).

| | | Total loss (present value) [1] (Kr ha $^{-1}$ 20-50 years $^{-1}$ ) | | Annual loss (annual value) [2] (Kr ha $^{-1}$ years $^{-1}$ ) | |
|---|---|---|---|---|---|
| **Ecosystem Function** | **Ecosystem service** | **Low** | **High** | **Low** | **High** |
| Habitat for fish | Fish products | 43 500 | 212 000 | 3 200 | 15 600 |
| Carbon uptake | Climate control | 49 900 | 68 600 | 2 300 | 3 200 |
| Uptake nitrogen | Nitrogen control | 76 000 | 201 100 | 5 600 | 14 800 |
| | **Totally** | **169 400** | **481 700** | **11 100** | **33 600** |

1 Total present value (Kr ha $^{-1}$ 20-50 years $^{-1}$) = SEK per hectare over 20 years (fish and nitrogen) or 50 years (carbon)
2 Annual value (SEK per hectare and year) spreads the total value over 20 years (fish and nitrogen) or 50 years (carbon)

For fish production, the chosen valuation method played a major role, with the fry compensation method providing approximately five times higher estimation of the value. This was because both juvenile cod were estimated to be almost four times higher as fry than as surviving adult fish, but also because juvenile eels could be included in the juvenile compensation method, which accounted for more than half of the total value (about SEK 8,000 per hectare per year). However, the estimates based on the fry compensation method must be considered preliminary as they have not been scientifically reviewed. For nitrogen regulation, the assumption of storage depth of nitrogen in sediment had a major role for the estimation, where erosion of the larger storage depth (25 cm) yielded barely three times higher value than the shallow depth (5 cm). The difference in analysed prices for the *social cost of carbon* (SCC) gave almost 40% difference in the value for climate control. Of the estimated ecosystem functions, nitrogen uptake (SEK 76,000–201 000) was generated and fish production (SEK 44,000–212,000) the highest economic values (about 42–44% each of the total value in the higher scenario), while carbon uptake (SEK 50,000–67,000) accounted for only 14% of the total value.

As can be seen, there are major uncertainties in these calculations**. These figures should therefore only be regarded as initial estimates of the value of some of the eelgrass meadow ecosystem services.**

### *The value of historical losses*

The historic loss of an average of 12,500 ha of eelgrass in Bohuslän since 1990 is estimated to have resulted in a total loss of approximately 9,000 tonnes of cod, 575 million eel, 99 million wrasse, and 3.7 million trout. Based on the fact that carbon and nitrogen are stored 25 and 5 cm down in the sediment respectively, the loss of eelgrass also resulted in 422,000 tonnes of absorbed carbon and 6,000 tonnes of nitrogen absorbed into the ecosystems. To put these figures into perspective, the estimated loss of caught cod (7,650 tonnes) is in the same order of magnitude as the total Swedish catch of cod from both the North Sea and the Baltic Sea in 2013 (7,895 tonnes; Sea and Water Authority 2014) . The "emissions" of carbon and nitrogen stored in the eelgrass biomass and sediment correspond to approximately 10 and 3 times the annual load of these substances to the Skagerrak from Swedish watercourses (Anno. 2016).

The estimation of the monetary value of these historical losses varied between SEK 3.7 billion and SEK 21.0 billion in total at present value, depending on whether the lowest or highest estimates of losses and prices were used, including a discount rate of 4% (Table 4.3). It is important to emphasise that this estimate should only be seen as an indication of the magnitude of lost values and not as an accurate calculation. This is because there are problems in assessing large-scale losses with a method intended for marginal changes, and that there is a problem of scaling up an average value per hectare to larger areas (see Cole and Moksnes 2016 for discussion). However, even though the estimate is rough, it can give a hint that very large values have been lost.

Table 4.3. The value of historical losses of eelgrass (1990–2014). A rough estimate of the current value losses in connection with the disappearance of eelgrass from the Swedish west coast since the 1980s. In calculations, two different valuation scenarios have been used where low and high estimates of how many hectares of eelgrass have disappeared, combined with low and high estimates of the annual economic value of eelgrass. Estimated economic value is based on ecosystem services fish production, climate and nutritional regulation. Three separate value calculations are presented for the 25-year period: (1) an annual loss, based on the *annual value* per hectare (see Table 4.2), (2) the *nominal value* of the total loss (the sum of the annual value of the total loss over 25 years with no discount rate), and (3) the *present value* of the total loss (the sum of the total value including a discount rate of 4% over 25 years; see text and fact box 4.1 for explanation of terms).

| Valuation scenario | Loss of eelgrass (ha) | Annual loss (annual value) (Kr ha $^{-1}$ years $^{-1}$ ) | Total loss (nominal value) (SEK million) | Total loss (present value) (SEK million) |
|---|---|---|---|---|
| Low | 8 000 | 11 100g | 2 200 | 3 700 |
| High | 15 000 | 33 600 | 12 600 | 21 000 |

SEK ha $^{-1}$ years $^{-1}$ = cones per hectare
per year million SEK = million

### 4.3.3. Limitations in the evaluation

The presented calculations of the economic value of eelgrass meadows in Bohuslän have several different types of limitations and uncertainties, which is why it is important that they are only seen as initial estimates. **It is important that decision makers and managers are aware that this estimate includes only a limited number of eelgrass meadows' various ecosystem services and therefore constitutes an underestimation of the total value that eelgrass generates in Bohuslän.** It is also important to point out that there are different types of uncertainty in the estimation, and that the value can vary widely between different areas. It is therefore recommended that these measures be used with caution, that local variations in value are taken into account and that they are used in scenarios that are relatively similar to the presented valuation scenario, i.e. for relatively small changes in eelgrass beds. The measures are less suitable to use for non-marginal major ecological changes such as complete loss of seagrass habitat within a region, where other values may apply.

#### *Only certain ecosystem functions are estimated*

In the estimation, only three of the many different ecosystem functions and services of eelgrass meadows have been evaluated, which is why the presented sum is an underestimate of the meadows' total economic value. Among other things, eelgrass beds have a very important function for the environment locally by stabilising the bottom and reducing the erosion and erosion of sediments, which has positive effects on water quality, production of growth, recreational values and possibly property values locally. However, this ecosystem service could not be included in the analysis due to the absence of suitable studies that evaluate this effect locally and separately from other ecosystem services that also affect water quality, for example, overfertilisation.

Furthermore, eelgrass meadows have a very important function as they constitute a habitat for a large number of plant and animal species, which increases the biodiversity locally (see section 3.2.1). This function generates important ecosystem services that are linked to valuable economic goods (e.g. for education, aesthetic values, potentially important substances for medicines, etc.), but have not been valued in this study. The important contribution of eelgrass meadows to biodiversity is also an important inherent, non-user value (see fact box 4.1), which, although not easily quantifiable in economic terms, can constitute an equally important argument for protecting or restoring this habitat.

### *Uncertainties in value*

As can be seen above, the estimation of the economic value of eelgrass contains many different uncertainties in terms of both the basis and calculations of the size of the ecological endpoint as well as the basis for calculating the economic value. For example, estimates of natural mortality in juvenile fish have been used to calculate the production of eels from eelgrass beds using the market-based method. This mortality has a great effect on the estimated production, but is very poorly known today, which makes these estimates uncertain. Another uncertainty is the amount of carbon and nitrogen stored in the sediment under Swedish eelgrass meadows and how much of this turnover in the meadow disappears. Today, this is poorly studied in Swedish eelgrass ecosystems. Since a large majority of the total amount of carbon and nitrogen is found in the sediment, this has major effects on the total value.

There are also uncertainties regarding the calculation of the economic value, including: because the price of the organic products varies widely in time and space. In estimating the value of nitrogen uptake, averages of local costs for nitrogen reduction measures have been used with the valuation method, the *replacement cost method* (see fact box 4.2.). However, these costs vary greatly (SEK 22–435 per ha; see Cole and Moksnes 2016), which makes the estimate uncertain. This method is also not optimal from an economic perspective as it is not based on the willingness to pay for a reduction of nitrogen concentration. The method of using *fry compensation cost* is a special valuation method and the results must be regarded as preliminary as the method is still known in terms of provenance (see discussion above in section 4.3.1). Finally, prices for other economic commodities such as fish and carbon dioxide also varied widely, which generates uncertainty in valuation.

Hopefully, further research will improve the basis for these calculations so that the uncertainty in the estimates diminishes over time. For example, an increased understanding of the economic damage that would result from, for example, climate change or eutrophication improve estimates. Considering nitrogen rehydration potentially high economic values are the set position to increase understanding of how different types of eelgrass beds act as nitrogen traps, what happens to the nitrogen in the sediment when a seagrass bed disappears, and obtaining better estimates of the costs of nitrogen removal measures.

### *Local variation in value*

In the calculations, an average value ("per hectare value") of an eelgrass meadow ecosystem function and its economic value in Bohuslän have been used. In reality, however, these things show great variation between different areas depending on the supply and demand of both the ecosystem function and its services. This means that the presented average estimate may represent an under- or overestimation of the value for a given room.

In general, an eelgrass meadow has a higher economic value if the ecosystem function is locally limiting the production of the ecosystem service, and if the product is in deficit. For example, if juvenile cod rearing habitat is in deficit in a region and restricts recruitment and production of cod in the area, eelgrass meadows in this area have a higher value than in an area where there is an excess of growing habitat (in the form of eelgrass or other suitable habitats). Similarly, the value of an eelgrass meadow's ability to reduce nutrients in the water is higher in a catchment area with the need to deploy costly nitrogen-reducing measures, than in an area with less need or where the measures are cheaper. An eelgrass meadow that improves water quality locally also has a higher recreational value in an area where demand for clear bathing water is high and in deficit, than in an area that is far from cities and tourists where no one is demanding the service. These examples indicate that there may be major local differences in the economic value of an eelgrass meadow that should be considered when managing eelgrass, e.g. in exploitation cases, or in selecting areas for protection or restoration.

### 4.3.4. Recommendation: monetary valuation of damage is based on the restoration cost

It may be important to clarify that monetary valuation of ecosystem services can be valuable to raise public awareness and decision-makers about how dependent society is on nature, and to justify the use of ecological compensation. By contrast, economic valuation is of minor importance when discussing the extent and level of a specific compensation measure for the loss of habitats and affected ecosystem services. Instead, the focus should be on getting the right ecological measures for the damage as well as the restoration through e.g. equivalence methods advocated by the REMEDE method (see sections 9.2 and 9.3).

We recommend that *ecological compensation* should be used for damage or loss of natural resources and ecosystem services so that the loss is replaced by new ecosystem services (see section 2.2). In addition, the damaged and compensated environment should, as far as possible, be made up of the same resource, i.e. through compensation restoration of the same habitat, and be as close to the damage as possible, where temporary losses of ecosystem services are also compensated (see Chapter 9 for details).

Damage to an eelgrass bed and subsequent compensation based on for example, The REMEDE method still requires an assessment of the financial responsibility of the operator. We recommend that this responsibility is based on restoration costs rather than financial valuation of ecosystem services, as the latter is characterised by uncertainties and often leads to an underestimation of the true value. **In summary, it is recommended that monetary valuation of damage resulting from the loss of eelgrass meadows should be based on the cost of restoring a corresponding meadow where the extent also takes into account temporary losses that occur before the restored meadow has developed all ecosystem functions**. For eelgrass, this cost is estimated to be at least SEK 1.2–2.5 million per hectare, including site selection and evaluation of results; see Chapter 7 of Moksnes et al., 2016. These recommendations are consistent with how compensation claims are practically handled in e.g. USA (Jones & Pease 1997, Cole 2013) and with recommendations within the EU (Environmental Liability Directive, Annex II, Sec 1.2.2).

# 5. Monitoring, mapping and spatial protection for eelgrass in Sweden

## 5.1. Introduction

For a functioning management of eelgrass with various forms of protection and measures, it is central to have knowledge of where the eelgrass grows today, and how the prevalence and condition of eelgrass meadows change over time. This is important, among other things, to be able to detect if and where measures are needed and to follow up on the measures taken. To increase the protection of eelgrass against e.g. exploitation and the possibility of taking action when the condition of eelgrass deteriorates, it is also important that eelgrass is included in the indicators used to assess the status of the marine environment in accordance with various EU directives.

This chapter describes the current situation with regard to mapping and environmental monitoring of eelgrass, and how eelgrass is included in various forms of spatial protection in Sweden. Here is an analysis of Swedish environmental monitoring of eelgrass where proposals are given and how it could be improved.

## 5.2. Eelgrass as an indicator of environmental conditions and changes

Because eelgrass has an important ecological function, is a common species with a large geographical distribution, grows in shallow areas where human activity is high, and is sensitive to several types of human disturbance, it is used as an indicator in marine environmental monitoring in many countries both in Europe and North America (Marba et al. 2013, Orth et al. 2016). In Europe, this monitoring is largely governed by EU directives, but also through commitments within regional marine environment conventions, which all recommend that eelgrass is monitored.

### *Water Directive*

According to the Water Framework Directive (2000/60 / EC, Annex V (P1.2.4)), the propagation of macroalgae and hiding-seed plants (including eelgrass) shall constitute biological quality factors for assessing ecological status in coastal waters (see section 6.3.1 for details). Many Northern European countries, including Denmark, Norway, Germany and the United Kingdom use eelgrass as an indicator (biological quality factor) for the classification of ecological status according to this directive (Marba et al. 2013). In Denmark, for example, the depth distribution of eelgrass at 65 different sites is monitored annually, which is a central indicator for assessing whether Danish coastal water achieves good status (Krause-Jensen et al. 2005, The Danish Nature Agency 2011). In the latest revision of the national guidance for status classification according to the Water Framework Directive, Norway has developed methods for using eelgrass as a quality factor. The proposal, which initially only applies to the coastal waters of Skagerrak, includes, in addition to deep expansion of eelgrass, also arable distribution and the bulk density of eelgrass, as well as the occurrence of filamentous algae and alien species (Environment Directorate 2015).

Within Swedish marine environmental monitoring, eelgrass can be included in the *sub-* program *vegetation-covered bottoms,* where it can constitute one of several different indicator species for the classification of ecological status of coastal water according to the Water Framework Directive. In practice, however, eelgrass has been included to a very small extent when assessing ecological status, which makes it difficult to protect eelgrass (see 5.3.1 below). The sub-program will be evaluated in 2016 and a new sub-program for monitoring vegetation covered sediment bottoms will be in 2017.

### *Marine Strategy Framework Directive*

Management of the marine environment in the EU is based on the Marine Strategy Framework Directive (2008/56 / EC), which was incorporated into Sweden by the Marine Environment Regulation. The Marine Strategy Framework Directive is based on eleven thematic areas, so-called descriptors with related criteria, which describe what is to be assessed and thus monitored (see section 6.3.2 for details). Environmental monitoring shall contribute with the basis for assessing environmental status, environmental changes, stress, activities that cause stress, and the effects of measures

Within the Marine Strategy Framework Directive, eelgrass is an important status *indicator* for *descriptor 5* (*no eutrophication*) in the EU Commission decision on criteria and methodological standards for *good environmental status*. The arable distribution of eelgrass as a habitat-forming species is also an important indicator for *descriptor 1* (*biodiversity*) as changes in propagation affect many of the species that use eelgrass as a habitat (EU 2010). In Sweden, however, the water directive's indicator and assessment basis for vegetation are used so far to assess *good environmental status in* accordance with the Marine Strategy Framework Directive, where eelgrass is included in very little scope (see below).

### *Regional marine environment conventions*

Sweden is also a party to the regional marine environment conventions OSPAR and the Baltic Sea Convention (HELCOM; see section 6.2.3. For details) where it is accompanied by commitments to map and monitor eelgrass, among other things. Eelgrass is included in OSPAR's list of threatened species and habitats. In 2012, the OSPAR Commission adopted a recommendation on the protection of eelgrass, which calls on the parties to the Convention to inter alia: monitor the propagation and recovery of the biotope (OSPAR Recommendation 2012). Similarly, eelgrass is considered to be an important habitat for many species in the Baltic Sea area, where it is included in the Baltic Sea Convention's general protection and is included on the HELCOM Red List of important habitats (HELCOM 2013).

## 5.3. Analysis of Swedish environmental monitoring of eelgrass

### 5.3.1. Deficiencies in today's environmental monitoring and assessment base

Despite demands and recommendations from EU directives and regional marine environment conventions, eelgrass is being monitored to a very small extent in Sweden today. In general, shallow sediments, where eelgrass and other hiding-seed plants live, are significantly under-represented within today's national environmental monitoring. These deficiencies in monitoring as well as knowledge about the extent of eelgrass were described in the initial assessment of the environmental state and the monitoring program in accordance with the Marine Strategy Framework Directive (Marine and Water Authority 2012, 2014). However, limited environmental monitoring of eelgrass occurs at regional level in some counties with large basic areas, including in Öresund, Blekinge and Kalmarsund where, above all, the maximum depth distribution is monitored. For example, the Öresund Water Conservation Association conducts annual sampling of eelgrass since 1997, where bulk density, biomass and depth distribution are measured (Olsson 2015).

Eelgrass is one of several indicator species whose depth distribution can be included for the classification of ecological status of Swedish coastal water according to the Water Framework Directive. In the national environmental monitoring sub-program *Vegetation-covered bottoms*, however, eelgrass is included to a very small extent in practice. This is mainly because the assessment basis (which describes methods and criteria for sampling design and status classification of the quality factor) makes it very difficult to include shallow soft bottom areas where the eelgrass normally grows. The method, which was originally developed for assessing macroalgae depth distribution on the hard bottom, poses, among other things, requirements that the sampling depth must exceed the maximum distribution depth of the species to be used in the assessment, and that at least three different indicator species must be found in each transect (Naturvårdsverket 2007, HVFMS 2013: 19). This means that the shallow sediments, where eelgrass is found, are largely excluded because they do not meet the requirements for sampling depth. In the Västerhav, where eelgrass meadows usually do not include any of the other indicator species, sites with eelgrass are also excluded because they do not meet the requirement for at least three indicator species (Blomqvist et al. 2012). In summary, these limitations mean that eelgrass is not included in the national environmental monitoring and thus does not contribute to the assessment of ecological status in most coastal areas (Sea and Water Authority 2012, 2014).

According to Chapter 1. Section 4 of the Water Management Ordinance (SFS 2004: 660), the quality requirements shall be established in accordance with Annex V of the Water Directive (2000/60 / EC), which provides that the occurrence of germinating plants shall form part of the classification and monitoring of the ecological status of the coastal water. Since eelgrass is by far the most common hiding-seeded plant in the North Sea and southern Sweden's coastal waters, it must be stated that Sweden today does not meet these formal requirements. However, a revision of the monitoring program is ongoing (see below). Today's shortcomings in assessment bases and environmental monitoring of shallow sediment bottoms have resulted in the documented loss of 60% of eelgrass in Bohuslän (Baden et al. 2003, Nyqvist et al. 2009) not affecting the status classification according to the water directive in these coastal waters. Although the loss can be captured by means of so-called expert assessments, so far only a few have been made. As the same assessment base for vegetation in coastal waters will also be used in the Marine Strategy Framework Directive (Swedish Agency for Marine and Water Management 2012), eelgrass will contribute to a very limited extent even when assessing *good environmental status* unless the indicator is revised. In summary, these shortcomings make it difficult to apply the non-deterioration requirements of the directives that are intended to protect the remaining stocks of eelgrass in the Västerhav (see section 6.3 for discussion). In fact box 5.1. it is proposed how eelgrass monitoring can be improved and the assessment base changed to meet the requirements of EU directives and international conventions.

**Fact Box 5.1. Proposal for improved monitoring of eelgrass**

Proposals on how Swedish monitoring and mapping of eelgrass can be improved and included in status classification to meet the requirements of EU directives and international conventions.

**1. Environmental monitoring and mapping**
Include monitoring of eelgrass distribution in national / regional monitoring programs in all coastal water types within eelgrass distribution area.

- Comprehensive national environmental monitoring of eelgrass (and other shallow vegetation-covered soft bottoms) annually via remote analysis of the entire distribution area.
- Estimation of the eelgrass's aerial distribution at least once per 6-year management cycle in all coastal water bodies and types of coastal water, supplemented and validated by field surveys via remote analysis.
- Annual environmental monitoring of the maximum depth distribution of eelgrass in representative areas in all coastal water types.

**2. Status Classification**
a. Revise quality factors / indicators and assessment bases / criteria in the Water Management Regulation and the Marine Environment Regulation so that:

- Vegetation in shallow soft bottom areas is included in the status classification in Sweden's coastal waters.
- Depth propagation of eelgrass is used for status classification in coastal waters within the eelgrass distribution area
- Aerial distribution of eelgrass is used in the status classification in coastal waters within the eelgrass distribution area

b. Use available data on changes in the distribution of eelgrass (see section 3.1 and appendix 1) and expert assessment of status classification of water management water bodies and marine environment management's coastal water types until monitoring data with new assessment bases become available.

### 5.3.2. Audit of assessment bases and environmental monitoring

The shortcomings of the sub-program *Vegetation-covered bottoms* have been known for a long time and an evaluation of the program is ongoing where a new sub-program for monitoring vegetation-covered sediment bottoms is planned in 2017 (*personal communication,* Karl Norling, the Swedish Agency for Marine and Water Management). As part of this work, the WATERS research program, on behalf of the Swedish Environmental Protection Agency and the Swedish Agency for Marine and Water Management, has worked to improve the quality factors used in water management in Sweden (waters.gu.se). In this work, the assessment base for macroalgae and angiosperm plants are evaluated. In the introductory proposals, depth distribution and aerial distribution of eelgrass are included as indicators for shallow areas with sediment bottom (Blomqvist et al. 2012).

## 5.4. Inventory and mapping of eelgrass in Sweden

Comprehensive maps of the marine areas' extent of distribution and area are of the utmost importance for a functioning marine management. In most counties in the eelgrass area in Sweden, inventories of eelgrass have been carried out in certain areas, including in basic inventories of marine protected areas. However, compilations of the eelgrass's arable distribution are lacking in most counties, and there is currently no comprehensive national inventory or mapping of eelgrass in Sweden. However, Västra Götaland County constitutes an exception where both historical and contemporary data on the distribution of eelgrass is available. In Bohuslän, extensive inventories of shallow soft-bottom areas were already carried out in several municipalities in the 1980s. The County Administrative Board of

Västra Götaland County, in collaboration with researchers, surveyed the same areas in the 21st century when large losses of eelgrass were documented (see section 3.3). The County Administrative Boards of Västra Götaland County, Östergötland County and Kalmar County have developed and tested methods for mapping the eelgrass in the counties with remote analysis of satellite images from several different years (Envall 2012, Lawett et al. 2013, Envall and Lawett 2016). The distribution of eelgrass in Västra Götaland County has been digitised and is currently available in GIS format at the county administrative board. In the Kungsbackafjord in Halland County, the municipality made inventories of the distribution of eelgrass in the 1980s (personal communication Ingvar Lagenfelt, County Administrative Board of Västra Götaland County) and 1999 (Karlsson 1999). In the Swedish parts of the Öresund and the Baltic Sea, there are no estimates of the aerial distribution of eelgrass, but inventories of occurrence have been carried out in several counties. The County Administrative Board and municipalities in Skåne have also carried out inventories of eelgrass in Skåne's coastal waters during the 21st century by means of sampling in certain areas where the degree of coverage and depth of distribution were determined (Olsson 2005, Svensson 2014). In Blekinge extensive sampling with, among other things, drop video has been implemented to model the expansion of e.g. eelgrass in the county within the Life project MARMONI (Wijkmark et al. 2015). In Kalmarsund, the county administrative board has monitored the presence of eelgrass during the 21st century as well as in Gotland on several sites. On the other hand, knowledge of the distribution of eelgrass is generally low along the Swedish east coast north of Kalmar Sound (Moksnes et al. In manuscript).

In the future, access to remote sensing data will probably increase through the EU's Earth observation program *Copernicus,* which has been providing satellite countries with environmental data since 2015 ( http://www.copernicus.eu/). This program could contribute to a comprehensive mapping of eelgrass and other shallow soft cure environments in Sweden. *Copernicus* data could also, with supplementary field sampling within regional monitoring of species, habitat types and marine protected areas, provide the basis for an annual national environmental monitoring of shallow soft seabed environments.

## 5.5. Marine protected areas for eelgrass in Sweden

There are several different types of protected areas in the Environmental Code that can be used to protect eelgrass meadows (national park, nature reserve, Natura 2000 area, biotope protection area and beach protection; see section 6.5.6. for detailed information on various area protection from a legal perspective). Natura 2000 sites, which are linked to the EU's species and habitat direct, are used to protect species and environments that are considered worthy of protection from a European perspective. Of the *nature types* included in the Species and Habitats Directive, the following may contain eelgrass: 1110 *Sublittoral sandbanks*, 1160 *Large shallow inlets and bays* and 1130 *Estuaries* (Swedish Environmental Protection Agency 2011a). According to the Environmental Code, operations and measures that could significantly affect the environment in a designated Nature 2000 area are not allowed. This may also apply to activities outside the protected area.

Nature reserves can be set up by county boards or municipalities to protect valuable natural environments such as eelgrass. A decision on a nature reserve specifies the purpose of the protected area where the county administrative board or the municipality concludes appropriate regulations governing harmful activities that may adversely affect conservation values. Unlike Natura 2000 areas, this protection applies only within the nature reserve. Many nature reserves that include marine areas were originally set up to protect onshore environments and therefore lack regulations to protect eelgrass and other marine habitats (see below).

The area protection type of biotope protection has existed for a while in the Environmental Code but has so far been used sparingly for aquatic environments. The protection means that activities that can damage the designated natural environment are not allowed in the area. In comparison with e.g. forming a nature reserve it is relatively quick and easy to designate a biotope protection (the county administrative board or the municipality may decide). The Swedish Environmental Protection Agency and the Swedish Agency for Marine and Water Management have also produced specific guidance for establishing biotope protection for eelgrass (the Swedish Environmental Protection Agency 2014). So far, however, the possibility of establishing biotope protection areas for eelgrass has been used to a very small extent. The first marine biotope protection area with eelgrass was decided by the County Administrative Board of Västra Götaland County in April 2016 in Uddevalla municipality in Bohuslän. **It is important that the establishment of biotope protection areas for eelgrass is increasing, especially in areas where large losses of eelgrass have occurred.**

Finally, the shore protection, which protects a 100–300 m wide zone from the shoreline and out to the sea, can also protect eelgrass by prohibiting activities that significantly change the conditions for animals and plants. However, dispensing from the beach protection is not uncommon, and the high exploitation of the beach zone along Sweden's coasts indicates that this protection is not strong enough.

There is no national summary of how much eelgrass is protected by marine protected areas in Sweden today, and how well this protection works in practice. In Västra Götaland County, however, the county administrative board has made preliminary calculations (see fact box 5.2.).

**Fact Box 5.2. Compilation of marine area protection in Västra Götaland County**

In the coastal areas of Västra Götaland County, there are currently about 90 different protected sites (about 30 Natura 2000 areas, 1 national park, 62 nature reserves / nature conservation areas and a biotope protection) with eelgrass. Most of the nature reserves and Natura 2000 areas overlap, in whole or in part, in the water area, which is why there are in practice about 70 different marine areas with protection in the coastal area, which cover a total of about 1191 $km^2$ of marine environments (about 36% of the Kosterhav National Park). Of the county's estimated 39,000 ha of shallow bottoms in the interval 0–6 m, approximately 18,000 ha (46%) are within these protected areas.

The total area of eelgrass in the county has been estimated via remote analysis (Lawett et al. 2013) in the years 2008–2014 to approximately 6,324 ha, of which a total of 3,023 ha (48%) is found in these area protections. However, out of a total of about 60 protected areas with eelgrass, the regulations in more than 20 nature reserves were assessed to have inadequate protection for eelgrass or completely no regulations for the marine environment. These areas with inadequate protection are estimated to contain over 500 ha of eelgrass (*unpublished data*, E. Lawett, County Administrative Board of Västra Götaland County).

The analysis of spatial protection in Västra Götaland County shows that, although a large proportion of the county's shallow seabeds and eelgrass meadows are found in protected areas, many of these formal protections are lacking in the reserve regulations. Preliminary results from a recent study of applications for exemption from the beach protection and the notification of water activities for construction of piers in Bohuslän between 2011 and 2015 show that area protection today largely provides insufficient protection of eelgrass against small-scale exploitation. Although the proportion of bridges stopped was lower outside protected areas (9%) than inside, only a minority of the bridge structures (41%) were stopped in the protected areas. The presence of eelgrass within a protected area also did not affect the outcome of the case. Only 31% of cases that were within an area protection with eelgrass were stopped (Eriander et al *in manuscript*). Although similar studies are lacking for other parts of the country, the situation is likely to be similar in the whole of Sweden. **It is therefore important to identify nature reserves**

**with marine environments that lack protection for shallow soft-bottom environments and revise its regulations, and to consider the presence of eelgrass in cases relating to dispensation, notification or permission. It is also important to continue working to extend the spatial protection for eelgrass meadows** (see section 6.5.6 for details). In Västra Götaland County, the County Administrative Board considers that it is justified to include a large proportion of shallow marine environments and, in particular, eelgrass meadows in marine protected areas, as these environments have very high natural values, constitutes for only a small proportion of the total marine environment (less than 5% of the total marine environment in Västra Götaland's sea area) and is closest to the coast where the human impact is greatest.

# 6. Legal protection and management of eelgrass

## 6.1. Introduction

There is rarely any legislation aimed at protecting only the eelgrass habitat. However, there is a large amount of legislation that specifies what legal protection eelgrass and other habitats have against different types of impact. Often, there are general requirements for operators to exercise caution and show consideration, in other cases specific requirements for a particular geographical area.

This chapter reviews international conventions, EU law and Swedish legislation that provides direct or indirect preventive protection of shallow coastal areas and eelgrass habitat. Often there is a connection between the different levels of regulation. EU legislation is often part of the fulfilment of Member States and the Union's international commitments. Today, national legislation almost always has a link with EU law and is a way of implementing Sweden's obligations as a Member State in the EU. The purpose of the description in this section of international agreements and EU law is to provide a background to the rules that apply to Swedish business operators, individuals and authorities. In addition to a description of relevant legislation, an analysis is also made of the protection provided the eelgrass as well as proposals for changes in the legal situation in order to strengthen the protection.

## 6.2. International legal protection for eelgrass habitat

International environmental law has emerged based on the need to protect common resources (such as migratory birds or the ozone layer) or deal with damage and disturbances that occur in one country but have repercussions in another. Many agreements are limited to certain species (e.g. the 1946 Vale Convention), habitat (e.g. the Wetlands Convention decided in Ramsar 1973) or a geographical area (such as OSPAR and the Baltic Convention - HELCOM). Other agreements apply more generally, such as the Convention on Biological Diversity. There is no international agreement that specifically seeks to protect eelgrass and other seagrass species, but as eelgrass are an important habitat for many different species and assessed as threatened in many areas, it is included in several international conventions general protection, and specifically mentioned in both HELCOM and OSPAR.

### 6.2.1. Convention on Biological Diversity

The Convention on Biological Diversity is generally intended to preserve biodiversity and a fair distribution of biological resources. States are required to work to preserve ecosystems and natural habitats, but also to restore viable populations, primarily by rehabilitating and restoring damaged ecosystems and promoting the recovery of endangered species in their natural habitats. If this is not possible or insufficient, there is also an obligation to protect populations outside their natural habitat.
This should be done, among other things, by:

*(c) take measures for the recovery and rehabilitation of endangered species and for their reintroduction into their natural habitats under appropriate conditions (Article 9 (c)).*
The Convention does not specify precise requirements, for example, about how and to what extent rehabilitation should take place. Instead, comprehensive guidelines are given that each country that has joined the Convention (today almost 170 states) is responsible for implementation. The states thus have great freedom to decide for themselves how the goals will be achieved, but there is a joint effort to coordinate and exchange experiences on how this can be achieved. Through the so-called Aichi targets adopted in Nagoya, Japan in 2010, the parties have specified 20 targets to reduce the direct impact on biodiversity, improve the conditions for biodiversity and increase the benefits of ecosystem services. Each state will then determine their own goals to achieve common goals by 2020.

### 6.2.2. The 1972 Wetland Convention

The Wetland Convention, also known as the Ramsar Convention, aims to protect wetlands as habitats. The definition of wetlands covers marine areas down to six meters depth at low tide, that is, the zone within which virtually all eelgrass in Sweden grows. The Swedish list of protection under the Wetland Convention covers for the west coast the estuary of the Northern River and the Stigfjord (Ramsar 2016). If measures are taken that reduce the designated areas, this reduction should be compensated as far as possible (Ramsar Convention Article 4 (2)).

### 6.2.3. Regional marine environment conventions

The two most important regional marine environment conventions are from a Swedish perspective OSPAR (The Convention for the Protection of the Marine Environment of the North-East Atlantic) and the Baltic Sea Convention (HELCOM).

**OSPAR,** which came into force in 1998, aims to protect the marine environment and preserve the biodiversity of the North-East Atlantic against pollution from land-based sources, dumping or incineration and from offshore sources. The 15 states and the EU parties to the Convention have also undertaken to monitor and assess the state of the marine environment. Within OSPAR, a number of declarations and recommendations have been decided on by the states. In 2010, the parties adopted strategic goals for the protection of the marine environment in the Northeast Atlantic 2010-2020 ("Northeast Atlantic Environmental Strategy"). As mentioned above (section 5.1), eelgrass is included in OSPAR's list of threatened species and habitats that need long-term protection. In 2012, the OSPAR Commission adopted on a proposal from among others Sweden a recommendation on the protection of eelgrass (OSPAR 2012). This recommendation calls on States Parties to the Convention (such as Sweden) to take measures to minimise the impact on eelgrass habitats and monitor the spread and recovery of this habitat.

**The Baltic Convention,** which aims to protect the Baltic Sea environment (including Kattegat), was signed in 1974 but reworked and a new convention entered into force in 2000. The Convention established the Helsinki

Commission - (HELCOM), which is a authority to monitor and drive the work of the acceding States to implement the objectives of the Convention. On the basis of the conventions, the Baltic States have decided on a number of declarations and recommendations aimed at influencing the states to take action against the threats to the Baltic Sea. In 2007, a comprehensive action plan (*Baltic Sea Action Plan (BSAP*) was adopted, which aims to achieve a good ecological status by 2021. The plan contains about 150 measures in four priority areas: eutrophication, hazardous substances, biodiversity and shipping's environmental adaptation. In May 2010, the Swedish government presented a proposal for a national plan to implement BSAP, which also includes a national plan for restoration of marine landscapes until 2021 (Swedish Environmental Protection Agency 2009a, Government Offices 2010). One measure in this Swedish plan is to identify and map potential and current habitats of e.g. seaweed, eelgrass and mussels as well as growing areas for coastal fish by developing models and other tools and developing a common approach to reducing negative impacts by 2013 (measure B7b Swedish Environmental Protection Agency 2009a).

In the work on implementing the respective conventions' strategies and action plans, as well as the EU marine environment directive (see more below), there is a collaboration between OSPAR and HELCOM. One of the most important measures to preserve biodiversity within the conventions is the establishment of a network of marine protection areas in the Baltic Sea and the North Sea. The goal is for these protected areas together with Natura 2000 areas to form an ecologically sustainable network that includes all protected species and habitats, including eelgrass (HELCOM 2010, OSPAR 2012). In addition, work has begun to produce common biodiversity indicators, which also include shallow bays and eelgrass meadows (HELCOM 2010).

## 6.3. EU legislation

In order to implement the above-mentioned Aichi targets to stem the loss of biodiversity and the deterioration of ecosystem services by 2020, the EU decided in 2011 on a strategy for biodiversity 2020 (vision 2050). The strategy includes six overall goals and 20 measures. Objective 2 of the strategy is to "By 2020, preserve and improve ecosystems and ecosystem services by introducing green infrastructure and restoring at least 15% of damaged ecosystems (EU Commission 2015)". One of the measures to achieve this goal is to ensure that there are no further net losses (no net loss) of biodiversity and ecosystem services. The Commission is working on making concrete proposals on how a regulation of the so-called no net loss policy can be specified, e.g. through the use of different types of compensation claims.

Legislation underpinning requirements for restoration of habitats such as eelgrass meadows is primarily the Habitats Directive (Directive 92/43 / EEC on the conservation of habitats and wildlife, as amended by Directive 97/62 / EC), the Water Directive (2000/60/EC ) and the Marine Environment Directive (2008/56 / EC). However, it is important to point out that a large part of EU environmental legislation indirectly affects the status of shallow sea coves and eelgrass habitat, through requirements that are placed on different types of consideration and emission reductions. Likewise, the EU's common fishery policy is important for fish stocks that affect the status of coastal ecosystems.

### 6.3.1. Water Framework Directive

The purpose of the Water Framework Directive is to establish a framework for the protection of EU groundwater, inland water and coastal water (out to a nautical mile off the baseline). An important starting point is that all water resources should be managed from a river basin perspective. By starting from the natural flows of the water, rather than administrative and geographical boundaries, the possibility of managing such effects on a water body increases, for example, reduced spread of eelgrass in a coastal area, caused by upstream activities in the basin. But a river basin management also demands close cooperation - between authorities and between nations. The Directive expresses a vision that citizens and organisations should be involved in water management and that openness towards different stakeholders should influence the implementation of the objectives (SOU 2007: 60 Appendix B 32, s. 16).

As an ultimate goal, it is stated that all surface and groundwater bodies within the Union must have achieved good status by 2015. There are opportunities to make exceptions to this goal under certain conditions and also to extend the time for its achievement, however, not further than 2027. Good status is assessed in relation to individual water bodies and includes both good ecological and chemical status. Apart from the objective of good status, the directive states that no deterioration of the water status may occur. Through a principally important judgment of the European Court of Justice in the summer of 2015 (C - 461/13) regarding dredging in the German river Weser, it has been made clear that the concept of deterioration does not require that the weighted status deteriorate. There is already an unauthorised deterioration when only the status of a single quality factor deteriorates. If a quality factor is already at the lowest level, it is sufficient for a parameter to deteriorate, e.g. chlorophyll concentration).

Ecological status is assessed by a combination of several biological, physicochemical and hydro-morphological quality factors and parameters. A water body can be classified on the basis of this assessment as high, good, moderate, unsatisfactory or bad. In assessing ecological status in coastal waters, angiosperm plants should be used as biological quality factor (2000/60 / EC, HVMFS 2013: 19). In several countries including Denmark the propagation depth of eelgrass (which is a angiosperm plant) is used as its own quality factor. In Sweden, however, eelgrass is used to a very small extent when assessing ecological status due to the design of the assessment base, and any monitoring of the status of eelgrass is done no more than sporadically (see section 5.2.1). Although expert judgment can be used to include eelgrass in the status classification, this has only been done in a few cases. This means that the strong impact on the status of eelgrass on the Swedish west coast, as described above, does not affect the classification of the water status (see further chapter 5). This is contrary to the directive previously pointed out.

Member States are required to *take all measures necessary* to prevent deterioration in water status (RDV Art. 4 (a) (i) and (b) (i)). In addition, they also have a general obligation to protect, improve and restore all surface water bodies, which have not been excluded from the scope of the Directive, *in order to* achieve the aforementioned objectives within the prescribed time frames. Among other things, environmental impacting businesses are required to make use of the best available technology and best environmental practices, and to comply with the emission limit values set by EU legislation. Sweden is thus obliged to ensure that the ecological status is restored so that at least a good water status is achieved.

For each river basin district, action programs shall be established which shall specify the measures needed to achieve the objectives of good status and avoid deterioration (RDV Art. 11 (1–3) and (4)). According to the case law of the European Court of Justice, the programs must be *sufficient* to implement the directive, which requires that the documents be considered binding at Member State level and that they apply to a wider circle than national regulators alone (C 96/81). To date, the water authorities have not prescribed measures in the action programs aimed at preventing further deterioration of the habitat for eelgrass (which, however, is included in the action program in accordance with the Marine Management regulation, MMR no 31; The Swedish Agency for Marine and Water Management 2015).

### 6.3.2. Marine Strategy Framework Directive

The Marine Strategy Framework Directive is structured in a similar way to the Water Framework Directive and aims to protect and preserve the marine environment, prevent it from deterioration and, where practicable, restore the environment where it has been adversely affected. The overall goal is to achieve good environmental status in the EU's marine waters by 2020.

The Marine Strategy Framework Directive applies in all marine waters and thus overlaps with the Water Directive in the area closest to the coast. In order to avoid double regulation in this area, the requirements of the Marine Strategy Framework Directive should only cover those aspects that are not included in the Water Framework Directive. The goal is to achieve good environmental status for larger sea areas such as the North Sea (Nordsjön) and the Baltic Sea. Good Environmental Status is assessed by means of a large number of indicators distributed between 11 descriptors - thematic areas - as defined in appendix 1 to the Directive. Several of these descriptors can relate to eelgrass, i.e. biodiversity, eutrophication, the integrity of the seabed, and marine nutrients. Descriptor 5 (eutrophication) eelgrass is mentioned in EU Commission Decision 2010/477 / EC, as an example of an indicator for perennial plants (EU 2010). In order to avoid such double regulation as mentioned above, the Swedish marine environment regulation (HVMFS 2012: 18, Appendix 3) uses the same indicator for macro vegetation as according to the regulations for assessment according to the Water Framework Directive, i.e. among other angiosperm plants. However, as pointed out above (section 5.2.1), eelgrass is only sporadically included in certain sampling sites, and in Bohuslän not at all.

Similar to the Water Framework Directive, Member States are required to take measures to achieve and maintain the ecological status of the sea. An action program has been developed by the Swedish Agency for Marine and Water Management, which includes that the County Administrative Board of Västra Götaland County, in collaboration with the authority and the municipalities concerned, will implement restoration measures for eelgrass in the Västerhav (Swedish Agency for Marine and Water Management 2015). Many prerequisites must be met for this measure to be implemented. Among other things, an investigation is required on suitable places for restoration as some areas that have lost eelgrass today are very difficult to restore (see also Moksnes et al. 2016, chapter 2). Causes of past and ongoing losses are also required to be identified and managed (see section 3.4) and that the restored areas are adequately protected from future damage.

### 6.3.3. The habitats Directive

The purpose of the Species and Habitats Directive (commonly known as, the Habitats Directive), is to safeguard biodiversity by conserving habitats and wildlife. Member States are required to take measures to maintain or rebuild a favourable conservation status of natural habitats as well as wild fauna and flora that are important in an EU perspective. What is meant by favourable conservation status is determined after an assessment of a number of factors specific to each habitat type.

Member States shall designate natural areas which, from a European perspective, are considered particularly valuable, as so-called Natura 2000 sites. There are a large number of Natura 2000 areas along the Swedish west coast that have been identified as particularly valuable because eelgrass grows or has grown there. Each biogeographical area should achieve favourable conservation status for the designated species or habitat type. Therefore, measures must be taken to achieve and maintain such a status. Intrusion into individual Natura 2000 sites, e.g. through exploitation or an operation, is not allowed more than in very special circumstances and then these infringements must be compensated (Chapter 7, Section 29 of the Environmental Code).

### 6.3.4. The Environmental Liability Directive

A large part of environmental legislation in both the EU and Sweden aims to persuade those who intend to conduct or carries out an activity that can affect human health and the environment, to take various forms of precautionary measures. Although preventative precautions are taken to prevent damage or at least minimise damage, environmental damage can occur. The EU's environmental responsibility directive sets out common rules for the requirements that must be set for remedying environmental damage.

The directive means that the Member States must make a claim on the person who caused a serious environmental damage to remedy it, whether caused by pollution or other disturbance. Serious environmental damage is considered, among other things, if the impact has a significant negative effect on the quality of the aquatic environment, or if it damages or makes it difficult to preserve an animal or plant species or a habitat that is listed as Natura 2000 or other areas in a significant way. If serious damage occurs, it is not enough merely to demand that the damaged environment be restored, but in addition, compensation must be made for the benefits that the natural area or natural resources would bring over time if the damage did not occur. In order to achieve full compensation, there may be a need to increase ecological resources compared to the original situation.

## 6.4. International law and EU law place demands on Sweden's environmental status

According to international law and EU law, there is therefore a duty for Sweden as a state to ensure that habitats and species achieve or maintain a certain status. These obligations may mean that Sweden must impose restrictions on new business or changes to existing business. If the prescribed status is not achieved, measures must be taken, for example through further precautionary measures or restoration. The Swedish legislature can largely choose which measures to take and how responsibility (and costs) should be distributed among different actors. Certain basic international principles, which Sweden has also committed to follow, mean that the distribution of responsibility and costs cannot be done in any case.

Such a principle is the *"polluter pays principle"* - the person who pollutes and who causes a risk of injury is responsible and must pay for the damage and inconvenience it causes. It is not always clear who is the pollutant and how this group is defined. For example, is the person using a manufactured product (consumers) also regarded as a polluter? Furthermore, it is not always possible to find a polluter and then you have to find other solutions, e.g. by financing the restoration with the help of tax revenue.

*The precautionary principle* also governs a states' way of imposing demands on citizens and means that the person conducting an activity or taking action has an obligation to prevent harm and inconvenience to human health or the environment, even if there is no complete evidence that such inconvenience or harm arises. This is a principle that aims to minimise the need for restoration. However, since the requirement of caution remains as long as the damage does so, the precautionary principle can indirectly also entail demands for restoration.

A legal standard that clearly follows EU law, but which also appears in the Baltic Sea Convention, for example, is the requirement for operators to use the *best available technology* , i.e. the technology (in the sense) available on the market somewhere on the globe and contributing to at least environmental impact, provided the cost is reasonable. The European Commission's task is to produce guidance documents on what constitutes the best available technology, which also aims to define the concept. The concept of best *available* technology is not used in the Swedish Environmental Code, but instead demands that the best *possible* technology be used, but only to the extent that it is considered environmentally justified (see further on this balance below in section 6.5.4). When assessing how costly requirements can be set, an objective assessment is made based on what a typical industry company can assume. EU law's requirements for best available technology can be said to be a minimum level. When applying the environmental bar's requirements to the best possible technology, more ambitious requirements may be imposed.

The main difference between international law and EU law is that there is a much greater opportunity for EU institutions to enforce compliance with requirements and commitments. The EU Commission can bring an action in the European Court of Justice against a Member State that does not fully implement a directive. The European Court of Justice may then order the Member State to implement the directive, but also to pay a fine as long as the implementation fails. International conventions usually contain various ways to increase the compliance of the parties, e.g. through various forms of reporting requirements or by establishing joint commissions (such as HELCOM and the OSPAR Commission) that can support and drive the parties' work in different ways. Admittedly, there is an international court that can be used if the parties do not fulfil their obligations but in practice it is very rarely used. Instead, it is political considerations that usually motivate states to fulfil their commitments.

It is also important to point out that, according to EU law, Swedish courts and authorities are required to interpret national law in the light of the wording and purpose of the directives. If a Member State fails to implement directives, national authorities and courts may also be required to apply the rules of a directive with direct effect to give individuals the opportunity to exercise the rights granted to individuals by Union law. The condition then is that the provision of the directive is unconditional and sufficiently clear and precise and that the EU country has not transposed the directive within the given time limit.

It is clear that, above all, EU law today plays a major role in the formulation of Swedish environmental legislation. Over time, the scope for national regulation has diminished and today most legislative initiatives in the environmental field are taken as a consequence of new EU requirements.

# 6.5. Swedish legislation that protects eelgrass

## 6.5.1. The environmental code protection of eelgrass

Operations and persons in Sweden that directly or indirectly affect eelgrass and its habitat are obliged to comply with Swedish legislation which also includes EU legislation. This applies to activities that may directly affect the living environment of eelgrass e.g. through dredging, in various types of construction in water (for example, construction of ports and bridges) or during anchoring. But the regulations are also aimed at players who more indirectly affect the eelgrass, for example, through the release of nutrients, fishing or the release of alien plant and animal species.

The Environmental Code contains general rules, in particular the general rules of consideration in the second chapter of the Environmental Code, which must be applied regardless of where within Sweden the effect on eelgrass is taking place (below, section 6.5.4). There are also more specific protection rules that apply in relation to certain activities or designated areas (below sections 6.5.5 to 6.5.7). The general consideration rules generally apply regardless of whether the business must have a permit, exemption or the like in order to operate or not. The rules are either intended to counteract further environmental impact or deterioration (e.g. eelgrass habitats) - *prevention* - or to repair and restore damaged areas - *repair*. As described in section 2.2, compensation restoration can be used to compensate for damage that inevitably arises from an activity that cannot be avoided through preventative precautions (see further chapter 7). In parallel with the Environmental Code, other legislation should be applied, such as the Planning and Building Act (regulates construction and exploitation of land and water areas), the Walls and the

Forest Conservation Act.

The Environmental Code consists of a large number of rules and regulations, but the review below only covers those rules that are considered to be of direct relevance to the management of eelgrass. The goals of the environmental bar are first described and how they link to the national environmental quality goals set by the Swedish Parliament. Thereafter, the general consideration requirements are described and how they can protect eelgrass. Furthermore, there are special protected areas that can also be important for eelgrass habitats, as well as requirements for certain activities to have permits or seek exemption. The rules on supervision is important to describe because the supervisory work is designed to monitor and enforce the requirements and counter unlawful activity.

### 6.5.2. The environmental code's goals and the Swedish environmental quality goals

The Swedish rules that protect eelgrass are mainly found in the Environmental Code and its regulations and prescripts. Before describing these, there is reason to briefly describe the goals that Swedish environmental legislation aims to achieve. These objectives may be of importance in the application of the rules of the Environmental Code, especially in cases where the rules allow for different interpretations. The targets also indicate what the legislature views as important public interests, which may have an impact on the extent to which compensation claims should be made (see further in Chapter 7).

Of Chapter 1 Section 1 of the Environmental Code states that the purpose of the Code is to *promote long-term sustainable development*. This portal paragraph also expresses the understanding of nature's protection value and that man has a responsibility to manage nature well. What is special about the portal's paragraph of the environmental code is that it clearly expresses significance in interpreting the rules of the code. Of Chapter 1 § 1, paragraph 2, the Environmental Code, states that “the Environmental Code shall be applied so that

1. human health and the environment are protected from damage and inconvenience, whether caused by pollution or other effects;
2. valuable natural and cultural environments are protected and nurtured,
3. biodiversity is preserved,
4. land, water and the physical environment are otherwise used so that, from an ecological, social, cultural and socio-economic point of view, good long-term economy is ensured.”

The meaning of this "interpretive imperative" differs between different courts. The Land and Environmental Court has referred directly to the target rule in Chapter 1. § 1 while the Supreme Court was less inclined to do the same (Michanek & Zetterberg 2012). In decisions on permits and supervision concerning the impact of operations on eelgrass habitats, it is advisable to refer to the aforementioned objectives where possible.

The 16 national environmental quality targets decided by the Swedish Parliament have no direct legal status and cannot be used as a basis for imposing demands on individuals or authorities to act. However, they indicate the political direction for environmental work and provide guidance on how the authorities' environmental work should be prioritised. Therefore, it may be appropriate to mention relevant environmental quality targets in decisions on permits and supervision. Of the 16 environmental quality objectives, some are particularly important in relation to the protection of eelgrass, namely:

- A balanced marine environment (“Hav i Balans”), flourishing coastal areas and archipelagos
- No eutrophication
- A rich plant and animal life

Each environmental quality goal has in turn been specified and a number of stage goals have been set up that show steps on the way towards the environmental quality goals and the generation goals.
The definition of the environmental quality target Sea in balance ("Hav i Balans") entails, among other things, that the requirements for good status under the Water Framework Directive, good environmental status according to the Marine Strategy Framework Directive and favourable conservation status according to the Habitats Directive are achieved;

- ecosystem services are maintained,
- ecosystems in shallow coastal environments are characterised by a rich biodiversity, with habitats and propagation paths for plant and animal species and
- endangered species are recovering and habitats have been restored in valuable coastal and seawater.

Environmental goals in Chapter 1 Section 1 of the Environmental Code and the national environmental quality objectives express what is stated in the Environmental Code as **general interests** and which in certain cases should be weighed against individual interests. The concept of general interests is also important in relation to claims for compensation (according to Chapter 16 § 9 of the Environmental Code), which is discussed below in Chapter 7.

### 6.5.3. Environmental quality standards

Chapter 5 of the Environmental Code sets environmental quality standards, which can be said to be rules for the status of the environment. The status description for coastal water can be found in regulations from the Swedish Agency for Marine and Water Management (HVMF 2012: 18 and 2013: 19). The Swedish Agency for Marine and Water Management provides more detailed guidance on environmental quality standards in water management (Swedish Environmental Protection Agency 2011b).

In Sweden, environmental quality standards may constitute limit values that *must* be achieved or benchmark values that *should* be achieved. Norms can also be designed as bio indicators or to specify environmental quality requirements that result from EU membership. However, the Environmental Code does not specify what legal effect the two latter types of environmental quality standards regulate, but it is something that can be determined by interpreting the EU law that the environmental quality requirements aim to implement.

The standards that regulate chemical status according to the Water Framework Directive are characterised as so-called *limit value norms* and have a more direct significance in assessing the requirements for caution to be imposed on an activity that affects the regulated water status. If there is deemed to be a risk that a limit value norm is exceeded, more extensive requirements may be imposed on an operation, compared with what is otherwise possible. Nor is it permissible to authorise activities that contribute to such increased pollution or disturbance that can be assumed in a not insignificant way, which entails that a limit value norm is in danger of being exceeded.

The environmental quality standards that relate to ecological status in water under the Water Framework Directive have not been perceived as limit values by Swedish lawmakers and courts and have therefore not had the same deterrent effect as environmental quality standards that describe chemical status. The previously mentioned Weser judgment makes it clear that Swedish legislation does not meet the requirements of EU law and that the environmental code needs to be changed with regard to the regulation in Chapter 2 of the Environmental Code of the legal effect of the ecological standards (Olsen-Lundh 2016, Michanek 2015). It is unclear how courts and authorities will handle these standards until the amendment is made. As mentioned above (section 6.4), courts and authorities are required to interpret Swedish legislation in the light of the wording and purpose of the directives. The prohibition on EU law to authorise activities or measures that may cause a deterioration of status or jeopardizing the attainment of good status / good potential of a water body would for example, be maintained by applying the siting provision in Chapter 2. § 6 or the stop rule in Chapter 2. § 9. Since the Swedish implementation of the Water Framework Directive is lacking and the directive's provisions on good ecological status are unconditional and sufficiently clear, Swedish authorities and courts are also obliged to consider applying the rules of the Water Framework Directive directly (Michanek 2015). This could, for example, be relevant in supervisory matters or in permit testing. An amendment to the Swedish assessment bases for angiosperm plants so that the presence of eelgrass can affect the status classification of coastal waters (as described above), would provide additional legal arguments for being very restrictive against granting permits to activities that may affect the habitats of eelgrass.

### 6.5.4. General considerations (Chapter 2 EC)

The Environmental Code's second chapter contains general rules of consideration that apply to all activities and measures that in any way affect the Environmental Code's goal of sustainable development. The term business includes not only professional activities but also private ones such as different types of land changes and construction of bridges, etc. Exempted from the general consideration rules are measures that are of negligible importance in the individual case, which in the preparations for the Environmental Code can be stated, for example, choice of holiday resort and place of residence. For the protection of eelgrass, relatively small negative effects should also be attributed importance, since together they can have a decisive impact on the status of eelgrass as a habitat.

The purpose of the rules is to limit the negative consequences of different types of operations, not to prevent them in themselves. In addition to specifying the type of consideration that the operator and the person who must take a measure, must also specify the extent to which consideration is to be taken, i.e. how costly precautionary measures may be required.

#### *The knowledge requirement - Chap. 2 § 2*

Anyone who is going to run a business or take action must "acquire the knowledge needed" to assess and manage the environmental and human health impacts that may arise from the intended action or activity. As a licensing or regulatory authority, there is thus the opportunity to require that the person planning a business or measure make clear what impact on, for example, eelgrass that may be the result of what is planned. Especially in cases that are not licensed, such as notification cases (such as certain water activities and upon notification according to Chapter 12 Section 6 of the Environmental Code) and in beach protection dispensaries, it is important that as an administrator, be aware of whether this is an activity or measure that could typically damage the eelgrass. See fact box 3.1. for more information on how the eelgrass may be affected.

Anyone who is to conduct an activity or is conducting such an activity, as well as the person who is to take a measure that can risk adversely affecting the natural environment, must therefore have sufficient knowledge to be able to assess in what way the activity or measure may affect, for example habitats for different species and how these effects can be avoided or at least minimised. Knowledge about the effects is about both the design of one's own business and the conditions on the seabed that is in risk of being affected. How far-reaching demands for knowledge about the condition of eelgrass, the possible impact of the activities on this, as well as possible precautions to minimise or avoid such impact, are to be asked in each case. If there is a risk that an operation will cause further disturbance to eelgrass in an area where the distribution and density of eelgrass has been negatively affected previously, however, the operator should have knowledge of the conditions in the immediate area and how even a small additional impact may affect the habitat in the area and over time. Likewise, if the business impact provides fewer opportunities for eelgrass to be re-established.

### *The precautionary requirement - Chapter 2 § 3*

Anyone who intends to carry out a business or conduct a business is required to:

> *perform the safeguard measures, observe the restrictions and take any other precautionary measures necessary to prevent, hinder or counteract damage or inconvenience to human health or the environment.*
>
> *These precautions should be taken* ***as soon as there is reason to believe*** *that an activity or measure may cause harm or inconvenience to human health or the environment.*

It is important to note that the *risk* of harmful effects already motivates precautionary measures to be taken. Precautions that can be actualised for eelgrass are the design of a construction to be built in water (e.g. to minimise shading of a bridge to be built), avoiding dredging in eelgrass meadows and to minimise the damage due to clouding in connection with dredging or other work in the water. For professional activities, the precautionary requirement in Chapter 2 § 3 has been expressed by clarifying that the business must use the best possible technology (see section 6.4 above for a more detailed description of the two concepts best available and best possible technology).

### *Choice of location - Chap.2 § 6*

A crucial precautionary measure to protect eelgrass is the requirement to choose the location that has the least environmental impact (intrusion and inconvenience) but which at the same time achieves the purpose of the business. For example, if a new port or marina is to be built in an area with eelgrass, the location requirement may require that such a site be chosen that allows dredging to be avoided or at least minimised, since dredging can have major direct and indirect effects on eelgrass. If all places are equally unsuitable - e.g. due to the spread of eelgrass - this may be a reason for not allowing the operation. As a basis for prohibiting operations at the site, the Environmental Code Chapter 2. § 6 may be used. You can also refer to the stop rule in Chapter 2. § 9, but it must then be possible to show that it is the individual activities that have a significant impact on the eelgrass habitat. Similarly, the Natura 2000 regulations in Chapter 7 of the Environmental Code may imply that a particular location is prohibited. An example is MÖD 2007: 57 where a dock for 22 boat seats was not allowed because the impact on the valuable environments in the Natura 2000 area was affected. The goal was not only about eelgrass, but it was one of the habitats protected by the denial of permits. Another example is Vänersborg’s District Court, which in Case M 2279-15 denied permission for an extension of existing bridge on Resö. The reasons for the decision were stated that the area was protected as a nature reserve, the Natura 2000 area and that it was not established that the impact on eelgrass was not unacceptable.

Since the requirement is to find the best place from an environmental and health point of view for the business, it is crucial to clarify how the area within which alternative sites can be located (the so-called search area) should be delimited. It must be taken into account here that both the purpose of the business can be achieved and that it must be done with the least intrusion and inconvenience to the environment. What the purpose is varies between different types of projects. If the purpose is to meet the need for ship transports to and from Sweden, the search area will be relatively large. If, instead, the purpose is to provide berths for recreational boats, the area that is reasonable to investigate is considerably smaller. In that case, it becomes a matter of weighing people's desire or need for closeness to a berth against the requirement to choose an alternative place where disruption is minimised.

The location selection is affected by whether there is any nature protection in the area in question or if it has been designated as a national interest for any specific purpose (see further section 6.5.6).

Until a change in the Environmental Code reflecting the conclusions of the Weser judgment has been made, the recommendation is to apply the location requirement in Chapter 2. § 6 of the Environmental Code, taking into account the purpose of the Water Framework Directive and in particular the requirement for non-deterioration. If there a risk that an activity or action will affect eelgrass in a way so that the deterioration of ecological status or achievement of ecological status is compromised, it's probably not permitted to locate the business on site.

#### *Economic trade-off between cost and benefit - Chapter 2 § 7*

As described above (section 6.4), all requirements in Chapter 2 of the Environmental Code must be applied to the extent that the protection measure is deemed to be environmentally justified. This is done by balancing the cost of the safeguard measures and their benefits. If a measure for the protection of eelgrass is perceived as unreasonably expensive in relation to the value of the eelgrass, then there is generally no requirement for the operator to take the safeguard measure. Therefore, it is of great importance how to calculate both the benefit of the eelgrass and the costs of taking the protective measures (see Chapter 4). This also means that the requirements to take protective measures may be affected by new knowledge about the importance of eelgrass. Regardless of whether after a trade-off according to Chapter 2. § 7 of the Environmental Code is not considered environmentally justified to take protective measures, according to the Weser judgment (C-461/13), a deterioration of a quality factor may not be allowed.

### 6.5.5. Maintenance provisions

The economy provisions in the chapters 3–4 of the Environmental Code aim to provide guidance on the interests that should be prioritise for land and water use. This is an issue that is of particular importance when choosing a location for an activity requiring a permit or notification and in deciding on an exemption for infringement in various forms of nature protection.

According to the general rule, land and water areas should be used for the purposes most appropriate with regard to location, nature and present needs (Chap. § 1 of the Environmental Code). Use that provides a good economy from a general point of view shall take precedence. Particularly ecologically sensitive areas shall, as far as possible, be protected against measures that can significantly damage the natural environment (Chapter 3 § 3). Areas that are important for fishing should be protected as far as possible against measures that can significantly affect the opportunity to fish. Areas designated as nationally important for fishing shall be protected against such impacts (Chapter 3 § 5). Damage to eelgrass meadows that act as a nursery for fish fry can subsequently affect fishing interest and should therefore be covered by protection against measures that can make fishing more difficult, e.g. dredging. Areas with great natural or cultural values or that are important for the outdoor life should be protected as far as possible from tangible damage (Chap. 3 § 6). If such an area is designated as a national interest, it must be protected against tangible damage, i.e. permanent negative impact or temporary large negative impact.

Chapter 4 of The Environmental Code follows that large parts of the coastal waters in Bohuslän are of national interest for nature and cultural conservation and have protection against various types of exploitation and impact, unless it is a question of developing an existing urban area or the local business or defence. However, in the case of areas designated as Natura 2000 sites (see further below), the protection is significantly stronger, and it will be considerably more difficult to apply any exception.

In the examination of the admissibility of a business location the economic provisions should be applied and thus can both hinder and promote locating the investment in an area where there is a habitat for eelgrass.

### 6.5.6. Area protection (Chapter 7 EC)

One way for lawmakers to legally control which consideration should be taken of species and habitats is to identify geographical areas and link these designations to rules on how the area may be used or affected. Below are described geographically defined protections that may be of importance for the protection of eelgrass. These rules are mainly found in the 7 and 8 chapters of the Environmental Code, but also the above-mentioned economic regulations in 3 and 4 chapters and environmental quality standards in accordance with the chapter 5 are linked to geographical areas. The different protections complement each other as they protect against different types of influence. In general, however, it can be said that the more precise rules with clear geographical demarcation are easier to apply since they do not leave as much room for interpretation.

The rules in Chapters 7-8 of The Environmental Code protects against various forms of human influence. In some cases, the legal text already specifies the type of impact that is limited. For example, shore protection provides protection against the erection of new buildings or alterations to existing buildings or facilities that can prevent or refrain the public from entering a shore area, as well as against measures that significantly change the living conditions of animals and plants. In other cases, the type of impact that is to be limited on a case-by-case basis is determined by specific regulations (e.g. for nature reserves).

#### *Nature Reserve (Chapter 7 § 4 EC)*

Land or water areas may be declared as nature reserves by county councils or municipalities to preserve biodiversity, nurture and preserve valuable natural environments, to meet outdoor recreational interests and to protect, restore or create valuable natural environments or habitats for protection. Nature reserves can thus be decided to protect a water area where, for example, there are protected species, such as eelgrass or seabeds where eelgrass would be able to grow. Nature reserves can also be a useful form of protection when an eelgrass meadow is restored and needs protection. Nature reserves do not protect against such effects where the source is outside the reserve, for example through long-distance air pollution. However, when locating a business and applying the general rules of consideration, the nature reserve indicates that there is a need for special consideration.

For each nature reserve, restrictions are also set on how the area may be used as needed to achieve its purpose. This can be a prohibition against building, setting up fences, excavating, cultivating, ditching, planting, felling, hunting, fishing, using pesticides or being in the area. Thus, in order to protect eelgrass, restrictions may be imposed on staying in an area, or prohibiting the construction of such facilities, e.g. jetties that can damage the eelgrass. These regulations can only be repealed if there are *special reasons*, e.g. when an area has changed significantly or when a detailed plan or area regulation has significantly changed the conditions for the area's protection (Prop. 1997/98: 45 Part 2). However, exemptions may be granted from regulations if *special reasons* exist.

Although eelgrass grows in many of the nature reserves along the coast of Bohuslän, the reserve has rarely been created to protect this species and its habitat. The reserve regulations are therefore rarely designed to prevent the effect on eelgrass (see fact box 3.1. For a summary of various the most important threats to eelgrass). **By reviewing existing regulations, the protection of eelgrass within existing reserves could be strengthened. Both municipalities and county administrative boards may also consider the possibility to identify new reserves in order to protect the remaining eelgrass meadows.**

#### *Natura 2000 (Chapter 7 27 § EC)*

Under the Habitats Directive, as mentioned above, all EU Member States must designate areas that represent important natural environments with species or habitats that are particularly worthy of protection from a European perspective. Together, these designated areas form a network aimed at fulfilling the EU's commitments, among other things, the Convention on Biological Diversity.

Eelgrass grows in several of Bohuslän's Natura 2000 areas. Operations and measures that may have a significant impact on a designated Natura 2000 area must not be initiated without permission from the county administrative board. This requirement applies regardless of whether the business will be conducted, or the action taken in the area itself or outside. There are possibilities for exemptions from this prohibition, but permits may only be granted under special circumstances and after a decision by the government. In 2004, an application for the construction of a small boat dock in the municipality of Tanum was rejected by the Environmental Court because the court considered that the location posed a great risk of impact on soft bottoms and eelgrass meadows in a Natura 2000 area (MÖD 2004: 29). No examination of the exemptions became relevant as the documentation was too poor to assess the natural values that were at risk of being affected. During permit testing and supervision of activities that may affect eelgrass, e.g. through clouding during dredging or dumping, it must be clarified whether there is a risk of affecting such Natura 2000 areas that are designated to protect natural types where there is or could be eelgrass.

### *Biotope protection (Chapter 7 § 11 EC)*

An opportunity for direct protection for eelgrass can be found in the Environmental Code (Chapter 7 § 11) and the Ordinance (1998: 1252) on area protection in accordance with the Environmental Code, etc. The Ordinance gives county councils and municipalities the opportunity to designate eelgrass meadows as biotope protection area. The protection means that activities and measures that can damage the natural environment are not allowed in designated areas (Chapter 7 § 11 of the Environmental Code). One advantage of biotope protection areas compared to other types of protection is that it is relatively easy to introduce, i.e. only a decision from the county administrative board is needed. One complication with the designation of eelgrass meadows is that the geographical distribution changes to a certain extent year by year (Nyqvist et al. (2009). Biotope protection must therefore include such areas to which eelgrass can be spread in the near future. As the method for mapping eelgrass develops, it can be expected to be easier to delineate for biotope protection relevant areas.

The Swedish Environmental Protection Agency and the Swedish Agency for Marine and Water Management have produced a specific guide for establishing biotope protection for eelgrass (the Swedish Environmental Protection Agency 2014). Until 2015, however, it was possible to designate specific areas with eelgrass as biotope protection areas were not utilised, but in April 2016, the County Administrative Board of Västra Götaland County decided to establish biotope protection for a 24-hectare area containing 2.4 ha of eelgrass (County Administrative Board 2016). **Highlighting eelgrass meadows as biotope protection areas can be an effective measure to increase the protection of this habitat and should therefore be intensified considerably. This is especially true in areas where large losses of eelgrass have occurred as in southern Bohuslän where the need to protect remaining eelgrass is acute.**

### *Beach shelter (Chapter 7 § 16 EC)*

The coastal zone, generally 100 meters from the shoreline both on land and out in the water (but not more than 300m), has legal protection against some type of impact. This area can be extended to a maximum of 300 meters from the shoreline. Within beach protection areas, it is prohibited (in accordance with Chapter 7, § 15 of the Environmental Code) to build, change the use of a building, dig or take measures that significantly change the conditions for animals and plants (e.g. eelgrass). This means that dredging, construction of bridges, refills etc. in a beach protection area is not allowed. For some buildings that are needed in agriculture and fishing, beach protection does not apply.

Exemptions from beach protection may be granted under certain conditions if there are special reasons, e.g. that a facility for its function needs to be located on the water and the need cannot be met outside the area (Chap. 7 § 18c). By permission according to Chapter 9 or 11 of The Environmental Code or permissibility in accordance with Chapter 17 of The Environmental Code (the government), a business can be permitted within the beach protected area. In addition, the municipality may, under certain conditions, by means of a detailed plan, exclude an area from beach protection (Chapter 4 § 17 of the Planning and Building Act) if there are special reasons for it and if the interest in using the area in the manner referred to in the plan outweighs the beach protection interest.

See fact box 6.1. for a summary of what the county administrative board can do to increase the protection of eelgrass. See also the Swedish Environmental Protection Agency's Handbook on Beach Protection (The Swedish Environmental Protection Agency 2009b).

**Fact Box 6.1. Recommendations for improving eelgrass protection: What the county administrative board can do**

Below are examples of what the county administrative board can do to increase the protection of eelgrass

- Accelerate work on establishing biotope protection for eelgrass meadows.
- Provide map material on the distribution of eelgrass to be used in matters of supervision, notification, dispensation, supervision, area protection etc.
- Review the regulations for existing nature reserves to clarify whether there is a need to introduce restrictions designed to protect eelgrass habitats. For example, it may be appropriate to introduce a ban on exploitation and precautionary measures to avoid damage caused by recreational boats.
- Consider whether conservation goals for Natura 2000 sites should include eelgrass.
- Consider introducing new nature reserves in order to protect eelgrass.

### 6.5.7. Permissions, dispensing and supervision

In connection with examinations of permits, notifications and dispensations for activities or measures and in connection with supervision, the need to protect eelgrass may be raised. The different types of tests where eelgrass protection can be activated are:

1. permit cases for environmentally hazardous activities (Chapter 9) and water activities (Chapter 11),
2. dispensation for intrusion into protected areas such as nature reserves, Natura 2000 areas, beach protection areas, biotope protection areas and national parks (Chapter 7);
3. exemption from the dumping ban (Chap. 15 § 33),
4. supervision of notification cases (chapters 9 or 11 or Chap. 12 § 6).

For businesses that do not require either a permit or a notification, the regulator still has a role to check that the business complies with the requirements of The Environmental Code. Below is a brief description of examples of different types of testing and supervision and which considerations in relation to the habitat of eelgrass should be considered. In connection with the text, there are a number of fact boxes with checklists of questions that are important to take into account when examining and supervising.

*Business required to report and notify*

Environmentally hazardous activities are any use of land, buildings or facilities that can affect human health or the environment through pollution or other disturbances (e.g. influence through sound, vibration, light, etc.). Environmentally hazardous activities are divided into four different categories where the first two categories (A and B) are subject to permits (one to the environmental court and the other to the environmental review delegation at the county administrative board), the third category (C) subject to reporting to the municipality and a fourth the category (U) which is neither subject to permit nor registration. There are also some activities, e.g. small drains with WC where permission is sought from the municipality. Which category a business type belongs to is stated in the Environmental Assessment Ordinance (2013: 251).

Water operations are such construction in water that affect the depth and location of the water (Chapter 11 § 2) and the main rule is that water operations require permits in accordance with Chapter 11. § 9 of the Environmental Code to be conducted. Some water activities are sufficient to notify before they can begin (Regulation 1998: 1388 on water activities, etc.). Permits for water activities are usually sought from land and environmental court and in some cases (e.g. soil drainage) at the county administrative board. Notification of water activities is made. Permission is sought by the person who is to conduct the business. Prior to submitting the application, the business must consult with important stakeholders (such as local residents, the municipality and certain authorities) and then prepare an environmental impact assessment that investigates what impact the intended business will have on alternative locations and how these can be counteracted (Chapter 6, Environmental Code). **If there is a risk that the operation will cause disturbances of eelgrass, this should be noted by municipalities and authorities already in connection with the consultation.** Deficiencies in the environmental impact statement or in the application may entail requirements for supplements and, ultimately, that the application is dismissed or rejected.

The licensing authority or the court examines the extent to which the business meets all the requirements set out above and decides whether to grant a permit and, if so, under what conditions and for how long. It is the operator who is responsible for producing the basis for the examination but the responsibility of the examining authority to ensure that the basis is sufficient for a decision on permission. The examining authority should therefore in particular ensure that there is information in the environmental impact statement and in the application for

- the extent to which there is eelgrass in the area where the activity is to be conducted or the action to be taken or in an area that may be affected by the activity / action (even indirect disturbances through, for example, traffic to and from a facility should be reported)
- what effect the activity may have on eelgrass and how this effect is affected by the fact that there may also be other activities that affect the same living environment;
- how these effects can be counteracted.

When the examining authority has received sufficient evidence, the application itself must be examined. The first question is to determine whether the business should be allowed at a certain location. As previously mentioned, the localisation rule sets in Chapter 2. § 6 requires that the site is suitable for the purpose so that interference and inconvenience can be avoided as far as possible. If the habitats of eelgrass along the coast of Bohuslän will be affected, the location of the operations should always be questioned. In addition to the location of the business, the reviewing authority shall set requirements on precautionary measures to minimise disruptions as far as possible. This can for example mean that, during dredging, requirements for turbidity are minimised, that turbidity must not be carried out during the growing season or that nutritional supplementation in a fish farm is limited by a mussel cultivation adjacent to the plant. Compensation requirements should only be set as a last opportunity to minimise disruptions (see further chapters 7 and 8).

The permit gives the operator some security in such a way that neither the supervisory authority nor the individual can come and impose additional requirements more than under certain special circumstances (e.g. if incorrect information was provided in the application or if knowledge of new serious injuries was obtained). Usually, however, a permit condition can always be reviewed after 10 years from the granting of the permit. It is therefore important that municipalities and authorities pay attention to the condition tests that are done and act at an early stage of the review process.

In some exceptional cases, no permit is needed, but it is sufficient that the activity is reported to the supervisory authority before it commences (see section 19 of the Ordinance (1998: 1388) on water activities, etc.). Notifiable water activities that may affect eelgrass are filling and piling or digging, dredging, blasting or similar measures - if they cover an area of less than 3000 square meters. It can, for example, apply to the construction of a new jetty or repairs to an existing one. However, these cases generally require beach protection dispensation, so notification will not be the only examination that is made. As a supervisory authority, it is important in these cases to ensure that sufficient knowledge exists in the same way as described above for the current permit assessment. If knowledge of the impact is insufficient, the operator must be submitted to present a detailed investigation of the consequences.

See fact box 6.2. for a list of proposals for information that may be included in an application for a permit. See also the Swedish Environmental Protection Agency's handbook on water activities (the Swedish Environmental Protection Agency 2008).

### Fact Box 6.2. Recommendations for improving eelgrass protection: Condition testing

The list below contains proposals for information that may be included in an application for a permit for an environmentally hazardous activity (according to Chapter 9 of the Environmental Code) or water activities (according to Chapter 11 of the Environmental Code) that may affect the habitat of eelgrass. The list is not exhaustive, and all information need not be included in all applications. Instead, the extent of the documentation may be assessed on a case-by-case basis. The list can also be used as a starting point when considering registration cases and when supervising. Sometimes additional information may be needed, and the reviewing authority may then request it from the applicant.

1. Description of bottom substrate and depth in the area that may be affected by the operation, including any occurrence of eelgrass (areal extent and bulk density), which is reported on a map with position indications.
2. Information on the current and historical distribution of eelgrass and the distribution of shallow (0-5 m) soft bottom areas within the water body where the operation is to be carried out, if available (can be provided by the County Administrative Board).
3. Description of how and when (continuously or on specific occasions) the activities may affect habitats in shallow sea bays, and in particular eelgrass meadows.
4. Description of measures and precautionary measures to reduce the impact on eelgrass and methods to follow the impact.
5. Description of any protected areas in accordance with Chapter 7. EC that may be affected by the business and information about possible eelgrass in these areas. If the activity or measure significantly affects a Natura-2000, a special permit is required in accordance with Chapter 7, § 28a of the Environmental Code.
6. Description of the operation's impact on the possibility of achieving the environmental quality standard good ecological status in the water body concerned.

When examining or supervising, the following issues should be clarified:

1. Is the operation permitted in accordance with Chapter 2. § 6 EC with regard to proximity to sensitive habitats such as eelgrass meadows? If there is a risk of a negative impact on habitats for eelgrass, the location can no more than exceptionally be allowed and then under conditions of precautionary measures to minimise the damage.
2. What precautions should be taken to avoid or at least minimise the disturbance?

Should compensation measures be required (in addition to precautionary measures)? See also sections 6 and 7.

## Exemptions Matter

As mentioned above, under certain conditions, it is possible to obtain an exemption from restrictions and prohibitions, under certain conditions in combination with special conditions and requirements for compensation (Chapter 16 2 and 9 §§ of the Environmental Code). How this works is described in more detail in section 7.3. Exemptions can be sought from the general ban on dumping waste (for example, mud pulp) within Sweden's maritime territory as it can damage the aquatic environment (Chap. 15 31 §). The dumping ban follows from a number of international conventions such as the so-called London Convention and regional maritime law conventions such as OSPAR and HELCOM.

Exemptions for dumping in coastal waters and within the territorial sea are applied for by the county administrative board and can only be granted provided that inconvenience to human health and the environment does not arise. The authority examining the exemption application must therefore have a good knowledge of the effects of dumping on the marine ecosystems, not least eelgrass that is sensitive to reduced lighting conditions, which may arise in connection with the dumping. Dumping inshore is always directly inappropriate in cases where eelgrass can be affected either directly or at a later stage. The Swedish Agency for Marine and Water Management has produced a report (2015: 28) "Dealing with a dumping dispensation - What to consider?" which provides guidance for authorities that consider exemptions from the dumping ban. It is also important to note that the exemption does not entail any right to carry out the exempt activities. If damage or inconvenience should still occur and this is not remedied, additional conditions for the dispensation may be set and in the end the dispensation may also be revoked. Thus, good supervision and follow-up of notified dumping dispensers is required.

Exemptions from the beach protection are in most cases sought by the municipality and in some cases by the county administrative board (e.g. within nature reserves decided by the county administrative board). If an activity or measure has been granted permission in accordance with other provisions of the Environmental Code (in particular, Chapter 9, 11 or 17), the question of beach protection must have been tested in connection with the general question of location. The Supreme Court has stated that it is not a question of disregarding the beach protection, but the purpose is to avoid a double examination of the same activity or measure (NJA 2008 p. 55). Therefore, in permit testing of, for example, water activities such as dredging, the beach protection regulations must be taken into account by the permit authority when examining an application for a permit (see further below).

Exemptions can only be granted if there are special reasons (for example that the area is needed for an urgent public interest and other reasons stated in Chapter 7 18c and 18d §§ the Environmental Code) and that the purpose of the protection is not affected (i.e. the animal and plant life as well as the mobile outdoor life). When examining exemptions, a balance is made between the individual's interests and the general interest. In order to protect the eelgrass, it is therefore important to clarify its many functions and values (see the descriptions above in section 3.2 and chapter 4). In a decision on the beach protection service, the specific reasons for the exemption must be clearly stated. Likewise, the decision must contain clear information on the area in which the dispensation is given and what action the dispensation is intended for.

When a municipality receives an application for a beach protection dispensation for an activity that also constitutes a water activity that must be reported to the County Administrative Board in accordance with Chapter 11. § 9 a of the Environmental Code, the municipality may in certain counties hand over the handling of the beach protection case to the county administrative board. This avoids duplicate testing, which is cost-effective for the society. Likewise, the authority may have better opportunities to make demands on relevant investigations and other evidence needed to determine whether an exemption should be granted. There are also other cases when an operation is to be tested in accordance with Chapters 9 or 11 when the beach protection exemption can be included in that trial instead of as a separate case by the municipality.

In order to be able to decide whether the dispensation should be granted and possibly be combined with conditions, further information is needed on how the measure for which the dispensation is sought may have an impact on animal and plant life, e.g. eelgrass habitats. In areas where eelgrass has greatly reduced, e.g. the coast in southern Bohuslän should not be granted a dispensation for activities that can affect eelgrass even to a small extent. However, should there be such very special circumstances that dispensation is considered, this should be combined with requirements for such precautions that no effect on the eelgrass is made.

See fact box 6.3. for a list of suggestions on what information applicants should provide when considering an exemption from beach protection and dumping bans.

**Fact Box 6.3. Recommendations for improving eelgrass protection: Beach protection dispensary and dispensation from dumping ban**

**Beach protection dispensary**

When considering an exemption from beach protection, the applicant should provide information on

1. The presence of eelgrass in the area for which dispensation is sought and in the immediate area (water body).
2. Historical occurrence of eelgrass in the area, if available (can be provided by the County Administrative Board)
3. The effect on eelgrass and the habitat where eelgrass can grow as the dispensation can cause and the effect of this

*If the planned water activity is to be tested by a land and environmental court, the issue of beach protection dispensation will be dealt with within the framework of the permit process. In cases where it is sufficient to report the planned water activities to the regulator, the issue of beach protection dispensation can be coordinated with the handling of the notification.*

More guidance can be found in the Swedish Environmental Protection Agency's Handbook on Beach Protection 2009: 4. Issue 2.

**Exemption from dumping ban**

**Dumping dispensing should never be allowed in areas** that are cut because these areas always contain vegetation (such as eelgrass) that can seriously damage the increasing turbidity and sedimentation that results from dumping.

When considering an exemption from the dumping ban, the applicant should provide information on:

1. Current conditions in the area where dumping is planned, if the area is to be regarded as the accumulation or transport bottom, and if there is a risk that the dumping may affect baselines.
2. The presence of eelgrass (living and historical) local area (water body) that could be affected by the dumping.

**More guidance can be found in the Marine and Water Authority's report Dealing with a dumping dispensation - What to consider? Report 2015: 28.**

### Supervision

The responsibility for verifying that the environmental code's requirements and judgments and decisions taken pursuant to this are really complied with lies with a number of supervisory authorities. This supervisory responsibility means that, in addition to controlling compliance, supervisory authorities are also obliged to take measures so that the operators carry out corrections and comply with the requirements of the Code and in judgments and decisions. This can be done by the supervisory authority directing the operator to follow certain instructions or completely prohibiting the operation. It may also mean that the supervisory authority initiates the investigation of police and prosecutors or makes decisions on other sanctions. In Sweden, the authorities' supervisory responsibility is supplemented by the operator's "self-control". As a business operator, you are not only obliged to comply with the Environmental Code's requirements for consideration, but you are also obliged to check for yourself that this is actually happening. Operations usually have a control program and not infrequently the permits state how this control should be done.

The authority that supervises, for example, a marina, is stated in the Environmental Supervision Regulation (2011: 13). Supervision of environmentally hazardous activities (categories A and B) is exercised by the county administrative board which can transfer this supervision to the municipality. The municipality is responsible for other environmentally hazardous activities, while supervision of water activities is usually carried out by the county administrative board. The Environmental Protection Regulation also states which authorities are to ensure compliance with the legal protections in 7 and 8 chapters of the Environmental Code.

If there no permit for a business that risks affecting a living environment for eelgrass, e.g. a jetty or a smaller marina, it is the supervisory authority's task to ensure that the operation is permissible and that adequate precautions are taken. If the operation is located directly inappropriately or contributes to a major impact on an eelgrass meadow, the supervisory authority shall consider whether the operation is permissible and whether such requirements for precautionary measures should be set that cause the disturbance to cease or reduce. Thus, it may be relevant for the supervisory authority to set requirements for precautionary measures afterwards, e.g. fisheries promotion measures (according to Chapter 11 §| 8 of the Environmental Code) or to pay a special fishing fee (Chapter 6 § 5 of the Act (1998: 812) with special provisions on water activities). If an activity that is subject to a permit or notification is not required to apply for a permit or notify its activities, the supervisory authority shall make a prosecution report (Chapter 26 § 2 of the Environmental Code).

See fact box 6.2. for a list of suggestions on issues that a regulatory authority should pay attention to when overseeing activities that may affect eelgrass.

## 6.6. Deficiency analysis of today's legal administration

### The protection of eelgrass meadows is insufficient

The negative development of the Swedish eelgrass habitats described in section 3.3 above indicates that the management of these environments has been inadequate. Further impact on already exposed areas has been possible without this

1 See also MEET 2015-06-26, case no M 11172-14.

considered to be unauthorised or sanctioned. From this, one can conclude that the lack of protection is not only due to a substandard application but also because the protection itself is insufficient. This situation causes difficulties in living up to international commitments in, for example, OSPAR and the Baltic Sea Convention (HELCOM) and also contradicts the objective of good ecological status in the water directive and good environmental status in the marine environment directive.

Several of the area protections according to Chapter 7. The Environmental Code (e.g. nature reserves and biotope protection) only covers restrictions on activities in the area. Activities outside the protected area are thus not directly limited by the protection rules, even though they have a significant impact on the protected habitats. Restrictions on activities outside this type of protection area may therefore be made with other instruments, e.g. supervision of the application of the general considerations rules in Chapter 2. Environmental Code.

### Cumulative impact on eelgrass meadows must be considered

The insufficient protection can largely be explained by the fact that the trade-off in the individual case rarely causes the value of eelgrass ecosystem services and its biodiversity to be valued higher than the value of the individual exploitation. Thus, it is not seen as environmentally justified to take more comprehensive protective measures or to completely stop operations such as bridges, marinas, boathouses, new homes, etc. The "tyranny of the many small steps" thus means that big values can be lost through new or changed operations and facilities, each of which is rarely seen as a direct threat, but which together over time can cause major damage. In addition, if the operations are not subject to permits (for example, water operations that affect an area of less than 3000 $m^2$) then the documentation is in the form of an environmental impact assessment generally smaller. It will then be more difficult to determine whether the risks associated with the business are such that it should be prohibited or subject to restrictions. It is therefore important that the reviewing and supervisory authorities not only take into account the individual activities individually but take into account that it can be part of a larger impact from many different sources over time. This is particularly important as there are environmental quality standards that may be affected.

### Anyone who affects the eelgrass meadows will not pay for the damages

The principle that the polluter should pay for the damage that can result from his activities is also difficult to apply in cases where the damage is already a fact. Admittedly, there is a general requirement for operators to deal with the damage, but in practice it can be very difficult and costly for a regulator to enforce such a requirement vis-à-vis many small operators who have affected the habitat over a longer period of time (e.g. through boating). Today, it is mainly the state that is allowed to step in to remedy old environmental sins, but so far no restoration has been done for eelgrass habitat. In the decided action program for the marine environment, it has been stated that restoration of eelgrass meadows should take place (the Swedish Agency for Marine and Water Management 2015). To succeed in these restorations, it is important to investigate the causes of ongoing losses and lack of natural eelgrass recovery in some areas (see section 3.4.8), and to carefully evaluate suitable locations for restoration according to the recommendations given in the Handbook on eelgrass restoration (Moksnes et al. 2016).

## The protection in Chap.7 is not utilised

The protection of natural areas in accordance with Chapter 7 of the Environmental Code is as described by different dignity and protects from different types of influence but usually only the influence within the protected area. The rules on impact on Natura 2000 sites are the only ones that directly protect from activities outside the area. Several of the protections require a direct designation of the area where the eelgrass grows, which can be a relatively complicated process, for example with regard to nature reserves. Biotope protection, on the other hand, is considerably simpler formally but has so far only just begun to be used. **County administrative boards should immediately accelerate the designation of biotope protections for eelgrass meadows and other valuable marine environments.** Biotope protection would not constitute a comprehensive protection of eelgrass habitats, but would be a further obstacle against harmful effects and could also constitute an important signal of the eelgrass's protection value.

## Focus on eelgrass in condition testing and supervision

A better protection of eelgrass habitat can be achieved by a different application of the general rules of reference described above. This applies in particular to the location requirement, but also to the precautionary requirement and the requirement to use the best possible technology. It has been shown that it is possible to make demands on precautionary measures, but then a well-documented basis is required of the losses of eelgrass, the value of the ecosystem services that the habitat contributes to and the knowledge of technology to protect against the impact.

## Revise assessment bases and quality factors for angiosperm plants to include depth and areal distribution of eelgrass

The presence of angiosperm plants (including eelgrass) must, according to the Water Framework Directive, constitute a quality factor in the status classification. This needs to be clarified in the regulations of the Swedish Agency for Marine and Water Management (HVMSF 2013: 19) as well as in guiding documents. Today, eelgrass is present in the regulation, but the design of the assessment basis means that soft sediments with eelgrass is in practice excluded from the status classification (see section 5.2.1). The assessment basis and the quality factor for angiosperm plants need to be revised so that the depth distribution of eelgrass is included in the status classification of the water types where it occurs. The arable distribution of eelgrass should also be an indicator of status classification according to the Marine Strategy Framework Directive, for example for biodiversity. Such changes, coupled with a clear prohibition on further deterioration of the water status, would result in significantly better protection of habitats such as eelgrass meadows. Such a prohibition of deterioration requires that environmental quality standards constitute so-called limit values according to the first paragraph of Chapter 5. § 2 of the Environmental Code.

# 7. Legal basis for demands for ecological restoration and ecological compensation

## 7.1. Background

As described in section 6.4, the precautionary principle and the polluter pays principle are support for requiring those who, through an activity or action, risk affecting the environment, to exercise caution, even if there is no complete evidence that the act may cause a certain disturbance. Likewise, the person who influences the environment through pollution or other impacts is responsible for the repair of the damage. In principle, therefore, activities that have caused damage to eelgrass meadows can be given the responsibility for restoring the destroyed meadow. In practice, however, it can be difficult to enforce such a post-treatment responsibility, especially if the activities that caused the impact ceased.

Despite the precautionary principle and the polluter pays principle, it can nevertheless be stated that a certain degree of influence, even such influence which is irreversible, has been accepted. An example is the many jetties and marinas that are built in eelgrass meadows. However, as described above in Chapter 6, it is important to note that a permit to an activity does not end the requirement for precautionary measures and restoration of destroyed habitats. Thus, even an activity that has fully complied with the conditions of the permit may be subject to additional requirements.

In order to prevent further degradation of biodiversity, EU law (for example, through the Water Framework Directive, the Marine Strategy Framework Directive and the Habitats Directive), and also through national law and the national environmental objectives work, have increasingly been required to achieve a certain environmental status. These requirements have often been supplemented with requirements aimed at preventing further deterioration from new or changed operations, since it is perceived as counterproductive to allow certain businesses to further deteriorate the same condition that other operators are required to improve. In the process of restoring environmental permits, it has also become clear that even those effects that in the individual case have been considered acceptable at one time may, at a later stage, entail costs for someone else.

The EU's biodiversity strategy (European Commission 2011) aims, among other things, to ensure that no further loss of biodiversity and ecosystem services occurs ("ensure no net loss of biodiversity and ecosystem services"). According to the strategy, the Commission is tasked with proposing in 2016 what a system for “no net loss” of ecosystems and ecosystem services might look like through for example ecological compensation (so-called "offsetting" in English; see fact box 2.1.). Therefore, in order to develop new or existing operations, new solutions must be used that would rather lead to net improvements than net losses of biodiversity and ecosystem services. One such initiative is, for example, “The Business and Biodiversity Offsets Program” (BBOP), which works to help companies protect biodiversity and builds its business on the harm reduction hierarchy (see fact box 2.1.), i.e. primarily to avoid, minimise, and recreate damage to natural values before consideration of compensatory measures.

The following describes how the Swedish Environmental Code regulates the issue of ecological compensation and the possibility of demanding that losses of ecological values be compensated. The Environmental Code contains, in part, a more general opportunity to claim compensation (in Chapter 16, § 9) and several more specific possibilities. In essence, these rules are aimed at preventive protection, in connection with testing activities and measures, but in relation to serious environmental damage there is also a compensation requirement in connection with restoration of already damaged nature. The description of the rules in section 7.2 focuses on the conditions for requiring ecological compensation for eelgrass losses. However, the rules in themselves have a broader scope.

## 7.2. Claims for compensation for infringement in the public interest (Chapter 16 9 § EC)

The general legal possibility of requiring compensation measures can be found in Chapter 16. § 9 of the Environmental Code. The rule states that permits and dispensaries *may be* combined with requirements for, among other things, compensation for the infringements in the public interest that an activity entails. Compensation requirements can thus be set in all tests of permits and exemptions in accordance with the Environmental Code. The important limitation is that the reviewing authority does not *have* to claim compensation. Thus, it is up to the person who is trying a single case to make the assessment whether compensation is required or not. What the compensation should consist of is not stated in this rule, which means that a relatively broad interpretation of the concept of compensation must be considered reasonable. Thus, it is conceivable that measures other than compensation restoration can be seen as compensation in accordance with Chapter 16. § 9 of the Environmental Code (see 2.2 section 2.2).

### 7.2.1. General interests

What constitutes a public interest is briefly touched upon in the preparatory work of the Environmental Code, where it is stated that general interests may be nature conservation interests but also other interests (prop. 1997/98: 45 s. 209). One argument that the eelgrass is of general interest is the various acknowledgments of the eelgrass's protective value found in both Swedish law and international agreements. Such legal recognition of protection value is found by eelgrass being one of the specially specified biotopes that can be protected with biotope protection (according to Appendix 3 to Regulation (1998: 1252) on environmental protection under the Environmental Code, etc.), that eelgrass is included as an indicator species for the assessment of water status according to the EU Water Framework Directive and the Marine Strategy Framework Directive, as well as the inclusion of eelgrass on OSPAR's list of threatened species and habitats (OSPAR 2008) and HELCOM's Red List of habitats in the Baltic Sea (HELCOM 2013). Sweden's signature of the RAMSAR Convention is also a reason to regard eelgrass as a general interest when it is covered by the Convention's definition of wetlands. In addition to the formal arguments for eelgrass being of general interest, it is also well documented how important it is for the coastal ecosystem as a whole, both in the food chain and more structurally for water quality and erosion protection (further described in section 3.2 and Chapter 4). Eelgrass is covered by the concept general interest is clear in the light of the description above. Section 7.2.2 describes the additional criteria that must be met in order to be able to claim compensation according to Chapter 16 § 9 of the Environmental Code.

### 7.2.2. Extent of the infringement and severity

The preliminary work to the Environmental Code (prop. 1997/98 Part II s. 209f) states that the requirement for compensation must be adapted to the severity of the infringement and what benefit any compensatory measures may entail. Although the legal text does not directly state that such a balance between cost and benefit should be made, it follows from the so-called principle of proportionality. The same principle lies behind the trade-off that is to be made in accordance with Chapter 2 § 7 of the Environmental Code (see section 6.5.4).

The arguments set out in 7.2.1 show that eelgrass should be perceived as an important public interest and that negative impact on eelgrass should therefore be considered serious. The impact on eelgrass can also present difficulties in achieving the goals that are found in both the Swedish national environmental goals and the EU's biodiversity strategy.

One question to consider is whether there is any lower limit in area counted where small intrusions are not considered serious. No formal such limit exists, and it should be borne in mind that even small individual infringements can have great effects when they become many in number. In particular, this approach should be used when, as in the case of eelgrass, there are already large losses of the current habitat, especially in areas where very little eelgrass remains today, such as for example, in the Municipality of Kungälv (see section 3.3.3). However, it must also be taken into account that the cost of compensation is proportionate to the damage. Since eelgrass restoration in accordance with current recommendations (Moksnes et al. 2016) includes one year of preliminary surveys to identify a suitable site, and 10 years of follow-up, the costs of these surveys can be considered disproportionately high for very small damage to individual or tens square meter.

**In this report, it is generally recommended that ecological compensation for eelgrass is *considered* in all cases where the damage to eelgrass comprises 100 m² or more of an eelgrass meadow, and that it is *required* if the damage comprises 1000 m² or more.** If a functioning system of so-called *habitat banking,* where operators can pay for restorations already made (see section 8.5), was available for compensation restoration of eelgrass in Sweden, compensation could be required for all damages, even very small, without the costs would be disproportionately high.

All in all, there are good grounds for claiming that the eelgrass meadows are of general interest and that their impact can thus form the basis for a claim for compensation.

### 7.2.3. How direct must the impact be?

Public interest infringement can occur in various ways. Here a distinction is made between direct and indirect influence. Direct physical impact may consist of dredging of eelgrass meadows, filling of bottoms, construction of bridges or the like that shade the eelgrass. That this type of influence involves an infringement is indisputable. It is also relatively easy to measure the size of the intrusion and thus to set a reasonable level of the compensation requirement. It becomes more difficult if more indirect or diffuse effects are to be assessed. The typical example of indirect influence is emissions of nutritional substances where a specific injury is difficult to associate with a certain emission. The intrusion is not linked to a certain injury but rather a supplement of an already too common substance. Compensation in such a situation may involve the construction of wetlands to capture nutrients before reaching sensitive water areas. This was the case in the case of MÖD 2005: 5 where the Land and Environment Tribunal decided that a wetland should be built as compensation for the release of nutrients from a fish farm. The purpose of the compensation was to prevent an increased nitrogen load in the North Sea. Fish cultivation in open net cases was considered to be the best available technology and at that time the nitrogen could not be captured at the source so compensation was considered an appropriate solution.

## 7.3. Requirements for compensation for dispensing and damage related to area protection in accordance with Chapter 7

### 7.3.1. Exemptions from reserve regulations or cancellation of reserves (Chapter 7 7 § EC)

If a nature reserve is to be canceled or an exemption for intrusion into the reserve is announced, special protection rules apply. Such decisions may only be made if there are exceptional or special reasons and if the intrusion is compensated in the nature reserve or in another area (Chapter 7 § 4 of the environmental code). Compensation is here to a fair extent compulsory, unlike the general rule in Chapter 16 § 9. Now it should also be reminded that such exploitation is exceptional cases - the nature reserve has been set up to protect nature. But in cases where exploitation nevertheless becomes relevant, compensation should be used to counteract the losses that occur.

The compensation can be implemented so that a corresponding area is protected or by increasing the natural value of another area, for example by restoring a wetland outside the reserve itself. Compensation that constitutes a designation of another area as a nature reserve can be called formal compensation, unlike ecological. In order to avoid long-term losses, it is important to prioritise ecological compensation. Financial compensation, i.e. that the operator or the operator pays for its impact, is according to the bill (prop. 1997/98:45 Part II p. 77) not permitted. The fact that compensation should be made to a reasonable extent means that “altogether insignificant” infringements can be made without any claim for compensation, as well as a balance between the benefit of the compensation measure and the cost of it (prop. 1997/98:45 Part II p. 76f). Outside of the compensation requirement there are also things that according to the reserve regulations can be done with permission, and are not prohibited.

It is therefore of great practical importance if a measure is prohibited (with the possibility of exemption) in accordance with the provisions of the reserve or if it may be carried out with the permission of the responsible authority. In MÖD 2009: 38, the Land and Environmental Court found that it should generally be easier to obtain a permit than an exemption, and that special reasons for the permit can only be required if it is stated in the reserve regulations. The judgment did not address the issue of compensation but shows how the design of regulations affects the protection of a reserve. A reminder is here in its place; if infringements are to be allowed, they must be compatible with the purpose of the reserve.

Compensation requirements for the effect on eelgrass in nature reserves therefore depend on how the reserve's regulations are designed. **The most important message regarding nature reserves is to ensure that the regulations protect eelgrass, as compensation will be easier to decide on in a situation where some form of exploitation is relevant.** If the impact is affected by, for example, dredging, compensation should be required if dredging is prohibited in accordance with the regulations, while compensation should not be required if it is stated that dredging may be carried out according to a permit. In the latter case, 16 chap. § 9 of the Environmental Code still applies, but as described above, it is not mandatory to use for decision-making authorities. However, the fact that the eelgrass is within a nature reserve should be further arguments for a serious infringement of a general interest to have a negative impact on the biotope and thus a stronger reason for a testing authority to seize the opportunity in Chapter 16. 9 § Environmental Code than in areas who is not a nature reserve.

### 7.3.2. In case of damage to Natura 2000 sites (Chapter 7 29 § EC)

As can be seen from section 6.5.6, the protection of the environment within a Natura 2000 area is strong and requires (according to Chapter 7 Section 28a of the Environmental Code) permits from the county administrative board for activity that can significantly affect protected species and habitats. Only the government can allow the activity to be significantly affected by protected species and habitats. Such permits are granted as only in real exceptional cases and then with requirements for measures needed to compensate for environmental values so that the purpose of the protected area can be met. According to the European Commission's Interpretation Guidelines (European Commission 2000), compensation may consist of the following measures:

- recreating a habitat in a new area or expanding an area to be incorporated into the Natura 2000 network;
- improves the habitat in another part of the area or another Natura 2000 area in proportion to the negative consequences of the project;
- in exceptional cases, a new area is proposed under the Habitats Directive.

Thus, it is primarily ecological compensation that must be applied, only in exceptional cases can the designation of another area be counted as compensation. The issue of when compensation should be implemented is also addressed in the same guidance. It states that the compensation should, as a general rule, be implemented before the harmful measures are implemented. In this way, temporary losses of ecosystem services are avoided and the risk of failure is minimised (see Chapter 9 for details). In the case of MÖD 2006: 44, the Land and Environmental Court has applied the compensation requirement in Chapter 7. § 29 as stated in the Commission's guidance. The goal concerned the construction of the “Botniabanan” and the habitat that was relevant was a wetland area of importance for bird life. The Land and Environment Superior Court did not approve a probationary period for the compensation, but stated that the compensation measures would essentially be implemented when the Natura 2000 area infringement occurred.

A very important point when it comes to Natura 2000 areas is that not all nature within the area is covered by the same protection. It is primarily the designated species and habitats that have the strong protection. Other species and habitats therefore do not automatically require compensation, even if they exist within a Natura 2000 area. However, they can, as usual, form the basis for compensation in accordance with Chapter 16. § 9 of the Environmental Code. In order to strengthen the protection in Natural 2000 areas, it can be combined with other area protections, such as nature reserves, which has been done in many places.

### 7.3.3. Dispensary from biotope protection (Chapter 7 11 § EC)

As shown in the Swedish Environmental Protection Agency's report (the Swedish Environmental Protection Agency 2015) on the application of compensation requirements, dispensaries from biotope protection are the decisions that are largely combined with claims for compensation. There is no independent claim for compensation for dispensaries from biotope protection, but the requirement may be set based on Chapter 16. § 9. However, intrusion into a protected biotope appears reasonable to be considered serious, which may explain the frequently occurring compensation requirements. **The designation of eelgrass meadows as biotope protection areas would thus, in addition to the direct protection against exploitation, also most likely lead to compensation** for infringements that are still allowed. A first biotope protection area for among other eelgrass (Sunninge sound- Sundsvik, at the southern fortress of Uddevallabron) was decided by the county administrative board in Västra Götaland in April 2016.

### 7.3.4. Dispensary from beach protection (Chapter 7 16 § MB)

Like biotope protection, beach protection can be seen as an expression of public interests and could therefore form the basis for compensation claims in accordance with Chapter 16. § 9 of the Environmental Code. The Swedish Environmental Protection Agency's review (the Swedish Environmental Protection Agency 2015) of the application of compensation shows that compensation was not required sometime between 2011 and 2014 in connection with the issuance of a dispensary from the beach protection. However, there is no obstacle to a compensation claim linked to the beach protection dispensary. Activities and measures taken in water, such as the construction of bridges, are also covered by the regulations on water activities and require at least one notification to the county administrative board (see further in section 7.5).

## 7.4. Claims for compensation with the support of the 2 chapter Environmental Code

The rules in Chapter 2 of The Environmental Code are primarily aimed at limiting injuries and risks of injury. The wording of the general precautionary requirement in Chapter 2. § 3 may give the impression of opening up to a claim for compensation measures. According to the legal text, the person conducting an activity must carry out the protective measures, observe the restrictions and take the **precautionary** measures necessary to hinder, prevent or **counteract** that the activity or measure causes harm or inconvenience to human health or the environment. Compensation could be a way of counteracting the problems that arise. However, neither the preliminary work nor the practice support such an interpretation. On the contrary, the placing in Chapter 16. § 9 of the general possibility of claiming compensation, a sign that it was not intended to include compensation claims in Chapter 2.

In the preliminary work (Prop. 1997/98: 45) to the Environmental Code it is said in connection with Chapter 11. § 8 that the measures mentioned there are also covered by Chapter 2. § 3. Compensation outside the injured area may be required with support in Chapter 16. 9 § p. 3rd. The statement argues for a dividing line between compensation measures and precautionary measures could be the geographical location of a specific measure. This interpretation is also supported by two cases from the Environment Court where wetland construction has been discussed. In MÖD 2002: 80, the Environmental Court considered the issue of a wetland as compensation for residual emissions after wastewater treatment in sewage treatment plants. The cost of wetland construction was not considered to be proportionate to the benefits it would bring. The judgment refers to Chapter 16. § 9, but in the judgment grounds the terms protective measures and precautionary measures are used, which indicates that the wetland was assessed in accordance with Chapter 2. § 3. Wetland has in another case, MÖD 2005: 5, been referred to as a compensation measure by the Environmental Court. It was about establishing wetland that would capture nitrogen somewhere between Lake Fryken in Värmland and the North Sea. The wetland in MÖD 2002: 80 would have been in the vicinity of the sewage treatment plant, while in MÖD 2005: 5 there was a greater distance between the fish farm and the wetland. The difference between the two cases is in line with the statement from the preliminary work (Prop. 1997/98: 45 Part 2 s. 130) regarding the relationship between Chapter 11. § 8 and chap 2. Environmental Code. Where the limit for the business goes, and thus how far the requirements in Chapter 2. § 3 of the Environmental Code extends, however, is not always clear.

Claims for compensation are, as a general rule, questionable with support in Chapter 2 of the Environmental Code. However, the rules are there, mainly 2 Chap. 3 and 6 §§, very important to avoid and minimise harmful effects on eelgrass.

## 7.5. Compensation claims in regard to damage to fish in water operations (Chapter 11 8 §)

According to the Environmental Code, fishing (i.e. human activity) affected by water activities constitutes **Chapter 11. § 8** a special protective interest for which there are compensation requirements. According to the law, requirements are needed to *take and maintain necessary devices for the emergence of fish or fish stocks [...] and to observe the other conditions or orders that may be required to protect the fish in the water affected by water due to the water activity*. Thus, it is possible to demand ecological compensation for the water activities that cause damage to the fishery. In case M 11172-14 (2015-06-26), the Land and Environmental Court has pointed out that the requirements in Chapter 11. § 8 can be applied both in permit testing and in the notification of water activities and in the supervision of water activities. In its judgment, the Court refers to Bill 2004/05: 129 in which the government took the position which the Court later reiterated. Here is a significant difference compared to the compensation rule in Chapter 16. § 9 of the Environmental Code, which only applies when examining permits and exemptions.

**Compensation in accordance with Chapter 11. § 8, on the other hand, can also be applied to the supervision of water activities**, with the limitation that follows if there is a permit for the operation. A situation where requirements can be made in connection with the supervision is **if a notifiable water activity caused damage to eelgrass that was overlooked in connection with the notification**.

An alternative to demanding ecological compensation is to decide on a fishing fee that is intended to compensate for the losses for the fishing that arises. It is important to note that the fishing fee is not an ecological compensation, but is intended to generally serve the interests of the fishery. The fishing fee can generally be used to take measures that promote fishing and thus need not go to compensation for a certain loss of fish or fishing. Funds from the fees can be used for measures to improve living environments.

For eelgrass, organic compensation is in accordance with Chapter 11. § 8 required in the permit for Gothenburg port to be expanded in Arendal (see further in section 8.2.1). In this context, it can also be mentioned that in the same case, the Court ruled that the proposed compensation by planting eelgrass would cover the need  that the fishing fee should fulfil, and therefore decided not to levy the fishing fee.

### 7.5.1. Ecological compensation

Already in the 1918 Water Act, there was a provision that compensation for fishing losses arising from construction in water should be compensated (Chapter 2. 8 § 1918 year's water act). This was the case, for example, for those who were allowed to build power plant dams. The obligation was not limited only to power plant construction but also applied to other buildings in water (Klintberg 1955). For example, ecological compensation may involve the construction of new play areas to replace those destroyed by power plant dams or any other activity. It can also be compensation for eelgrass meadows.

One limitation that has existed for a long time is the trade-off between cost and benefit in terms of the compensation measure itself. If the benefit of fishing for a compensation measure cannot reasonably be considered to be equal to the cost, the claim for compensation may be reduced. Exactly how the benefit is to be calculated is not clear, but it is the interests of the fishery that must be met.

### 7.5.2. Fish tax

In practice, compensation for intrusion on fishing is often done through a fee instead of demands for concrete compensation measures. The possibility of this transformation is given in Chapter 6. § 5 of the Act (1998: 812) with special provisions on water activities. The size of the fishing fee has been the subject of discussion in trials. In relation to the costs of a restoration of eelgrass (SEK 1.2–2.5 million per hectare; see Chapter 7 in Moksnes et al. 2016), the fees have generally been very low, but increased in recent years, which is reported in Chapter 8. As discussed in Chapter 4, fish production is only one of many valuable ecosystem services that eelgrass meadows provide to humans. A fishing fee therefore risks becoming insufficient compensation for a lost eelgrass meadow.

## 7.6. Claims for compensation for environmental damage

The previously reported compensation rules relate to assessments in advance of the effects that may result from operations and measures. However, losses of eelgrass can also occur more unexpectedly. Injuries that have occurred without being part of a permit test can in some cases be classified as pollution or serious environmental damage. The responsibility for compensating injuries depends on the type of injury that is relevant and why they are treated separately below.

### 7.6.1. Pollution damage

Pollution damage is an environmental damage that can cause harm or inconvenience to human health or the environment. For such injuries, the person responsible for them **to a reasonable extent** must perform or pay for the remediation needed due to the pollution to prevent, hinder or counteract damage or inconvenience to human health or the environment. Consideration should be given to how far back the pollution damage is, if there was an explicit responsibility to prevent harmful effects and other circumstances. The limitations mean that there must be a clear connection between a certain pollution and injury, and that the remedy is considered reasonable.

### 7.6.2. Serious environmental damage

As part of the implementation of the Environmental Liability Directive (2004/35 / EC) in Sweden, changes were made in 2007 to the Chapter 10 Environmental Code. In particular, § 5 was amended which, after the amendment, prescribes requirements for the person responsible for a serious environmental damage. Serious environmental damage is defined in Chapter 10. § 1 and constitutes contamination of land that poses a significant risk to human health, affects on water with a significant adverse effect on the quality of the aquatic environment or a significant deterioration in the protection of species or habitats, listed in accordance with Chapter 7. § 27, first paragraph or Chapter 8. § 1 or 2 of the Environmental Code.

Claims for compensation arise when the environment after serious environmental damage cannot be restored. The reasoning about when compensation is actualized is similar to what applies in pre-testing, for example, testing of permits. According to Chapter 10. § 5 of the Environmental Code, the person responsible for a serious environmental damage must perform or pay for immediate prevention of further damage and restore the environment to the condition that would have been had the damage not occurred. In addition, compensation must be made for temporarily lost environmental values while it takes the recovery of the damaged environment. If a recovery is not possible, the permanent damage should be compensated. The scope of the compensation claim is limited by the fact that liability for environmental damage can be mitigated if what caused the problem has been allowed by the authorities or if the danger was not known when the damage was caused. Compensation for serious environmental damage has not yet been tested in Swedish practice.

## 7.7. Summary analysis

When eelgrass is affected, there are several options for claiming compensation, but the number of cases where these opportunities have been applied is limited. The rules in Chapter 16 are generally applicable to water operations. § 9 and chap 11. § 8 of the Environmental Code. There are advantages and disadvantages to the use of the two compensation rules. **To be able to claim full ecological compensation, it is most appropriate to make claims with support in Chapter 16. § 9.** As a rule, all ecosystem functions and ecosystem services may be used as arguments for compensation, making the need for ecological compensation clearer.

The disadvantage is that so far there is very little practice to rely on to make far-reaching demands for compensation. There is also no clarity on when compensation should be updated. A conceivable shift can be seen in the judgment on the expansion of Gothenburg harbour at Arendal where the port was obliged to compensate for the expected loss of eelgrass (Case No. M 4523-13, 2015-11-24. Vänersborg District Court.) See further in section 8.2.1.

Requirements to compensate losses for fishing in accordance with Chapter 11. § 8 is the second alternative, either as organic compensation or in the form of a fishing fee. The advantage of referring to Chapter 11, § 8 is that it can be applied even when supervising water activities and thus can capture more situations than compensation in accordance with Chapter 16, § 9 of the Environmental Code, which only applies when examining permits and exemptions. The disadvantage is that it is explicitly only losses for the fishery that are to be replaced, while other ecosystem functions and services are not compensated. The fishing fees have also been low in relation to the costs of ecological compensation, although they have increased in recent years.

A future situation in which **more eelgrass meadows are designated as biotope protection areas could further strengthen the possibility of demanding compensation, but above all place greater demands on avoiding and minimising losses.**

# 8. Use of ecological compensation in marine environments

## 8.1. Use of ecological compensation in Sweden in general

Ecological compensation means that damage to natural environments must be compensated by the addition of new natural values, for example through demands for the creation of environments, protection and maintenance of new areas or through restoration. In 2015, the Swedish Environmental Protection Agency conducted a survey aimed at investigating the extent to which ecological compensation is applied in Sweden today and in what type of cases (the Swedish Environmental Protection Agency 2015). According to the report, where more than 10,000 decisions (from 2011–2014) were investigated, it was found that the rules on ecological compensation were applied in a very different way, both when comparing different types of cases but also when comparing the application in different parts of Sweden. Generally, minor intrusions and intrusions in nature that were not included in any formal protection very rarely led to any claims for compensation. It is interesting to note from the report that the absolute majority of cases where compensation was required were in the case of dispensaries from biotope protection, where the requirements were prescribed with explicit support of Chapter 16, § 9 in many cases. Otherwise, refer to the report for details.

In marine environments, according to the report, ecological compensation has been used to a very small extent. In about 210 decisions concerning water activities there were found only two decisions requiring compensation (the Swedish Environmental Protection Agency 2015). Both cases involved groundwater drainage, but the requirements for compensation differed, one of which included restoration of a wetland, while the other included maintenance measures and restoration of a meadow and a ditch. However, no cases are found where the requirements for ecological compensation included restoration, innovation or protection and management of completely marine environments. At present, the negative impact on fish is usually only compensated by a fishing fee (in accordance with Chapter 6 § 5 and § 9 of the Act 1998: 812 with certain provisions on water activities etc.). Since this type of compensation means that the damage is financially compensated, it cannot be regarded as an ecological compensation (see fact box 2.1.), although the funds can ultimately be used for various forms of nature conservation.

In summary, the report shows that the use of ecological compensation has increased and that there are many examples of ecological compensation performed in terrestrial environments, although development and clearer guidance are needed. For marine environments, however, considerable development needs to be made of methods for ecological compensation and restoration. A toolbox with scientifically-based methods and measures is needed. There also seems to be a need to expand the possibilities of claiming compensation for intrusion into these environments.

## 8.2. Ecological compensation requirements in marine environments

There are very few cases where the impact on marine environments has led to demands for compensation in the form of actual measures. To the best of our knowledge, no compensation restoration has yet been carried out or evaluated in the marine environment, although several cases relating to eelgrass are now in progress (see below). In some cases, it has been set as an condition that black tang is put out after work in water, which could be referred to as ecological compensation (See e.g. Case 30030-05, 2006-09-28, Stockholm District Court; Case no. 1048-11, 2012-11-12 Växjö District Court; Case 2414-12, 2014-10-10, Nacka District Court). However, in none of the cases has the Court referred to the measure as compensation but seems to have seen it as a measure under the Chapter 2 of the Environmental Code.

### 8.2.1. Requirements for ecological compensation of eelgrass

Court cases where compensation for eelgrass losses have been required are easily counted. The cases that could be identified are briefly presented in this section. The special case of fishing fees is dealt with separately in section 8.2.2.

In a case in 2007, the Environmental Court in Vänersborg decided that in connection with the construction of a marina in Hälleviksstrand, an attempt should be made to facilitate the new establishment of eelgrass meadows (Case no. M 417-06, 2007-03-13 Vänersborg District Court). The requirement was made for experimental purposes as there was no experience of how good the opportunities were to succeed. The compensation would consist of dumping mud pulp to raise the seabed to a depth where eelgrass could establish, not through planting but through natural colonisation. The judgment lacks detailed conditions on how the compensation is to be implemented and instead the licensee and supervisory authority are instructed to agree on the details. In the case, the direct impact on eelgrass was small and the compensation can be seen as a proposal for ecological compensation of potential eelgrass habitat, although with little scientific support for the methods. Follow-up of the case shows that the raising of the bottom has been accomplished to some extent, but that the masses from the dredging became to a lesser extent than expected. There are no signs of eelgrass colonizing. The measure has therefore been assessed as unsuccessful and a fishing fee of SEK 103,125 for 0.3 ha of eelgrass has been imposed on the company (Case no. M 4428-15, 2016-05-12, Vänersborg District Court).

In the permit testing of an expansion of the industrial port Wallhamn at Tjörn 2013, the impact on eelgrass was also consisted of dredging of parts of meadows and possible long-term impact even outside the muddy areas (Case no. M 1956-12, 2013-11-13 of Vänersborg District Court). There are two separate positions of the court, one being that the final issue of compensation is postponed pending the evaluation of the final effects of the business and, secondly, a decision to pay the fishing fee. The deferred decision means that Wallhamn will present a report on the development of eelgrass in connection with the port's operations five years after completion of dredging. If reduction of eelgrass can be attributed to the dredging, proposals for compensatory measures must be presented.

In the case of expansion of Gothenburg harbour, the Swedish Agency for Marine and Water Management and the County Administrative Board demanded that ecological compensation, in the form of restoration of eelgrass, should be a condition of the business (Case No. M 4523-13, 2015-11-24. Vänersborg District Court). The port did not oppose planting. The court issued a demand for planting eelgrass in the form of a probationary condition. The methods of compensation were considered somewhat uncertain on the scale that was relevant, which was stated as a reason for prescribing a probationary period of eight years during which compensation would be established. The requirement during the trial period was for 1.7 ha of eelgrass, which corresponded to the area that would be adversely affected by the port's expansion. It is clear from the judgment that compensation (if successful) may also be regarded as protection for fishing in accordance with Chapter 11. § 8 of the Environmental Code. This indicates that the compensation requirement is basically based on Chapter 16. § 9, although not explicitly stated. The Court also refers to the environmental quality standards for water and that compensation should be able to help reduce the risk of deterioration of the water body.

In Verkö harbour in Blekinge, the possibility of replanting eelgrass should be investigated, however there is no stated requirement for replanting to be carried out (Case no. M 31 2831-14, 2015-12-17, Växjö District Court).

## 8.2.2. Fishing fees

With the terminology used in this report, the fishing fee is not to be regarded as ecological compensation. However, it is often referred to as compensation or replacement in the decisions that require a fee to be paid, and can be seen as compensation for damage to the general fishing interest. The size of the fee has varied in different cases. As described in section 7.5.2, the purpose is to compensate for damage to the fishery, not generally the loss of habitats caused. Below are some examples of cases where a fishing fee has been sentenced.

The Land and Environmental Court of Nacka District Court, in an assessment of the extension in Klintehamn on Gotland in 2014, decided on a fishing fee of SEK 191,000 (Case M 6215-12 announced on 9/9/2014 Nacka District Court). The fee was intended to fill in an area of 2.7 ha which was partly overgrown with eelgrass. The fee was stated calculated on the basis of an annual fry compensation of SEK 2,825 / ha, which was capitalized at 4% interest. Further, the Court did not describe the calculations, but the figures indicate that it was a period of 25 years without indexation of the fee and with an interest rate of 4% for the entire period, not annually. Such a calculation model for converting the annual fee into a lump sum seems doubtful (see sections 4.2.3 and 8.4.2 for discussion on discounting).

In the Wallhamn 2013 case mentioned in Section 8.2.1, a fishing fee of SEK 350,000 was decided where the dredging was planned to destroy 0.25 ha of eelgrass meadow. The size of the fishing fee here included both the impact on parts of the seabed with eelgrass and without any macro vegetation, but which are nevertheless important for fish. The judgment does not specify any details of what is behind the charge.

One case where a larger sum was sentenced in 2014 is the permit test of Stockholm's plans to build a large port at Norvik outside Nynäshamn where eelgrass meadows would be adversely affected (Case no. 2414-12 announced 10/10/2014, Nacka District Court). The Land and Environmental Court has decided on a fishing fee of SEK 4,750,000 as a lump sum on a proposal from the Swedish Agency for Marine and Water Management. The fee is calculated as an annual fee of SEK 40,500 which has been calculated and capitalized for a period of 50 years (apparently with just over 3% in interest). It was taken into account that the port project is extensive and partly affects previously unaffected areas.

In the earlier case of the Verkö Port in Karlskrona, this also meant a high fishing fee of SEK 4,700,000. An annual fee was set by the court at SEK 41,807 for 8.5 hectares. The lump sum was calculated through capitalization over 50 years with a 3% interest rate.

It is clear from the above examples that different calculation principles have been applied in different cases, where both time period and interest values differ, which has major effects on the calculated fee. Therefore, there seems to be a need to review different methods for finding common principles when calculating fishing fees. In the first instance, however, it is recommended to prioritise compensation restoration over fishing fees.

## 8.3. Discussion on application

Apparently, the application of compensation requirements for eelgrass losses has so far been very scarce. There are no known cases of implemented ecological compensation in Sweden. What has happened in recent years, however, is that demands for ecological compensation have been made to an increasing extent in connection with the exploration of exploitation that affects eelgrass. The judgment that the Port of Gothenburg was required to compensate for damage caused by planting eelgrass may indicate that a change is underway.

However, the demands that have been made by courts to reduce the effects of the impact on eelgrass have, however, so far in most cases been about paying a fishing fee. The fact that the fishing fee is the instrument most often used is partly due to the fact that it is generally applicable throughout the coast, while other compensation requirements (apart from Chapter 16 § 9) are tied to area protection. Compared to the general compensation rule in Chapter 16. § 9 of the Environmental Code, it is also the case that compensation for the impact on fishing *must* always be implemented, while general interests *may* be subject to compensation requirements. The fact that fishing fees have been more common than ecological compensation may also be due to the lack of proven methods for e.g. eelgrass restoration.

The fishing fee does not constitute ecological compensation, and has historically been set lower than the estimated cost of ecological compensation of the corresponding area of eelgrass. In recent years, however, there have been judgments where the fee is closer to what a restoration would cost. Although the fishing fee has increased, all fees entail short-term and incomplete compensation for loss of ecosystem services, which in many cases can be seen as more or less permanent. Therefore, ecological compensation is always preferred.

## 8.4. Experience of Eelgrass Compensation Restoration USA

In the United States there are lessons to be learned about work on the restoration of eelgrass and other seagrass species. The legal basis for ecological compensation in the United States is the federal “Clean Water Act” (CWA, 1977) under which a *no-net loss policy* for wetlands has been developed. The definition of wetlands under the Clean Water Act accommodates seagrass meadows, as in accordance with the Ramsar Convention. Permits are required for certain types of activities under the Clean Water Act, relatively similar to what counts as water operations in Sweden. In cases covered by the examination in accordance with the regulation, the *injury mitigation hierarchy* (see fact box 2.1.) is applied where compensation for injuries is only applied in the last resort, when avoidance and minimisation of injuries are insufficient.

In the United States, seagrass transplantation has been used as a method to restore damaged or lost habitats since the 1940s, and today, well-functioning, scientifically based methods are available (Fonseca et al. 1998). Based on the Clean Water Act, offshore restoration of seagrass has been carried out in most of the US coastal states since the 1980s. Most projects have been relatively small (less than 1 ha), but several large projects (up to 400 ha) have also been completed, often in connection with the expansion of national ports. Success has been variable (overall less than 50% survival), with many failures, usually due to incorrectly chosen planting areas and because scientifically proven planting methods have not been applied. In many states, there is also no documentation and follow-up of the projects, so the success is unclear (Fonseca et al. 1998).

There are also examples of where compensation restoration has been applied successfully, which is the case in Southern California where around 90% of all eelgrass restorations since the 1980s (about 50 cases) have reached set targets. What distinguishes Southern California from other parts of the United States is that state and federal authorities, together with various private actors, have developed detailed recommendations for the restoration of eelgrass (*Southern California Eelgrass Mitigation Policy* ; SCEMP; NOAA 1991) that has been used in all compensation cases since 1991. SCEMP is not in itself a legally binding document, but is the basis for normative recommendations that the National Marine Fisheries Service (NMFS) provides in matters relating to compensation for eelgrass. The purpose of SCEMP is to avoid net loss of ecological function linked to eelgrass in California, where the injury mitigation hierarchy is followed and compensation is only used as a last resort.

SCEMP contains a detailed description of methods for selecting a site, planting, and following up, as well as how the results should be evaluated. An important aspect of SCEMP is that the responsibility for successful restoration is placed on the developer, and unless the goal for the restoration is reached within 3 years, a new planting must be done according to detailed specifications. In order to take into account natural variations in eelgrass growth that the developer cannot control and should not be held responsible for, the planting result is compared with the growth in natural reference meadows. Another important aspect is that the operator must also compensate for temporary losses of ecosystem services that occur during the period between the destruction of the exploited meadow and until the restored meadow regains all ecosystem functions (see section 8.4.1 for details), which is why the compensation is made in the ratio. 1.2: 1 (i.e. the area of the restored meadow must be 20% larger than the destroyed one). For the same reason, delays are penalised by increasing the area by 7% for each month of delay. To reduce the risk of failure and to have to repeat the planting, the policy encourages the operator to plant a larger area than the one required. This “surplus” may be used by the developer in future cases through so-called “habitat banking”. Major players such as the Port of San Diego and the US Navy are restoring large areas in advance to use as compensation for future exploitation. This gives the advantage that no overcompensation need be carried out as there will be no temporary losses. It also reduces the risk of failure as the new meadow is already in place when the exploitation is allowed.

Since 2014, SCEMP has been replaced by the California Eelgrass Mitigation Policy (CEMP) that applies to the entire state with substantially the same requirements as its predecessor (NOAA 2014). In order to reduce the risk of net losses over time, according to CEMP, the risk of restoration failure must also be taken into account when calculating the extent of compensation, up to 480% more than the lost area (NOAA 2014).

A comparative study of compensatory restoration of seagrass in different parts of the US shows that there are major regional differences in the demands placed on the performers, the methods used, how the projects are followed up and how successful they are, despite the same legal demands are made throughout the United States and that scientific methods for seagrass restoration are well described and are available in all regions (K. Laas et al., unpublished data). States with detailed recommendations or policies for compensation of seagrass have to a greater extent used established methods and followed up the restoration, and also appear to have been more successful with the compensation than states without common recommendations. In the latter states there is greater variation between the methods as well as in the demands placed on the performers, e.g. in terms of the extent of compensation. Therefore, a policy with a recommendation for compensation restoration does not only appear to increase the likelihood of success of the projects, but also reduce the legal uncertainty for business executives, who with clear information in advance can create a realistic picture of the requirements that will be set. The success in California may be due to the policy being written in a collaboration between government agencies and private actors working with compensation measures, which increased acceptance of the recommendations. The fact that the methods for restoration of eelgrass in the state was well-functioning when the recommendations formulated also facilitated opportunities to make demands on the business provider to be responsible for compensation being successful (Merkel, Hoffman, personal communication, San Diego, 2013).

## 8.5. Habitat banking

*Habitat banking* means market-based systems where private actors or authorities have the opportunity to restore ecological habitats in order to work up and sell compensation credits to business operators (private or public) who need to offset their impact on biodiversity and ecosystem services. In order for *habitat banking* to function, a credit broking role (the bank itself) as well as regulatory authorities that approve an established bank are also needed, oversees the transactions that take place and exercise supervision.

*Habitat banking* has been applied for many years in countries such as the United States and Germany and is currently being tested in England. In the US, *habitat banking* is estimated to have sales of $ 1.3-2.2 billion (Enetjärn Natur AB 2015). In Sweden, *habitat banking* does not yet exist as a solution for providing compensatory measures, but work is in progress, mainly among private actors exploring opportunities in, among other things, forestry. Important prerequisites for the development of *habitat banking* in Sweden are that the interest in biodiversity and the requirements for compensation is increasing, and there is a legally secure and predictable system with clear frameworks (Enetjärn Natur AB 2015).

A functioning system with *habitat banking* would have several advantages in applying compensatory restoration of eelgrass. Among other things, it would give an operator who performs a compensation incentive to plant more than is required if the surplus can be sold in a market. This would reduce the risk of unsuccessful restorations without increasing the cost of the operators. Furthermore, the problem of disproportionately high costs for small damage to eelgrass meadows would be eliminated (see section 7.2.2), as operators could buy already planted areas of eelgrass that compensate for the damage. With *habitat banking,* any damage – also very minor - would therefore be compensated.

## 8.6. Recommendations for compensation restoration of eelgrass in Sweden

The American experience of compensatory restoration shows that it is not only of great importance to develop scientific methods for how a restoration of seagrass should be performed. It also shows that it is central to formulate common rules or recommendations for a number of important aspects:

- what methods to use
- how the extent of compensation should be calculated
- how to follow up the restoration
- how the result should be assessed as well
- as what will happen if the restoration fails

Follow-up of the projects is of the utmost importance, partly to ensure that compensation has really reached set goals, and partly to benefit from the experience in the future. Today, there are scientifically based methods for all aspects of eelgrass restoration in Swedish waters (choice of area, planting and follow-up; *see* Moksnes et al. 2016). However, there are no rules or recommendations for what requirements should be made in a restoration, as well as how it should be designed and evaluated. The few legal cases in Sweden where compensatory restoration of eelgrass has been relevant indicate that there is a need to also inform courts about scientifically based methods for eelgrass restoration (see section 8.2.1) and about how the extent of compensation should be estimated, and the result assessed.

As support for authorities, courts and consultants handling cases where compensation for eelgrass may be relevant, **Appendix 2** to this report presents **recommendations for compensation restoration of eelgrass in Sweden**. The proposal is based on *Southern California Eelgrass Mitigation Policy*, but is adapted to Swedish conditions and the current situation where a large-scale compensation restoration is still unproven. The Swedish Agency for Marine and Water Management intends to issue Appendix 2 to the report as a digital guide.

The purpose of the proposed recommendations is to avoid or minimise net losses of eelgrass environments and its ecosystem services. It is therefore crucial that the injury mitigation hierarchy is used in all cases, which means damage to eelgrass should be avoided in the first place, secondary minimised and only allowed in the latter, and then only combined with the requirement for a restoration of compensation to be implemented. Allowing exploitation of eelgrass as a last resort is especially important in the North Sea where losses of eelgrass can lead to local deterioration of the aquatic environment so that eelgrass growth and restoration is no longer possible (see section 3.4.8). In Bohuslän, this is also important because of the large losses of eelgrass that have already occurred in the region, so the areas where a compensatory restoration can be carried out largely consist of bottoms where eelgrass grew in the 1980s. Compensation in these areas therefore always leads to a net loss of eelgrass in total, if exploitation results in a permanent loss (see section 2.2.3).

The following is a summary of the most important recommendations:

- Compensation restoration of eelgrass should be required in all cases where the damage to eelgrass covers at least 1000 $m^2$, and is considered if the damage covers at least 100 $m^2$.
- Compensation restoration shall be carried out using the best available scientifically proven methods for Scandinavian conditions and include evaluation of suitable sites and monitoring for 10 years to evaluate the results.
- Compensation that starts after the damage should correspond to an area that is at least 30% larger than the lost eelgrass meadow, (ratio 1.3: 1) to compensate for temporary loss of ecosystem services
- It is the operator who is responsible for the successful restoration. If the target for the restoration has not been achieved after 10 years, new measures must be implemented.

# 9. Assessment of the scope of a compensation measure

## 9.1. Background

Important issues in the event of damage or loss of an eelgrass meadow or other habitats where ecological compensation is relevant are where and how compensation should be implemented, and how the extent of compensation should be assessed (*scaling* in English). Most methods developed for these assessments are based on economic theory, where it is man (and not nature) who should be compensated (Cole 2011). A generally socially accepted norm is that a person who is injured can be replaced (compensated) by the person receiving something other than what was lost in the injury. The same principle can be used when society loses ecosystem services in connection with the damage or loss of an environmental resource. In order for compensation to be perceived as fair and as a compensation for society at large, it is important to be able to estimate how different individuals judge what is damaged and what should compensate for the damage (Cole 2012).

Although the methods described below for calculating the scope of a compensation measure do not explicitly use the concept of *ecosystem services* without changes in an environmental resource, we have chosen to do so in this report. This is because ecosystem services have become increasingly prominent in Swedish environmental policy (SOU 2013: 68), and especially in the discussion on ecological compensation in the EU (Enetjärn et al. 2015) and the USA (NAS 2013). The ecosystem service concept also provides increased flexibility and cost-effectiveness when compensation measures are to be used as a management tool. In Chapter 4, we have also used this concept when evaluating ecosystem services economically (in this case with monetary values).

In order to be able to make correct compensation, it is necessary that the damage or loss be assessed quantitatively, either monetarily in, for example SEK or in a non-monetary unit such as the number of fish or hectares of eelgrass. Therefore, in order to carry out this type of assessment, a multidisciplinary working method with both economic and ecological knowledge is generally needed. The advantage of including economic theory is that what society prefers can be included in the valuation. For example, supply and demand for a resource or ecosystem service can be included in the valuation so that e.g. the ecosystem service *uptake and storage of nutrients* is valued higher in a coastal area where nutritional outflow to the sea is large and where purification opportunities are limited than in a coastal area with well-developed wastewater treatment plants and limited nutrient load. Economic expertise can also contribute by taking into account how the compensation measure is valued if it occurs near the location where the injury occurred or from afar, and to calculate how time affects the value of it, for example if it takes a long time to restore damage or for the compensated habitat to regain its ecosystem services.

For ecological compensation, the ecological damage (which has occurred or will occur) is first estimated, after which the extent of the compensation is calculated so that no net loss in ecosystem services or environmental resources occurs from the damage (*offsetting* in English). Below are descriptions of methods for performing these types of calculations.

## 9.2. Methods of equality

In the United States, where legal requirements for ecological compensation have been well developed since the mid-1990s, equivalence methods (*Equivalency Analysis*, EA) are mainly used to assess the extent of ecological compensation. The use of equivalence methods is also expected to increase in Europe when assessing compensation matters due to the requirements of several EU directives focusing on ecological compensation (see Chapter 7). In support of this development, the EU Commission has funded the development of a guide to conducting equivalence analyses (*Resource Equivalency Methods for Assessing Environmental Damage in the EU*; REMEDE *Toolkit*; Lipton et al. 2008). Below is a brief description of these methods.

**Equivalence analysis** is a method for calculating the extent of a resource-based compensation so that it is "equivalent" in value to the current environmental damage. There are several different types of equivalence analysis depending on how the damage is evaluated. **Value-equivalence analyses** measure the value of environmental damage and the compensation measure in terms of how it affects an individual's "well-being". Most often (but not always) this is measured in monetary units. **Habitat equivalency analyses** and **resource equivalency analyses** measure the value of environmental damage in the same way, but in ecological (non-monetary) units that are considered to represent an individual's change in well-being. For example, acres of damaged and restored habitat could be the unit of analysis. According to both the EU Environmental Responsibility Directive (Annex II, Section 1.2.2) and US legislation, habitat and resource equivalence analyses are preferred (see e.g. EU LD Annex II, Sec 1.2.2).

All three types of analysis are multidisciplinary and require both ecological and financial expertise. Although habitat and resource equivalence analyses appear to be simple "hectare-against-hectare" or "fish-to-fish" type (non-monetary units), they include specific assumptions about how society is affected by the damage. Both monetary and non-monetary methods constitute *valuation* analyses in which the decision on an injury should be compensated, and how large the compensation should be, implicitly includes an analysis of society's acceptance of the trade-off between advantages and disadvantages, regardless of which unit the damage is valued. In an injury analysis using equivalence methods, a number of important questions need to be answered, such as how to measure the well-being and welfare of an individual or a community, how to choose a relevant measure that allows a balance between environmental damage and compensation, how to adjust so that the injury and compensation can occur at different times or at different locations (Cole 2011). For a more detailed description of equivalence analyses (in English) see Cole (2014).

## 9.3. The 5 steps of the REMEDE method

According to the REMEDE project's guidance (*REMEDE Toolkit*; Lipton et al. 2008), a five-step process is recommended in order to be able to assess the extent and level of a compensation measure through equivalence methods. This process is general and can be used for all types of compensation projects in both terrestrial and aquatic environments, and both for projects involving unforeseen environmental damage (e.g. chemical emissions) and for planned projects where compensation restoration is to be carried out either before or after an injury occurs. The described methods are applicable both in cases where a resource is permanently destroyed, and when the damage is temporary.

**Fact Box 9.1. The five steps of the REMEDE method for equivalence analysis and assessment of scope and level of compensation measures**

**Step 1: Initial evaluation**

| | |
|---|---|
| Determine if equivalence analysis is suitable for the case | • Describe the damage and identify available data<br>• Identify the affected environment<br>• Determine the appropriate scale for the evaluation |
| Calculate the extent of environmental damage | • Identify damaged resources, habitat and services.<br>• Determine the cause of the injury.<br>• Identify the appropriate valuation unit with which the damage can be quantified.<br>• Quantify the extent of the damage.<br>• Calculate temporary losses of ecosystem services and the total environmental debt (debit). |

**Step 3: Determine and quantify the compensation (Credit)**

| | |
|---|---|
| Identify the compensation method and calculate | • Identify and evaluate compensation options that can be specified in the same valuation unit.<br>• Calculate the environmental gain per unit of compensation for each compensation option<br>• Choose the most appropriate compensation option based on a number of criteria that are considered relevant to business operators, authorities and other stakeholders. |

**Step 4: Calculate the extent and implement the compensation**

| | |
|---|---|
| Compare the compensation environment gains with the total environmental damage. | • Calculate the extent of the compensation for the selected project by dividing the environmental debt (debit) with the environmental gain per compensation unit.<br>• Carry out the compensation project. |

**Step 5: Evaluate results**

| | |
|---|---|
| Plan, implement, follow up and evaluate the compensation | • Identify the target of the compensation. Define what constitutes successful compensation and how this should be measured.<br>• Describe methods for carrying out the compensation and evaluation.<br>• Carry out the compensation and evaluation. |

The methods can also be used in different types of situations, for example where the damaged and compensated environment is made up of the same resource (e.g. the same habitat), in the same place, or where a resource is to be replaced by another type of resource, or at another place. The five steps of the REMEDE method start with collecting data and measuring the extent of environmental damage and ending with a recommendation on the amount of compensation required to consider the loss that the environmental damage caused society (see fact box 9.1. for a summation and *www.envliability.eu* for details).

## 9.4. Assessment for compensation restoration of eelgrass

The REMEDE method may be relevant to many types of cases involving eelgrass environments, e.g. if a meadow has been damaged in an oil accident or extensive damage from boat activities, and where restoration of eelgrass is not an alternative. In compensation restoration of eelgrass in matters relating to planned exploitation, which is the focus of compensatory measures in this report, the analysis is simplified for several reasons, including: because the loss of eelgrass is permanent, and because the valuation unit is the area of eelgrass for both the loss and the addition of ecosystem services (i.e. "debit" and "credit" in the economic analysis). The challenge in this type of case is mainly to calculate the value of the temporary loss of ecosystem services, which is why this is described further below.

### 9.4.1. Temporary loss of ecosystem services

A very important part of a equivalence analysis is to estimate the value of the temporary loss of resources and ecosystem services that occur from the damage or loss occurred, until the compensation has restored all services in full if this is possible *(Interim losses* in English; see Figure 9.1). It is important to note that this loss to society applies separately and in addition to any market losses (e.g. for tourism or fisheries) and fees or damages that may arise through civil liability. **The point here is that it is not enough to offset the loss of a habitat in the event of damage or exploitation in the one-to-one relationship, as there is a loss in the form of ecosystem services during the period that the habitat recovers.** Even with a relatively rapid and natural recovery of damaged habitat, there is a loss of ecosystem services to society. The only occasion when one-to-one compensation can suffice is when the compensation is performed and the habitat with all ecosystem services is fully established (which can take many years), before the damage occurred.

This temporary loss has often not been noticed in Swedish compensation cases (see section 8), but can represent great value to society if the damage is serious and it takes many years for ecosystem services to be restored. For example, in a case study in which a 12 ha large soft bottom was seriously damaged in Helsingborg, but which was assumed to be able to recover naturally after 4 years, the loss in ecosystem services during the 4-year period was calculated to equal the value of restoring about 1 ha of eelgrass and its ecosystem services for 100 years (Cole & Kriström 2008; see www.envliability.eu for more real and hypothetical case studies).

The extent of a temporary loss is mainly determined by the severity of the damage to the resource, the amount of affected area and how long it will take before ecosystem services are restored (where the form of the recovery process is also important). Since the habitat is damaged overtime, the total damage (debit) is often stated in the unit "hectare-year" (Cole & Kriström 2008). Furthermore, the scope is also strongly influenced by the **discount rate** used to calculate down the value of habitat ecosystem services in the future. Below is an example of the scope of the temporary loss can be calculated at compensatory restoration of eelgrass.

### 9.4.2. Discounting of the value of ecosystem services

When calculating values (monetary or non-monetary) that will not accrue to society until in the future, it is often taken into account that society values these future values lower than if the resource had been obtained today. This type of calculation is called *discounting* and means that the value of e.g. ecosystem service is counted down by an annual percentage rate (see section 4.2.3). Discounting can have a major impact on the estimated value of ecosystem services and the estimated extent of a compensation at current value. It depends on both the discount rate used and the length of time the calculation is based on. The advantage of using the discount rate is that comparisons can be made between environmental losses and profits (debit and credit) that occur at different times. It can also motivate operators to perform compensation restoration as soon as possible.

# 9.5. Examples of calculation when compensatory restoration of eelgrass

An important issue when compensating eelgrass restoration is how much larger eelgrass area than what is lost should be planted to compensate for temporary losses of ecosystem services. If compensatory restoration has been carried out and all ecosystem services have been resumed before the exploitation has taken place, it can be argued that it may suffice to plant the same area that has been lost (if, for example, compensation is carried out at the same location). However, a larger area must be planted if the restoration starts at the same time or after the eelgrass is lost as it may take 10 years or more before all ecosystem functions and services are fully recovered after planting (see below). To calculate the extent of this area, the total loss of ecosystem services during the period that the ecosystem services in the restored meadow are developed (debit) must be weighed against the total amount of ecosystem services received by the extra area of eelgrass during an estimated life of the restored meadow (credit). The discount rate is then used to adjust the value of the future meadow to the present value.

Below is an example of calculations for both debit and credit for a case that may represent a typical example of a compensatory restoration of eelgrass for a planned exploitation. In the example, it is assumed that the loss on the exploitation is 100% within the affected area, and that the restoration takes place in the immediate area with eelgrass shoots that are planted at the same time as the exploitation starts (see Figure 9.1). The unit of value for the calculation is area of eelgrass (i.e. the number of hectare-years) where for simplicity it is assumed that one hectare of eelgrass is being exploited. For practical reasons, the quality (for example, the density of shoots) of the eelgrass meadow exploited is not taken into account as it is very difficult to predict the quality of the restored meadow, and because it is unclear how this affects different ecosystem services. Instead, the restored meadow should achieve a shoot density that at least corresponds to the exploited one (NOAA 2014). Because there are uncertainties in how long it will take before ecosystem services are returned after a planting, and different perceptions about the discount rate and time period to be used in calculating future values, several values have been used to give an estimate of the uncertainty in the calculations.

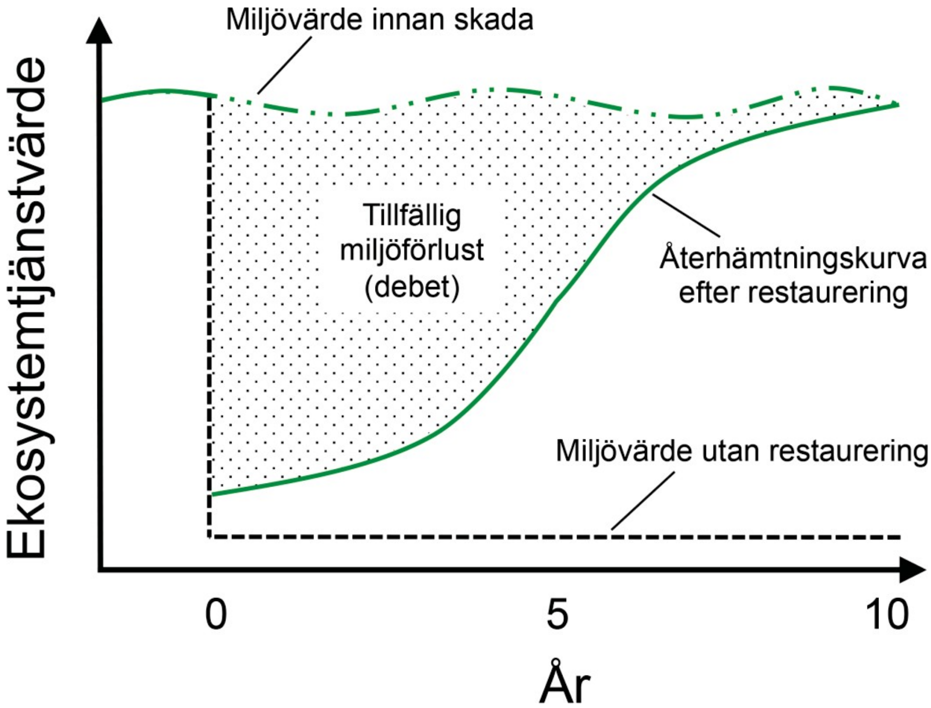


Figure 9.1. Temporary environmental losses in compensatory restoration of eelgrass. In an exploitation that results in the loss of an eelgrass meadow, the value of ecosystem services in the habitat is dramatically reduced, with little opportunity for natural recovery (dashed line black line). If an eelgrass compensatory restoration is carried out at the same time as the loss, in this example, it will take about 10 years before all ecosystem services reach the same level as in the natural meadow before the damage, resulting in a temporary loss of ecosystem services (shaded area). It is this temporary environmental loss (debit) that must be compensated by planting a larger area than what was lost in the exploitation.

### *Recovery period*

According to the literature, it takes at least 5 years after a planting before certain ecosystem functions such as food and protection for juvenile fishes approach those in a natural meadow (Fonseca et al. 1998). However, some ecosystem functions, such as carbon deposition rate, may take up to 18 years before a restored meadow reaches values comparable to reference areas (Evans & Short 2006; Marba et al. 2015). In the calculations, two time periods are investigated (5 and 10 years) as the values of the recovery. How ecosystem functions recover over time has been poorly studied, but can be assumed to have a sigmoid form where it occurs slowly during the first years, after which it accelerates and then slowly decays when only certain ecosystem functions and services slowly increase (9.1). In the calculation, this has been estimated with a linear function where the ecosystem functions increase by 17 and 9% per year from year zero until they reach 100% after year 5 and year 10 respectively in the two cases (some ecosystem services are assumed to be obtained immediately after planting shoots).

### *Discounting*

Given uncertainty about an appropriate discount rate, we investigate three different values in the calculation (0, 2.5 and 5.0%) where the valuation is made at the start of the restoration and the value of the ecosystem services is then counted down during the life of the planted meadow that generates ecosystem functions. Two different time periods were studied (25 and 50 years).

#### *Results*

In this example, the exploitation of one hectare of eelgrass results in a loss of ecosystem services equivalent to 2.5–2.8 ha of eelgrass at 5 years of recovery, and 5.0–6.3 ha of eelgrass at 10 years of recovery, at 0–5. % discount during the 5 and 10 years of recovery, respectively. This loss can be offset by planting 0.06 to 0.30 ha of extra eelgrass at 5 years of recovery at various discount values and 25 or 50 years time horizon. At 10 years of recovery, the value varied between 0.13 and 0.86 ha of extra eelgrass (Table 9.1). On average 0.30 ha of extra eelgrass was required.

Table 9.1. Compensation for temporary losses of ecosystem services (*interim losses*) in the loss of one hectare of eelgrass in the hypothetical example. The table indicates the percentage of extra eelgrass that needs to be planted to compensate for the temporary losses in ecosystem services that occur from the eelgrass planting until the restored meadow regains all ecosystem services corresponding to a natural meadow depending on the speed of recovery (Recovery), and over what time horizon (Time) the future ecosystem services are valued and what discount value is used.

| | | Discount (%) | | |
|---|---|---|---|---|
| **Recovery** | **Time horizon (year)** | **0** | **2.5** | **5** |
| 5 years | 25 | 12.5 | 19.5 | 29.8 |
| | 50 | 5.6 | 11.4 | 21.3 |
| 10 years | 25 | 25.0 | 47.4 | 86.3 |
| | 50 | 12.5 | 29.5 | 63.5 |

The results from this example show that the discount rate and the time period over which the restored meadow ecosystem services are valued have major effects on the estimate of how much extra eelgrass needs to be planted. In this example, a higher discount rate and a shorter time horizon gave higher compensation requirements (however, note that these conditions may be different in other cases). The estimated recovery period also affected the results, with a 10-year recovery giving about 2-3 times greater compensatory requirements than a 5-year recovery. It is therefore important to carefully choose these variables.

If the discount rate is used as recommended by Swedish authorities (4%; Swedish Environmental Protection Agency 2003, SIKA 2009) over a time horizon of 50 years, 0.32 ha of extra eelgrass need to be planted in average, which is similar to the average in table 9.1 (0, 30 ha).

Therefore, based on these results, and for cases similar to this case, it may be **recommended that eelgrass lost during exploitation be compensated by at least 30% more than what was lost (at least intio 1.3: 1)** to compensate for temporary losses of ecosystem services during the recovery. These recommendations are well in line with a US policy for compensating eelgrass restoration in California where 1.2: 1 compensation is recommended when the risk of failure is low (NOAA 2014; see also Section 8.4). Note that there are other factors that affect scope (see below) and that the 1.3: 1 ratio only applies to the examples described above.

If compensatory restoration starts after the damage has occurred, this results in greater temporary losses of ecosystem services and therefore a larger area must be planted to compensate. In the aforementioned US policy for compensatory restoration of eelgrass, it has been calculated that the extent needs to be increased exponentially with time since the injury occurred (due to discounting), for example, the extent needs to be increased by 17% if the restoration starts a year after the injury, but with 38% and 63% if the restoration starts 2 or 3 years after the injury (based on 3% discount and 13 years time horizon; NOAA 2014; Table 9.2). This means that restoration with seeds, which means that ecosystem services are provided with a one-year delay after the seeds are planted, may need to compensate a 17% larger area than if the restoration is carried out with shoots (in these assumptions and all ecological conditions are equal).

Table 9.2. Summary of the recommended increase in the extent of compensation in the event of delay in the implementation of the restoration to compensate for temporary losses of ecosystem services. The increase in the extent (percentage increase of restored area) is shown in relation to the size of the delay (from NOAA 2014).

| Delay (months) | % increase in area |
|---|---|
| 0-3 | 0 |
| 4-6 | 7 |
| 7-12 | 17 |
| 13-18 | 27 |
| 19-24 | 38 |
| 25-30 | 50 |
| 31-36 | 63 |
| 37-42 | 76 |
| 43-48 | 90 |
| 49-54 | 106 |
| 55-60 | 122 |

## 9.6. Other factors that may affect the scope of compensation

The extent and level of compensation are also affected by other factors (see Table 9.3 for a summary). Below is a discussion of some aspects that are relevant in the restoration of eelgrass.

Table 9.3. Summary of factors that may affect the extent and level of a compensatory restoration.

| Factor | Impact on the extent and level of compensation |
|---|---|
| Dimensions (SEK, | Depending on the measures used, debit / credit can be valued differently which can increase / decrease the extent of the |
| Discount rate | A higher interest rate drives down the present value of future debit and credit. Depending on the time period, this may increase / decrease the extent of compensation. |
| The time | Debit and credit can be valued over different time periods, which can affect the extent of the compensation, but varies from case to case on among other things the discount rate and when various ecosystem functions are delivered. |
| The likelihood of success with the restoration | Can be used as an argument to increase the scope of compensation in areas where compensation matters have been less successful. |
| The probability of natural recolonisation | Can be used as an argument to increase the scope of compensation in areas where the probability of natural recovery is high. |

| | |
|---|---|
| *Off-site* | Can be used as an argument to increase the scope of compensation if lost ecosystem services constitute a deficiency in the immediate area, or *vice versa*. |
| *Out-of-kind* | Can either increase or decrease the extent of compensation depending on the ecosystem services provided by the new environment and how society values them. |

## The likelihood of success

In areas where the result of restoration is more uncertain, it may be justified to require greater compensation to ensure that no net loss occurs of eelgrass as a result of compensation. This is especially relevant if there are no regulations that require a failed restoration to be redone. In the state of California, a calculation tool is used to estimate the extent of compensation that takes into account how successful past eelgrass restorations have been in an area when the extent is calculated, to reduce the risk of net loss of eelgrass habitat. For example, in central California where all compensation restorations have been successful, a 1.2: 1 ratio is required, whereas in e.g. Northern California where only 25% of the compensation cases have been successful requires a 4.8: 1 compensation (NOAA 2014).

In Swedish waters where the restoration of eelgrass is still an unproven method, it is not possible today to include this aspect in calculating the extent of the compensation. However, experiments conducted in Bohuslän show that the risk of a planting failure is high in several areas, including due to the deterioration of water quality locally after the eelgrass has disappeared (see section 3.4.8). Therefore, it may be justified to include this aspect if or when compensatory restoration began to be used.

## The probability of natural colonisation of eelgrass

In Bohuslän, eelgrass has probably occurred at some point in history in all soft bottom areas that allow the growth of eelgrass (see Appendix 1). All natural habitats where eelgrass restoration can take place should therefore be considered as potential eelgrass habitats where natural colonisation sooner or later probably occurs (although it may take hundreds of years). Compensatory restoration is therefore primarily about accelerating the return of ecosystem services to the habitat. In areas where there is a high probability that natural colonisation will occur in the near future (for example, if a natural eelgrass meadow is nearby), the value of a restored meadow is lower than in an area where a colonisation is unlikely. This is because the net effect of restoration on ecosystem services over time is lower in the former case when the profit is included over a shorter period of time. It can therefore be argued that greater compensation should be required when restoration occurs in areas where the probability of natural recovery is high within the time horizon used to calculate the environmental benefits (credit) from the compensation, because the profit from ecosystem services when summed over a shorter period.

### *Off-site*

If compensatory restoration cannot take place in the same neighborhood where the eelgrass is damaged (*off-site* in English), this could possibly affect the extent of the compensation, and it could be argued for a larger compensation effort if the lost ecosystem services constitute a deficiency in the immediate area.

This is especially true if compensation takes place in an area where it is judged that the need for eelgrass ecosystem services is lower than in the damage area due to needs and access to alternative habitats so that the net effect of ecosystem services from the restored meadow is not comparable with those from the lost. On the other hand, if the reverse situation prevails that ecosystem services are deemed to be more valuable in the area where the restoration is being carried out, this could be considered to offset off-site compensation, or even be an argument for performing less compensation than the injured one, if it can be shown that the positive net effect in the damaged area justifies this. This aspect of California's Computational Compensation tool includes this aspect (NOAA 2014).

### *Out-of-kind*

Above, we have only discussed the cases when a damage to eelgrass is compensated by restoration of the same habitat. In cases where this is not possible, it may be appropriate to compensate with a different habitat that provides similar ecosystem services (*out-of-kind* in English; NAS 2013; Enetjärn et al. 2015). It is important to point out that this is not preferable in the first place as the eelgrass provides unique ecosystem services that cannot all be replaced by a different habitat. In these cases, many different factors affect the extent of compensation, not least of how society values different types of ecosystem services, which is why it is difficult to draw general conclusions. Among other things, the lost ecosystem services and those from the compensation can operate on different time horizons, which affects the calculation of the extent of the compensation. See REMEDE *Toolkit* for more information on this type of compensation (Lipton et al. 2008; www.envliability.eu ).

# Management and restoration of eelgrass in Sweden

## - Ecological, legal and economic background

The report provides a background and description of the ecological and legal situation for eelgrass management in Sweden today. The focus is on descriptions of how ecological restoration and compensation of eelgrass can contribute to the development of better management of eelgrass ecosystems and other habitats in shallow coastal areas in Sweden.

Compensatory restoration is a complex business where many conditions interact. There are currently few completed restoration projects in coastal environments and case law is not yet particularly developed. It is important to point out that compensatory restoration cannot be seen as a precautionary measure among others. Instead, compensation should be used as a way to minimise damage to ecological values when an activity is still considered permissible.

It is the hope of the Swedish Agency for Marine and Water Management that this report can provide support for, above all, the supervisory and reviewing authorities in matters relating to the management and restoration of shallow coastal water environments and eelgrass.

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