Indicators of Biodiversity

The Case of the Port of Gothenburg

Master's Thesis in Industrial Ecology

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Division of Environmental System Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
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The Port of Gothenburg from air. Used with permission from The Port of Gothenburg

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ABSTRACT

The aim of this study is to find suitable indicators for biodiversity that can be used at the municipality owned company the Port of Gothenburg and to try a methodology for scientifically based indicator selection. The used methodology is a so called eDPSIR network, which both enables assessment of indicators for factors influencing biodiversity and indicators for assessment of biodiversity in itself. Since the Port of Gothenburg have many different stakeholders, and to ensure the function and usefulness of the indicators, the project included several stakeholder interactions. The recommendation drawn from the study is for the Port of Gothenburg to implement a naturalness based Natural Capital Index for assessment of biodiversity, and also to start measuring noise in green areas, light pollution and emissions of untreated ballast water. Furthermore the Port is recommended to collaborate with its owner, the municipality of Gothenburg, regarding data collection for the Natural Capital Index. If this is made as a citizen science project the indicator can fulfill several purposes, such as education and raising awareness, and can thereby achieve a high cost efficiency.

Key words: Indicators, Biodiversity, Port, Natural Capital Index, The Port of Gothenburg, DPSIR, eDPSIR

Indikatorer för biologisk mångfald
En fallstudie för Göteborgs hamn
Examensarbete inom mastersprogrammet Industriell Ekologi

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SAMMANFATTNING

Syftet med denna uppsats är att hitta lämpliga indikatorer för biologisk mångfald som kan användas vid kommunalägda bolaget Göteborgs Hamn samt att pröva en vetenskaplig metod för val av indikatorer. Metoden som valdes var ett så kallat eDPSIR nätverk. Detta möjliggjorde ett urval dels av indikatorer för faktorer som påverkar den biologiska mångfalden men även för indikatorer som mäter den biologiska mångfalden i sig. Eftersom Göteborgs Hamn har många olika intressenter togs ett flertal kontakter med intressenter, detta gjordes för att säkerställa användbarheten samt framtida implementeringsmöjligheter. Utifrån studien rekommenderas Göteborgs Hamn att börja använda ett naturlighetsbaserat Natural Capital Index för bedömning av den biologiska mångfalden samt även starta mätningar av buller i grönområden, ljusföroreningar och utsläpp av orenat barlastvatten. Vidare rekommenderas hamnen att samarbeta med sin ägare, Göteborgs kommun, angående datainsamling till Natural Capital Index. Om detta genomförs genom att involvera medborgare i ett så kallat Citizen Science projekt kan den valda indikatorn uppfylla flera olika syften, så som spridning av kunskap och engagemang, och därmed även möjliggöra en hög kostnadseffektivitet.

Nyckelord: Indikatorer, hamn, Biologisk mångfald, Natural Capital Index, Göteborgs hamn, DPSIR, eDPSIR

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Albin Pettersson

Abbreviations

BHQ	Benthic Habitat Quality Index
BLI	Biopollution Level Index
Bellagio STAMP	Bellagio Sustainability Assessment and Measurement Principles
BQI	Benthic Quality Index
CBD	Convention on Biological Diversity
CBI	City Biodiversity Index, also called Singapore Index of Cities' Biodiversity
DPSIR chain	Driving force-Pressure-State-Impact-Response chain
eDPSIR network	Enhanced Driving force-Pressure-State-Impact-Response network
IAS	Invasive Alien Species
LPI	Living Planet Index
NCI	Natural Capital Index
NIS	Non Indigenous Species
PSR chain	Pressure-State-Response
RPSB chain	Response-Pressure-State-Benefit chain
TBT	Tributyltin

Contents

1 Introduction

Below follows an introduction to the study. The section starts with the definition of biological diversity used in this report. Thereafter follows descriptions of the prevailing biodiversity loss, the need for biodiversity indicator, biodiversity in the Port of Gothenburg, aim of the study, and finally delimitations of the study.

1.1 Definition of Biodiversity

In this report biodiversity is defined according to the UN Convention on Biological Diversity. The definition is the following:

"Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." (United Nations, 1992)

1.2 Biodiversity Loss and its Effects

During the past 10 000 years the environment on earth has been unusually stable (Rockström, et al., 2009). Under this period, called the Holocene, the human civilization has evolved. Our influence on the environment has grown to such an extent that we are starting to change the very foundation on which our civilization is build forcing the earth into a new period of time, the Anthropocene (Steffen, et al., 2011). A new earth is forming. In many ways changed from the earth we have taken for granted. The new earth will be a warmer planet with diminished ice cover, changed precipitation patterns, a different biosphere and a landscape dominated by humans. However, with a responsible stewardship of the planet the Halocene will probably last for several thousands of years yet to come.

A responsible and sustainable stewardship can be developed in accordance with the planetary boundaries suggested by Rockström et.al (2009), further developed by Steffen et al (2015). Totally 9 boundaries has been suggested of which three already have been exceeded, see figure 1. One of the exceeded boundaries, climate change, is frequently discussed and is also seen as a major threat against humanity. However the by far most exceeded boundary is the rate of biodiversity loss. At the current level it results in a mass extinction of species which has not occurred since the extinction of the dinosaurs (Bernes, 2011). The natural rate of biodiversity loss over time is in the area of 0.1 – 1 extinctions per million species per year. Estimates of the current extinction level shows that the natural extinction rate is exceeded by a factor between 100 – 1000 (Rockström, et al., 2009). With approximately 10 million species in the world today this means that species are getting extinct on a daily basis (Bernes, 2011).

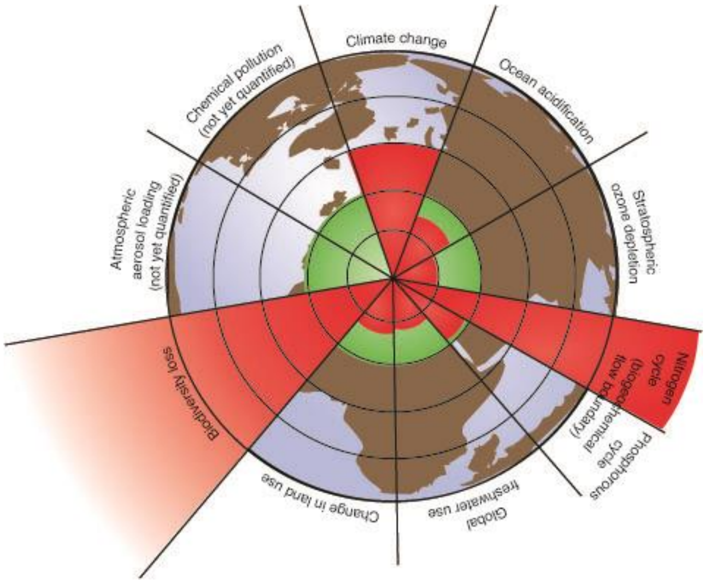

Figure 1- Planetary Boundaries, The safe operating space is represented by the inner circles (Rockström, et al., 2009).

As with all environmental problem the loss in biodiversity is an effect of human actions. There are primarily five different pressures causing the global biodiversity loss. These are habitat loss and degradation, climate change, excessive nutrient load and other forms of pollution, over-exploitation and unsustainable use, and invasive alien species (SCBD, 2010). Of these five the main driver is land use change, which removes the natural habitats for species resulting in habitat loss (Rockström, et al., 2009). Furthermore introduction of non-indigenous species into natural ecosystems often results in increased competition and leads to difficulties for the naturally occurring species. In many cases the new species lack naturally occurring enemies and can therefore take over and change complete ecosystems (Bernes, 2011). The introduction is mostly connected to human action and it can be made on purpose as with the Canada goose in Europe, or unwillingly as with several kind of algae in the Baltic Sea which has contributed to the increased algal bloom. During the last decades there has also been an increased awareness about losses in biodiversity as a result of climate change. A change of 1.5 – 2.5 C threatens to extinct up to 30% of all mammal, bird and amphibian species within this century (Rockström, et al., 2009). From a Swedish perspective species living in the cold environment of the Swedish mountains will be particularly vulnerable (Bernes, 2011).

Our society is dependent on a high level of biodiversity (EASAC, 2005). The plants and animals around us provide different kinds of ecosystem services. These are divided into four different types; provisioning services which include provision of products the different ecosystems provide humanity with, such as food, timber and medical substances. Regulating services provide us with functions such as run-off regulation and carbon sequestration. Supporting services include services such as the photosynthesis and primary production. Finally, cultural services reflect the value of recreation and cultural activities connected to nature. High biodiversity underpins the resilience of an ecosystem and is therefore essential in order for nature to provide us with these ecosystem services (Rockström, et al., 2009). It is difficult to set a level on how large the loss in biodiversity can be before this resilience is eroded. However with the current level of biodiversity loss it can with certainty be said that any limit proposed will be overreached. Finally biodiversity can also be seen to have an intrinsic value, a value in itself (EASAC, 2005). Thereby the occurring mass extinction of species can be seen as a loss of irreplaceable values.

Attempts have been made to halter the prevailing rate of biodiversity loss and both UN and EU aimed to achieve this before 2010. Despite the efforts made it is now widely recognized that no decrease in biodiversity loss rate was achieved and EU has therefore started an initiative called No-net-loss (European Comission, 2015). One of the main purpose of this initiative and its working groups is to find ways to extend the current requirements of compensation for exploitation of areas under the bird and habitats directives to also include other natural areas, hence enforcing no-net-loss of habitats in EU. In April 2012, the European Parliament adopted a resolution urging the commission to develop an effective regulatory framework based on the No-Net-Loss initiative.

1.3 The Need for Biodiversity Indicators

The reason for the high levels of biodiversity loss can partly be explained by the complexity of biodiversity and the difficulties of understanding biodiversity properly (EASAC, 2005). In order for decision makers to contribute to a reduction in the current rate of biodiversity loss there is a need to assess the current level and also the results from the efforts taken. In order to provide decision makers with suitable assessments, indicators are crucial. Without indicators the assessments will be too complex for decision makers to act upon. The need of assessing biodiversity is however not something new and there are several indicators assessing biodiversity (Blamford, et al., 2005). The problem is that most existing indicators are too detailed to be useful for most decision makers.

The need for indicators of biodiversity has been highlighted by the Port of Gothenburg. To be able to handle biodiversity issues in an effective way, the port is in need of suitable indicators that can be used to monitor progress towards their environmental objectives. At the moment the Port is missing an indicator for biodiversity, wherefore this master thesis was initiated in order to investigate the topic.

1.4 Biodiversity in the Port of Gothenburg

The Port of Gothenburg is the largest port in Scandinavia and handles cargo of several different types such as container, cars and energy. It is, as many other ports, owned by the local municipality, in this case the municipality of Gothenburg, and is therefore working in accordance with the environmental program of the municipality. The environmental program of the municipality of Gothenburg covers 12 different areas and is based on the national targets of Sweden. The twelve areas includes for instance reduced climate impacts, only natural acidification, living lakes and waterways, a healthy ocean, a rich agricultural land, and a rich flora and fauna (Göteborgs Stad, 2013). The work with reduced climate impacts have been relatively successful and the municipality of Gothenburg has been awarded for its work by the WWF (WWF, 2015). Except for these environmental issues, the Port of Gothenburg also works with other aspects of sustainability and they use the three pillars of sustainability (economic, ecologic and social) to describe their view of sustainability, see figure 2 (Göteborgs Hamn, 2014).

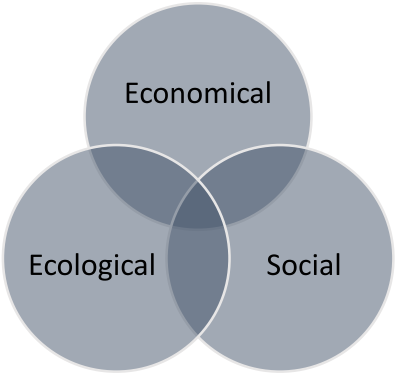

Figure 2 - Three perspectives of sustainability (Göteborgs Hamn, 2014)

Within or in close connection to the port areas there are especially two nature areas of interest from a biodiversity perspective. These two are Torslandaviken, which is classified as a Natura-2000 area, and Rya skog, which is a nature conservation area. The port influences the biodiversity in these areas both positively and negatively (Länsstyrelsen, 2005). In Torslandaviken which is shown in figure 3, negative effects can occur due to leakage of oil or other emissions even if this probability is small. Large negative effect will however definitely occur if the port decides to expand into the area in accordance with the general plan for the port (Göteborgs hamn, 2010). However such an expansion would be controversial and as long as the area is classified as a Natura-2000 area, expansion of the area is not of interest (Ternström, 2015). In fact, the current efforts made in Torslandaviken by the Port of Gothenburg are positive regarding biodiversity. In connection to Torslandaviken and its extensive birdlife the Port of Gothenburg has plans to create a new bird area on land that is currently being used for storage of dredged material (Göteborgs Hamn, 2014). This is made in order to compensate for previous negative impacts. Due to the extensive birdlife in Torslandaviken, the area is of high interest for local ornithologists and therefore the efforts made to improve the biodiversity in the area is made in collaboration with the local ornithology association. In close connection to the port areas there is a nature conservation area called Rya Skog. The small forest has been a nature conservation area since 1928 and has a wide biological diversity of plants, animals and fungi (Länsstyrelsen, u.d.). The area is not owned by the port of Gothenburg and is therefore not of interest for exploitation. However, the port still impacts the biodiversity in the area (Göteborgs hamn, 2010) (Stenström, 1996). For example, by installing birdhouses in both Rya skog and in a similar area outside Kungsbacka, is could be seen that the level of usage by nestling birds was five times higher in the reference area outside Kungsbacka than in Rya skog. There could be several reasons for this difference, but the operations in the port is probably part of the explanation.

Figure 3- Torslandaviken with industrial and port areas in the background. Photo: Kåre Ström

1.5 Aim of the Study

The aim of this study is to find suitable indicators for biodiversity that can be used at the municipality owned company the Port of Gothenburg in order to monitor progress towards environmental objectives for biodiversity. Furthermore, the study also aims to try a methodology for scientifically based indicator selection.

1.6 Delimitations

A large source of losses in biodiversity is overexploitation from the fishing industry. Many ports are used as a base by the fishing industry and its fishing vessels. However the Port of Gothenburg is not extensively used for this purpose and impacts on biodiversity from fishing operation will therefore be neglected in this report.

In a port, goods of different kinds are exported and imported. The goods can possibly carry invasive species or other things which in its turn effects biodiversity. These possible effects are not included in this thesis.

1.7 Outline of the Thesis

This thesis is organized into eight chapter. After the introduction above, the report continuous with a theoretical framework section where the literature used in this report is described. The literature includes indicators, indicator development and environmental impacts from ports. This section is followed by a methodology chapter where the methodology / working procedure used in this study is described. The chapter includes four parts; construction of a causal network, indicator selection, stakeholder interactions, and a description of the three different scenarios used in this report. In the next chapter, results, the results from the thesis are presented including results from; interviews, the causal network, possible Indicators and data Sources. The result is then discussed in the coming chapter, discussion. Here the indicators suggested will be discussed and compared with characteristics of a good indicator. Furthermore, a general discussion regarding use of indicators and the methodology used will be presented. Finally in the two last chapters, conclusions and recommendation, the outcome of the discussion and the thesis is presented.

2 Theoretical Framework

In the coming section literature used in this report is described. The literature includes indicators, indicator development and environmental impacts from ports. In the first part, aspects regarding what an indicator is and how it can be used are discussed. This is followed by a part regarding the use of indicators in complete indicator sets. The following three parts are about different aspects of the development of indicators and what to consider in the selection process. Finally the last part describes a number of environmental impacts that can be derived from ports and port operations.

2.1 Indicators

Indicators are used in many ways in our society, from simple indicators such as body temperature to more complicated measurements such as GDP. This wide range of indicators is used for decision making at all level. In fact, to measure progress or change of any kind requires the use of indicators (EASAC, 2005). Despite, or perhaps because of the wide use of indicators, there is no formal definition of what an indicator actually is. Bockstaller & Girardin (2003) discuss the function of indicators and comes up with two properties. Firstly, an indicator is informative, i.e. translates a complex system or an unmeasurable criterion into simplified information. Secondly, indicators aim to support decisions in order to achieve objectives.

When using indicators for decision support it is of high importance that the indicators are wisely chosen. One widely applied indicator, used to assess the wealth of nation, is gross domestic product (GDP) which is an interesting example when looking at the effects from indicator selection. Many decision makers work hard to maximize the GDP and thereby also the wealth of the country. However an increase in GDP does not directly imply an increase in freedom, environmental quality or even real health (Meadows, 1998). Furthermore, Meadows argues that if the infant mortality rate would have been used to reflect the wealth of a country in the same way as GDP is doing today, the world would probably have looked a bit different. This example illustrates the effects our choice of indicators have on the society and the importance of a wise indicator selection.

2.1.1 Qualities of Indicators

The characteristics of a good indicator has been discussed among scientists for a long time (Niemeijer & de Groot, 2008 A). Depending on the context the requirements of an indicator has naturally been different, but there are also many similarities regardless of context. Some scientists have been working with criteria for indicators assessing sustainable development or environmental issues in general while others have been working with indicators for biodiversity directly. However since sustainability, environmental issues and biodiversity are closely interlinked one can argue that the qualities characterizing a good indicator for sustainability also can be applied for biodiversity.

Table 1 - Criteria suggested by Meadows

Meadows (1998)
Clear in value
Clear in content
Compelling
Policy relevant
Feasible
Sufficient
Timely
Appropriate in scale
Democratic
Supplementary
Participatory
Hierarchical
Physical
Leading
Tentative

As mentioned above, important qualities of indicators have been discussed for a long time which has resulted in several suggestions for lists of important qualities. Meadows (1998) state a number of qualities which groups commonly come up with when brainstorming for important properties of indicators for sustainability. These qualities have been listed in table 1. Noss (1990) and Dale & Beyeler

(2001) have suggested qualities regarding indicators for biodiversity. Even if their suggestions are not as general as the suggestion from Meadows, there are still many similarities. Furthermore, Meadows also refers to the Bellagio Principles, which were created by an expert group meeting at the Rockefeller Foundations Study and Conference Center in Bellagio, Italy. These principles were updated in 2009 into a new version called the Bellagio STAMP – Sustainability Assessment and Measurement Principles (Pintér, et al., 2012). These principles aims to guide overall indicator design and analysis and is not expected to lead directly to new indicator sets. The principles regards eight different topics which are listed in table 2. A complete description of the principles can be seen in appendix I.

Table 2- Bellagio STAMP topics

Ballagio STAMP (2008)
Guiding vision
Essential considerations
Adequate scope
Framework and indicators
Transparancy
Effective communication
Broad participation
Continuity and capacaty

Table 3- Indicator criteria from Dale & Beyeler and Noss

Dale & Beyeler (2001)	Noss (1990)
Easily measured	Sufficiently sensitive to provide an early warning of change
Sensitiv to stress on the system	Distributed over a broad geographical area or otherwise widely applicable
Respond in a predictable manner	Capable of providing a continuous assessment over a wide range of stress
Be anticipatory	Relatively independent of sample size
Predict changes	Easy and cost effective to measure, collect, assay, and/or calculate
Integrative	Able to differentiate between natural cycles or trends and those induced by anthropogenic stress
Known response	Relevant to ecologically significant phenomena
Low variablity	

Niemeijer & de Groot (2008 A) have complied a number of different qualities characterizing good indicators. They have focused on properties for environmental indicators in general and have summarized a list of qualities taken from several different sources. This compilation consists of nine different sources including Dale & Beyeler (2001) (presented in table 3), OECD (2001) and EEA (2005). Normander et.al (2012) have complied a similar list, however they have focused on properties of indicators for biodiversity more specifically. Except only summarizing the criteria from others they have also modified the criteria slightly and have come up with a new list of suggestions. The original sources of qualities includes among others Noss (1990)(presented in table 3) and EEA (2009). Due to the extensive foundation, the properties suggested by Niemeijer & de Groot respective Normander et.al can be seen as well-grounded for assessment of biodiversity indicators. Furthermore their ideas are also in line with those of Meadows (1998) (see above). The criteria from the two suggestions are presented and compared in table 4. For a full description of the criteria see appendix II and appendix III.

Table 4 – Comparison between Niemeijer & de Groot and Normander et.al. The criteria are sorted according to the categories suggested by Niemeijer & de Groot

Niemeijer & de Groot (2008)	Normander et.al (2011)	Niemeijer & de Groot cont.	Normander et.al cont.
Scientific dimension	**Scientific dimension**	**Financial and practical dimensions**	**Financial and practical dimensions**
Analytically soundness	Repetative and good coverage	Costs, benefits and cost-effectiveness	Realistic
Credible		Data requirements and availability	Relatively independent of sample size
Integrative		Necessary skills	Temporal and up-to-date
General importance		Operationally simplicity	
Historic dimension	**Historic dimension**	Resource demand	
Historical record		Time demand	
Reliability		**Policy and management dimensions**	**Policy and management dimensions**
Systemic dimension	**Systemic dimension**	Comprehensible	User-driven and acceptable
Anticipatory	Sensitive	International compatibility	Normative and policy relevant
Predictable	Predictable	Linkable to societal dimension	Comparable
Robustness	Not sensitive to background changes	Links with management	Explainable
Measurability		Progress towards targets	Clear presentation
Space-bound		Quantified	Simplifying information
Time-bound		Relevance	
Uncertainty about level		Spatial and temporal scales of applicability	
Intrinsic dimension	**Intrinsic dimension**	Thresholds	
Measurability	Quantitative and statistically sound	User-driven	
Portability	Aggregatable and Disaggregateble		**Others**
Specificity			Indicative
Statistical properties			
Universality			

Several similarities can be derived from the two lists of qualities, see table 4. Firstly, requests from and adaptation to the user of the indicator is present in both lists. The importance of this quality is twofold. On one hand it is important that an indicator is requested by the user in order to create an acceptance for the indicator. On the other hand, the indicator needs to be easy to use and to understand by the target audience, which the indicator probably will be if the indicator is user driven. Furthermore an indicator closely connected to the user will most likely also imply that it reflects the issue in a good way, a fact which is also highlighted in the Bellagio STAMP (Pintér, et al., 2012). According to the seventh principle; Broad participation; it is essential to engage the users early in the process in order to make the assessment method, i.e. indicators in this case, fit their needs in the best way. This in turn will strengthen its legitimacy and relevance. In addition to focusing the users, both the lists highlight the importance of an indicator being policy relevant and thereby connected to policy targets and baselines.

The two lists, discussed above, also has flexibility as an aspect in common. Flexibility can mean different things but here the focus is on the flexibility or adaptability to different context, areas situations and scales. This will also mean that the indicator can be used for comparison and the indicator can e.g. be used as benchmarking between countries or harbors. However, even if the indicator should be flexible the two lists also agrees that the indicators should be sensitive enough to provide an early warning of change. This warning should be early enough so that decision makers have the possibility to act upon it before an irreversible change occurs. The indicator also needs to be sensitive to the right things. An indicator that are effected by natural fluctuations and therefore also indicates naturally occurring phenomenon will be hard to use since it is difficult to determine if a change is caused by humans or nature.

Finally the creators of the two lists agrees upon the fact that indicators should be realistic and cost-effective. In order for an indicator to meet this criterion several aspects can be considered. Firstly the costs from using an indicator needs to be outweighed by the benefit one can get from using it. Furthermore the use of an indicator needs to be feasible regarding resources and time.

This implies, in many cases, that there is a need for a good availability of already existing data or that the required measurements is made easy in order to produce suitable data.

In addition to the qualities mentioned above Duelli & Obrist (2003) highlights the need to agree upon the purpose of monitoring biodiversity. Measurements of biodiversity has historically been made mostly in order find out other aspects than the actual status of biodiversity. Naturally occurring species in nature have been used to indicate several different things such as human impact or water quality (Duelli & Obrist, 2003). After the launch of the UN Convention on Biological Diversity in Rio 1992 there was a rather drastic shift in focus and indicators for biodiversity in itself was put higher on the research agenda.

2.1.2 Indicator Sets

An indicator can tell us many things, however one single indicator seldom provides us with enough information to make decisions on a sound basis. A doctor, as an example, often wants to know our body temperature but in order to understand why a person feels sick the doctor need other information as well. If the doctor understands the linkage between the different indications she can understand what the issue is and make a correct decision. If the indicators of a person's health were selected randomly, without considering the connection to other indicators as well, it would be hard for the doctor to determine the correct diagnosis. In the same way as for the doctor, it is important for decision makers handling environmental issues to be provided with necessary and interlinked information. This fact is highlighted by Sparks et al (2011) who argues for the usage of indicator sets instead of individual indicators, since a set of indicators will be easier to understand, communicate and interpret. Dale & Beyeler (2001) argues in the same way and means that the use of few or just one indicator in an ecological management program makes the program too narrow and oversimplified which often leads to poorly informed management decisions. Furthermore also Lin et.al (2009, p. 1114) argues in the same way and even if they states that it is *"impossible to clone the complex ecosystem by a limited number of indicators"* they also argues that a well-constructed indicator-set however have the possibility to reflect it in a rather sufficient way.

As for environmental indicators in general scientists also argue for the use of indicator sets when it comes to biodiversity alone. Haines-Young (2009) states that it is generally accepted that it is not possible to represent biodiversity in a single indicator and that in order to understand the effects of changes in biodiversity on ecosystems, a multidimensional approach is needed. This statement is in line with the arguments from Noss (1990) who after suggesting seven qualities of a good indicator for biodiversity concludes that it is probably impossible for a single indicator to possess all these qualities and that a set of indicators is required. A fact that is also shown by Dale & Beyeler (2001) who present similar qualities for indicators as Noss and implement these on a generally accepted indicator for eutrophication. Despite the acceptance the indicator still not fulfill all criteria. Dale & Beyeler argue that this fact speaks for the need of indicator sets.

2.1.3 Developing Indicators

The development of indicators can take place in different forms. Niemeijer & de Groot (2008 A) argue that it is common that indicators are selected on an almost random manner without considering the overall context. In order to ensure the quality of the indicators and that they are used in an appropriate context they argue for the use of a framework or a scientific approach in the selection process. This can be especially useful when developing complete sets of indicators since it can be hard to find interlinks between the different indicators if they are selected separately in a more or less random manner. Furthermore, the usage of a scientific framework in the selection process of environmental or biodiversity indicators will also make the process systematic and transparent (Niemeijer & de Groot, 2008 A). Dale & Beyeler (2001) argue for the importance of this in particular and mean that it is difficult to validate the information given by indicators that is developed without a robust scientific selection procedure. Moreover they highlight the need for the development of such procedures which will enable selection processes that is repeatable and reliable.

Noss (1990) and Dale & Beyeler (2001) both present and argue for the use of frameworks based on a hierarchal approach in order to monitor biodiversity. This hierarchal approach should be based primarily on three attributes of biodiversity; composition, structure and function. These attributes are furthermore divided into four different scales; landscape/region, ecosystem/community, population-species and genetic (Noss, 1990). By doing so, the complexity of biodiversity is shown and it is possible to assess all the dimensions in the UN definition of biological diversity, see definition section 1.1. However, depending on the context in which the assessment will be used the hierarchal approach can be too detailed. This dilemma is highlighted by Lin et al (2009, p. 1114) who states that "*Scientists are primarily interested in "seeking the truth" while managers are looking for the feasible."* This implies that there is a need for other and less detailed ways of monitoring biodiversity or assessing impacts on biodiversity.

Other frameworks for developing indicators can be found in reports from OECD, UN and the European Environment Agency (EEA) (Niemeijer & de Groot, 2008 B). Among others they are using some of the most common indicator frameworks used today which is the so called Pressure-State-Response (PSR) framework and the Driving force-Pressure-State-Impact-Response (DPSIR) framework, see figure 4, which will be described in the coming paragraphs.

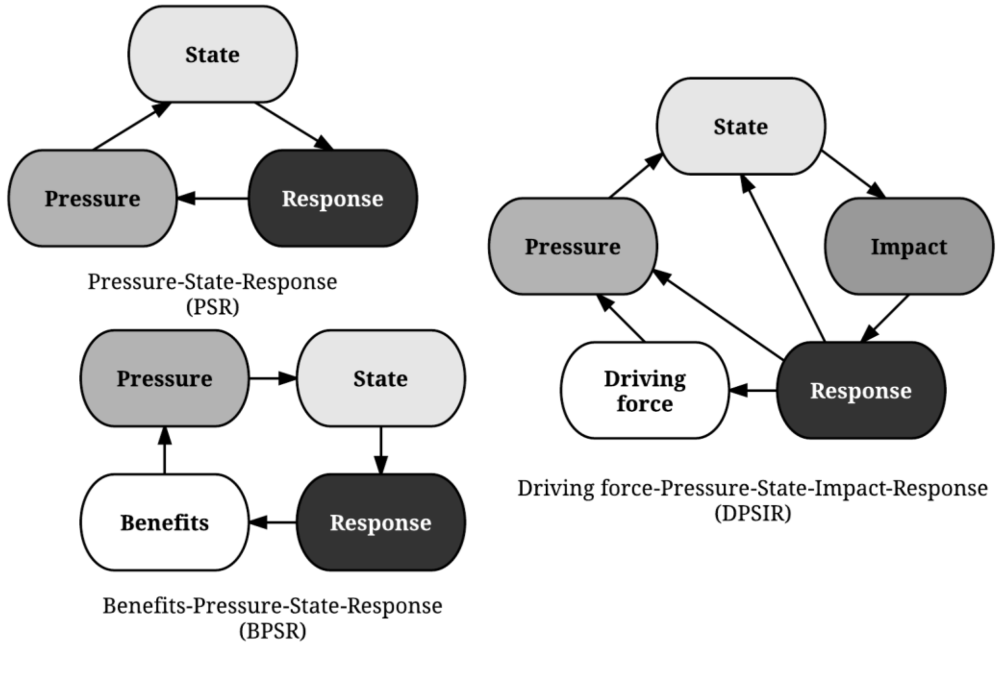

Figure 4 – Different types of causal chains

In a pressure-state-response (PSR) framework, the focus is laid on the anthropogenic pressure and responses and does not consider the underlying causes of the anthropogenic pressure (Lin, et al., 2009). For each step of the cause-chain indicators are identified and sorted into a PSR matrix which is exemplified in table 5 below (Niemeijer & de Groot, 2008 B). By doing so the links between the three steps are highlighted in an effective way. However the use of a PSR chain also has a tendency to neglect interlinks between different environmental problems. This can results in a lower understanding for the complexity of crosscutting environmental interactions and the real cause-effect relations that exists (Niemeijer & de Groot, 2008 B). The low recognition of the complexity is not seen as a problem when monitoring changes in an indicators over time but as soon as decision-makers use the indicators to predict effects of future actions, the crosscuttings between environmental issues becomes highly important. Niemeijer & de Groot (2008 B, p. 96) exemplifies this; *"As a consequence, species abundance may be a useful indicator of the state of biodiversity, but that not necessarily means that changes in species abundance can be traced back to changes in any of the biodiversity pressure indicators."*

Table 5 - Example of PSR-matrix

Issues	**Pressure**	**State**	**Response**
Climate change	GHG emissions	GHG concentration	Energy intensity; environmental measures
Ozone depletion	Halocarbon emissions	Chlorine concentrations; O3 column	Protocol signed; CFC recovery; fund contribution
Eutrophication	N and P emissions to water and soil	N, P and BOD concentrations	Treatment connections; treatment investments/costs
Biodiversity	Land conversion	Species abundance compared to virgin area	Protected areas

Sparks et.al (2011) develop the PSR chain and argue for the use of a chain which also includes benefits as one step. By doing so they develop a more detailed PSR- chain which they express as a response-pressure-state-benefit (RPSB) chain, see figure 4. By using the RPSB chain when developing indicators the benefits from e.g. biodiversity will be clearer for policy-makers and it therefore allows a more effective assessment of the actions taken. One can argue that also the PSR chain is in some sense rotated through a benefit level. The state of biodiversity is, as an example, always given some level of benefits. Furthermore, the RPSB chain faces much of the same criticism as the PSR chain does.

One more extensive type of chain is the driving force-pressure-state-impact-response (DPSIR) chain. In this chain, social and economic development, a driving force, put pressure on the environment which in turn result in either impacts on human health, ecological systems or materials (Niemeijer & de Groot, 2008 A). This in turn leads to action from the society in order to deal with the impacts. The chain has, as the name implies, many similarities to the chains mentioned above, however the major benefit of the DPSIR chain is the more detailed description of the causal chain. However, neither this chain includes the crosslinks between environmental interactions in a sufficient way.

In order to include crosslinks between the indicators, Niemeijer & de Groot (2008 A) suggest an enhanced driving force-pressure-state-impact-response (eDPSIR) framework. The main difference from the frameworks mentioned above is that the eDPSIR framework is built up as a causal network instead of a causal chain. In fact, the causal network can be seen as a combination of different causal loops (Lin, et al., 2009). The main benefit in using an eDPSIR framework is the possibility to find out common denominators for different environmental areas which enables fewer but more solid indicators. In this way, the complexity of real world interaction will be dealt with in a more appropriate way (Niemeijer & de Groot, 2008 B).

2.1.4 Developing a eDPRIS Network

In their *enhanced DPSIR* framework Niemeijer & de Groot (2008 A) are recommending a certain procedure to create a network which furthermore will be used as a foundation in order to select indicators. The procedure starts with the construction of the network which involves five different steps. The five steps are:

1. Broadly define the domain of interest
2. Determine boundary conditions that can help determine which aspect to cover and which to omit
3. Determine the boundaries of the system
4. List (abstract) indicators covering the factors and process involved
5. Organize the abstract indicator graphically according to their place in the DPSIR-chain and according to cause-effect pathways

The first step in the process is relatively simple and this step is often already clear beforehand. The domain of interest can be stated very broadly for example as; environmental impacts from the transport sector. The more specific the domain of interest, the easier it will be to keep the causal network small and manageable. In the second step the system boundaries are set in order to make limitations in the work and focus the causal network on the area of highest interest. The boundaries can for instance be geographical or be set to only include factors related to climate change. In the third step the second step is made more precise and the boundaries are clearly defined. If the transportation sector is used as an example, decisions whether to include production of fuels or not should be made in the step. In the fourth step one should list the indicators covering the factors and processes involved. These indicators can be either abstract or concrete. However in this phase of the indicator development process it can be hard to come up with specific indicators. One good example of an abstract indicator can be plant population. This indicators will be hard to measure since it do not specify what is included in plant population such as diversity between species, genes or types of plants. Nevertheless, this abstract indicator is a good start and the specification of the indicator will be made later on.

Finally in the fifth step the construction and organization of the network is being made. By this time it is also important to figure out linkages between the different indicators in order to formulate a correct picture of the complexity and to gain the real benefits that a network provides. Niemeijer & de Groot recommend to start with indicators at a pressure level since these are typically more concrete than indicators at the driving force level. The driving force level can preferably be considered in the end of the construction. When constructing the network, the abstract indicators can also be sorted into different subcategories and Niemeijer & de Groot suggest air, water and soil as possible subcategories.

When the causal network is constructed, the actual indicator selection takes place based on the network. Niemeijer & de Groot (2008 A) recommend that this is made in three steps which are;

1. Define the research question

2. Identify key-nodes in the causal network and explore relevant sections of the causal network in more detail
3. Select the best concrete indicators for the selected nodes

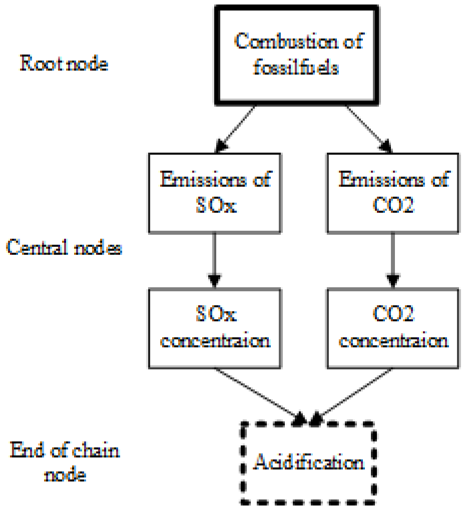

Figure 5- Example of different nodes

If the research question is not already defined it should be formulated in this part of the working procedure. The research question can be based on the available information that exists, the scale of the work, where and whether the perspective is from an environmental or a human point of view. When the research question is formulated the second step begins where so called key-nodes are identified. There are three different kinds of key nodes of which two are exemplified in figure 5. Combustion of fossil fuels represents the first category, root nodes, and acidification represents the second category, end-of chain nodes. The third type of node is called central node which will be represented by acidification if the causal network in figure 5 were further expanded downwards with more central nodes. The purpose with the second step in the indicator identification is to find the different nodes in the network and also to further develop the relevant sections of the network. How relevant a section actually is can be hard to determine and will depend on several different aspects, but in particular on how the research question is formulated. The process of identifying key-nodes are important since these parts of the causal chain provides information associated with several different issues or environmental problems.

In the third step the selection of concrete indicators is being made. This will be made by comparing different indicators with the different criteria suggested for assessment of individual indicators above. However it is important to not only assess the indicators as individuals but also to include them in the overall picture created in the causal chain. An indicator that scores a little lower according to the criteria above might still be the better choice if it compliments other indicators in the causal chain in a more effective way.

2.1.5 Stakeholder Interactions

As discussed above, the common way of selecting indicators is facing a general criticism for lack of scientific rigor (Dale & Beyeler, 2001; Lin, et al., 2009; Niemeijer & de Groot, 2008 A). Primarily this criticism concerns the failure of producing a defined protocol for ecological indicators selection. Bockstaller & Girardin (2003) agree to this criticism, however they also argue that one of the most important aspects in a scientific approach to environmental indicator selection would be the validation of the process and the developed indicators. They propose a methodological framework divided into three phases; design validation, output validation and end-use validation.

In the first phase of the framework, design validation also called conceptual validation, the design and construction of the indicator set and its framework will be reviewed by a panel of experts (Bockstaller & Girardin, 2003). By doing so it will be ensured that the set and framework is scientifically founded. Hence the design validation will take place in the form of a pear review and if possible also include a comparison with other approaches. In the second phase the focus is on the output of the indicator in order to make sure that it achieves the overall objectives and produces the intended effect (Bockstaller & Girardin, 2003). The output validation can take place in several ways. If one as an example uses the presence of a specific species in order to assess biodiversity in an area, the relationship between the presence and biodiversity can be validated by statistically verify the relationship. One other way of doing the output validation can be made in a similar way as for the design validation by using experts in the field to evaluate if the indicator inform about the reality and if it is realistic.

The third validation, the end-use validation, confirms that the indicator will be useful for the user and this phase is important in two ways. Primarily it enables the end-user to give feedback on the output from the indicator and it makes sure that the indicator provides the requested information. Secondly it also provides an opportunity to ensure that the end-user understands the indicator, what it shows and what the use of it can imply. This last phase is of particularly high importance since one of the most important properties of an indicator is that it is user-driven and adapted to the circumstances in which it will be used (Niemeijer & de Groot, 2008 A; Normander, et al., 2012).

Involvement of end-user and different stakeholder is also highlighted within the Bellagio STAMP. According to the seventh principle, broad participation, involvement of different stakeholders is important in order to strengthen the legitimacy and relevance of assessment of progress towards sustainable development (Pintér, et al., 2012). Furthermore stakeholder interactions can also be used as a tool to increase the possibilities of creating successful sustainability strategies and according to existing stakeholder theories stakeholder interaction can result in improved performance of a company (Waddock, 2013).

There are several ways of involving different stakeholders in the development of assessment methods and indicators. Common ways of involvement includes focus groups, interviews etcetera (Pintér, et al., 2012). These activities can make the measurement process more complicated, however in return these methods have proven successful in many situations when conventional development methods have failed. This have especially been the case in situations when the result from the process is connected to decision-making.

2.2 Impacts on Biodiversity from Ports and Port Operations

Ports and port operations have several negative impacts on the environment and biodiversity (Göteborgs Hamn, 2014). Of the five main pressure that according to the UN Global biodiversity outlook cause the ongoing loss in global biodiversity, ports and port operation can be connected to all five. These are climate change, invasive alien species, habitat loss and degradation, pollution and overexploitation (SCBD, 2010). While climate change and invasive alien species are related to a global context, habitat loss and degradation and pollution is more related to local effects, which however in turn effects the biodiversity on a global level. Included in habitat loss and degradation are sources such as noise, light pollution and land use change. The connection between ports and port operations and the different pressures for biodiversity loss will be described more in detail below with and exception for overexploitation which is excluded from this report.

2.2.1 Habitat Loss and Degradation

Habitat loss and degradation is currently seen as the largest single source of pressure on biodiversity worldwide (SCBD, 2010). This is primarily due to the transformation of wild lands to agriculture which primarily occurs in tropical areas and which is partly driven by the demand for biofuels. However many other habitat types are also facing a high pressure resulting both in habitat loss and habitat degradation. In Sweden as an example several species are threatened by reforestation of old pasture land (Bernes, 2011). Ports and port areas partly have the same impacts as other industrial and urban areas however by the nature of ports they are located in coastal areas which is a habitat type heavily effected by exploitation and the relatively small land requirements from ports can still have severe effects. In Sweden, as an example, which is relatively sparsely populated, still about 30 percent of the coastal areas are exploited within 100 meters from the waterline.

Except for land use-change due to physical removal of habitats as mentioned above, habitats can be degraded due to other pressures related to ports and port activities in other ways. These pressures include dredging, landscape fragmentation, noise, underwater noise and light pollution and will be described further below.

2.2.1.1 Dredging

Dredging is made regularly in port areas and the removal of bottom sediments naturally have negative impacts on the biodiversity in the port area. However if the overall environment has a good status the new bottom will be oxygenated relatively fast and animals and plants living in the bottom sediment will return (Magnusson, 2015). The status of the local marine environment may be reduced due to the dredging since port areas often have a high content of toxic substances in the bottom sediment (Sturve, et al., 2005). When the dredging is made sediment particles whirl up resulting in increased interface between the toxic particles and water. This in turn result in a higher level of dissolved toxic substances in the water. Furthermore the release of dredged material in marine dumping sites will have negatives effect for the biodiversity in the dumping site.

2.2.1.2 Landscape Fragmentation

Landscape fragmentation occurs when natural areas are divided and cut from each other by infrastructure or other kinds of constructions (EEA, 2011). The fragmentation mainly takes place in urbanized or intensively used regions with a high demand for infrastructure and for exploitation of different kinds. Ports can partly be seen as a driver for these exploitations and in many cases ports in itself works as a barrier between different natural areas. Fragmentation have several different impacts on the wildlife including diffusion possibilities, foraging, and species composition. The latter is an effect from the fact that different species are present depending on if the habitat is a so called interior habitat or an edge habitat. When an area is divided in two by some kind of infrastructure the area of edge habitats increases while the interior habitats decreases and so does the species living in the respective habitat type. Finally one important aspect of landscape fragmentation is that species requires a minimum area in order to survive. When a large area turns into many small landscape patches the individual area of each patch might be lower than the minimum requirement hence resulting in extinction in that area.

2.2.1.3 Noise

Newport et al (2014) define noise pollution as “any human-made sound that alters the behavior of animals or interferes with their functioning. This includes altering reproduction, communication, survivorship, habitat use, distribution, abundance or genetic composition.” Nosie can originate from several different sources however traffic is usually the most common source, including noise from cars, trucks, airplanes and motorcycles. Due to noise pollution the biodiversity in an area is affected in several different ways and the change can be mainly due to two different responses; habitat avoidance or decreased health among the animals (Newport, et al., 2014). Regarding habitat avoidance, research has shown that areas under long-term exposure of noise tends to be avoided by wildlife (Lynch, et al., 2011). Thereby the noise pollution are contributing to a reduction in an already limited area of potential habitat for wildlife. Nosie also affects the health and reproduction of the animals in areas effected by noise (Newport, et al., 2014). The main disturbance that is caused is the problem with hearing for the animals. This gives the animal problem regarding communication both in the purpose of warnings but also in the purpose for their reproduction behavior. Furthermore high levels of noise also makes the animals restless and irritable since their ability to discover potential threats gets degraded. In its turn this affects the food intake, social interactions and parenting which eventually can result in a decrease in population.

The effects from noise pollution for biodiversity is often neglected even though it often have considerable effect in areas close to infrastructure or cities (Helldin, 2009). Already at long lasting sound levels of 55 dB LAeq half of the birds in an area have disappeared. This level is at the same level as the noise from a normal speech and a long lasting noise of this magnitude is common in many parks and green areas close to cities. This sound level can be seen in relation to the normal level of bird calls which is about 45dB. With this comparison in mind it is easy to imagine the communication problem that birds faces in urban areas.

2.2.1.4 Underwater Noise

Underwater noise is a problem that has gained increased attention from the society during recent years, however it is compared to noise in air still a relatively unexplored area (Slabbekoorn, et al., 2010). In general underwater noise can be divided into two categories – impulsive and continuous noise (Galilaiou & Tsioumani, 2014). Shipping and port operation is primarily a source of continuous noise emission since the sound from vessels and propellers travels long distances in water, furthermore continuous noise also include sources such as long term drilling. Impulsive noise can however also be caused by port related activities especially when ports are expanding since the building process results in noise from e.g. pile driving. Included in impulsive noise are also high frequency sonar, seismic surveys and other types of marine constructions.

In general underwater noise have the same properties as noise in air however water is a better medium for sound transmission than air and underwater noise therefore have about three times higher speed than noise in air, about 1500 m/s versus 300 m/s (Slabbekoorn, et al., 2010). Water also enables the sound to travel longer distances than in air which is used by several marine animals for long distances communication however this also implies that underwater noise will spread over large areas.

It is not only the sound level that decides the impacts from sound but also the frequencies of the sound (Slabbekoorn, et al., 2010). Different species are using different frequencies for communication fishes in generally have their best hearing in the frequencies between 30-1000Hz while some dolphins can hear frequencies up to 100 000Hz.

The effects that underwater noise have on marine animals are similar to those land living animals gets from noise in air (Slabbekoorn, et al., 2010). Due to interfering noise, communication abilities are reduced due to range reduction and regular losses in information. Furthermore, the interaction between predators and prey is changed by the interfering noise. All in all the result is changed distribution of marine animals and reductions in growth and reproduction possibilities.

2.2.1.5 Light Pollution

Longcore & Rich (2004) describe ecological light pollution "as artificial lights that alters the natural patterns of light and dark in ecosystems" and they include direct glare, chronically increased illumination and temporary unexpected fluctuations in lightning. Light pollution originates from all kind of non-natural light emitting sources including sky glow (light reflections in the night sky), lighted buildings, street lights, vehicles, flares on offshore oil platforms etcetera.

Light pollution have several different effects on biodiversity in a local perspective (Hölker, et al., 2010). With a lighter environment the night habitats of animals and plants are changed which result in changed behavior of foraging and mating behavior for animals and disruptions in the natural day-night cycle for plants. The effects can be rather complex which can be illustrated by insects congregate around a light source dying for exhaustion. An effect from this is a reduction in individual numbers and in total biomass which will have effects along the whole food-chain. One other example which regards port in particular is the problem light pollution can create for migrating fishes which gets confused by the light and waste energy resulting in an overall reduction in migrating success. Despite all the potential effects light pollution have on biodiversity the area is still relatively unexplored and many scientist argue for intensified research in the area (Newport, et al., 2014) (Hölker, et al., 2010).

2.2.2 Emissions of CO_2

A general problem for the transport sector is emissions of greenhouse gases, mainly CO_2. The maritime industry is not an exception and emissions from vessels contributes to the increased greenhouse effect with a changing climate as one of the effects. Regardless of where the emissions is being made the effects will be seen at a local scale including port areas. In Swedish coastal areas the effects can already be seen by a higher frequency of overwintering among several different bird species (Bernes, 2011). Other effects that probably correlates with the warmer climate can be seen in the Baltic Sea where cyanobacteria, a blue-green algae, has got more common while diatom algae has decreased. The increased temperature will put a pressure on the local ecosystem. Pressures of this kind is known to enable the spreading of Non-indigenous species (NIS) and therefore the emissions of CO_2 also have a connection to the spreading of NIS (Occhipimti-Ambrogi, 2007). This connection will be described further below.

Except for causing climate change emissions, CO_2 also contributes to the ongoing acidification of the oceans. When reacting with water, CO_2 is transformed into carbon acid which causes a lowering of the pH-value in the ocean (Bernes, 2011). This acidification is in particular a major concern for marine organisms such as corals and crustaceans who will be having problems to create shells or skeletons. With an even lower pH-value in the oceans the shells will eventually start to dissolve.

2.2.3 Non-Indigenous Species and Invasive Alien Species

One environmental impact that differentiate the maritime industry from other transport modes is the dispersion of non-indigenous species (NIS) and invasive alien species (IAS). NIS is species that is introduced outside of their natural range and outside of their dispersal potential (Olenin, et al., 2010). A NIS can also be an IAS if it is established in an area and has spread, is spreading or has a known potential to spread elsewhere. To be called an IAS the species also needs to have adverse effects on biological diversity, ecosystem functioning or socio-economic values.

The introduction of NIS and IAS in marine environment primarily takes place in eight different ways of which commercial shipping is one (Bax, et al., 2003). In addition to commercial fishing, these eight main vectors for marine introductions are; aquaculture and fisheries, drilling platforms, canals, aquarium industry, recreational boating, dive practices, floating debris. The commercial shipping contributes to the introductions of NIS in primarily three ways; ballast water, hull fouling and the transportation of solid ballast such as rocks and sand. Of these three vectors ballast water is gaining a considerable attention while the other two are mostly of minor concern. This is in some sense starting to become a problem since the work with ballast water management has led to the incorrect conclusion that the problem as a whole is being dealt with. In fact hull fouling is historically the main vector for introduction of NIS in many places including San Francisco Bay, Australia, New Zealand and the United Kingdom. Other figures shows a slightly different picture and Gollash (2006) estimates the 22% of the NIS in European coastal waters was transported by ballast water while 17% were transported as hull fouling. Nevertheless these proportions is still not represented in the attention the respective dispersal way is given.

During later years and in the future ballast water will probably increase its importance for diffusion of invasive species even further (Bax, et al., 2003). This is partly because of increases in vessel size and transit times but also, ironically, due to improved environmental management in the maritime industry. Ports today are getting more hospitable for different species and also the ballast water is cleaner which implies that the NIS will have a more convenient journey and the survival rate will be higher.

There are numerous existing and potential IAS around the world. The effects from an introduction differ however between the species and it is hard to know the effects of an introduction. Gurevith & Padilla (2004) argue, however, that the effects on ecosystems from

IAS in many cases are overestimated. IAS are often given the blame for extinction of native species and this is true in some cases as for the introduction of snakes on isolated islands etcetera. However in many cases a decline in the native population has already been seen before the introduction of an IAS is made. Gurevith & Padilla mean that this implies that something has affected the ecological system before the introduction and it has led to a decline in the native population but also to a changed environment which enables the dispersion of the IAS. Furthermore they highlight that this fact should not be seen as an argument for not preventing the introduction of IAS rather as a realization that the most effective way of mitigating threats against the biodiversity might be more complex that just avoiding to introduce IAS.

As discussed by Gurevith & Padilla, the impacts an IAS makes differ between different species. However, those IAS that affects the ecosystems the most also threatens to affect other biodiversity protection measures such as environmental and marine protection areas (Bax, et al., 2003). Hence it is crucial to stop further dispersion of NIS in order to be able to succeed with other protection measures.

2.2.4 Pollution

The main pollution threat to global biodiversity is nitrogen and phosphorus causing eutrophication (SCBD, 2010). Port and port operation is not contributing to eutrophication in a noticeable way, however they are a source of other pollutions such as sulphur and toxic substances which will be described below.

2.2.4.1 Toxic Substances

Ports have historically been a very hostile environment due to the release of oil and other toxic substances however the port have gradually got cleaner and today the release of oil and toxic substances are probably lower that for a long time (Bax, et al., 2003). In many ports one of the main sources of toxic substances have been hull coating which for a long time contained Tributyltin (TBT) (Göteborgs Stad, 2013). This toxic substance have accumulated in port areas due to hull cleaning and cleaning in connection to recoating. Today the use of TBT is regulated however it is still used in some parts of the world primarily in developing countries with a low environmental requirements. Regarding oil spills the number of oil spills are reduced and the spills are also getting smaller in port areas however on a global scale the shipping industry contributes with much of the releases of oil due to accidents and shipwreck.

2.2.4.2 Emissions of SO_x

Emissions of SO_x is a problem that the shipping industry have been struggling with for a long time. However in 2015 new regulations entered into force due to the directives in the Sulphur Emission Control Area (SECA) that reaches from the English Channel going north including the Baltic Sea (Transportstyrelsen, 2015). A result from these new directives is a relatively drastic decrease in emissions of SO_x.

3 Methodology

Below follows a description of the methodology / working procedure used in this study. For a theoretical description of the frameworks used, see the theoretical framework section above. The chapter is divided into four parts; construction of a causal network, indicator selection, stakeholder interactions, and a description of the three different scenarios used in this report.

As recommended by Niemeijer & de Groot (2008 A) the working procedure, aiming to find suitable indicators for biodiversity, was conducted in two major steps – creation of causal network and indicator selection. Alongside this process ongoing stakeholder interactions were made as shown in figure 6. These stakeholder interactions were inspired by the validation process suggested by Bockstaller & Girardin (2003). This validation process was also complimented with other literature regarding stakeholder interactions.

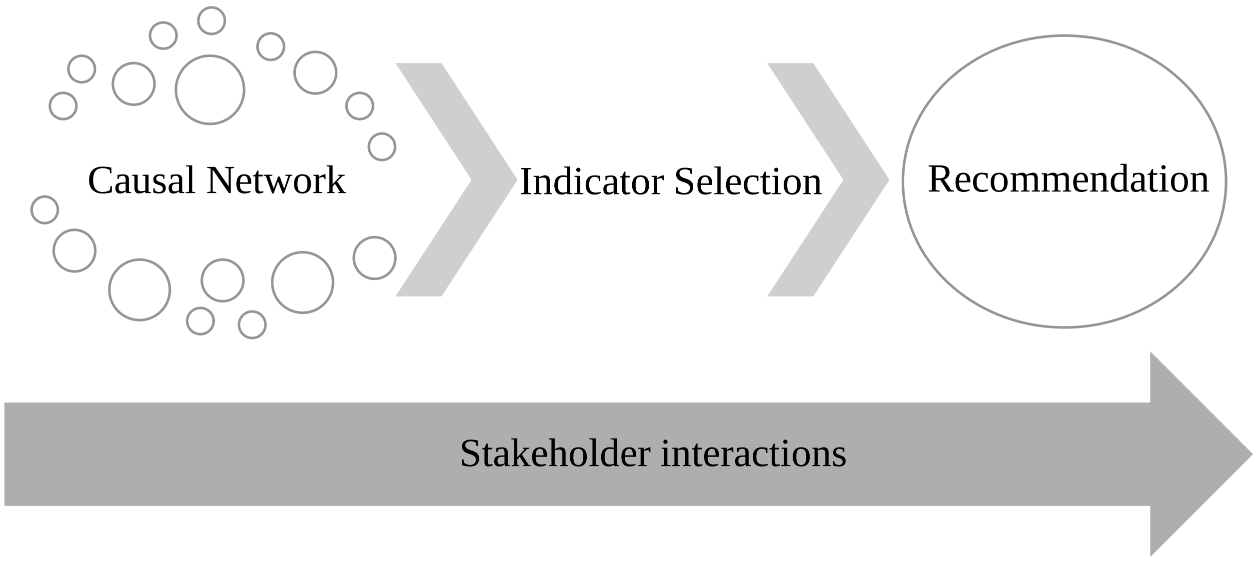

Figure 6 - Description of the working procedure

3.1 Construction of a Causal Network

The construction of the causal network was made mainly according to the eDPSIR framework recommended by Niemeijer & de Groot (2008 A) (2008 B). This process includes five different steps, however the main efforts were laid on the latter two since the first three regarding domain of interest and boundaries for the study were given by the Port of Gothenburg in the original construction of the task. The listing of abstract indicators were primarily made based on the description of *impacts on biodiversity from ports and port operation* described in the theoretical framework and by scanning for indicators used by different agencies and organizations working with issues related to biodiversity. Initially the focus was laid on finding abstract indicators on a pressure level followed by the state, impact and response level. The driving force level was added later in the work as recommended by Niemeijer & de Groot (2008 A), see section 2.1.4.

During the scanning for abstract indicator identified indicators were systematically placed in the causal network on the respective level in the DPSIR network. In the fifth step the main focus was to find the linkages between the different abstract indicators on the different levels. This procedure also showed some missing links in the respective chain which sometimes created a need to shortly return to the previous step. During the work new aspects were found out continuously and therefore the cause network was added with new abstract indicators and connections consciously.

3.2 Indicator Selection

In accordance with the framework suggested by Niemeijer & de Groot (2008 A) (2008 B) the indicator selection started with an identification of the different kinds of key nodes in the causal network. As seen later in the results part, the relatively wide scope of the study did not allow too much details in the network and therefore the different nodes did not seem to be as important as they could be in more narrow case with more details. Nevertheless, the different kinds of nodes were identified and were used as a base later on when the indicator selection was made.

Initially in the indicator selection step, specific indicators were taken from the sustainability report of the Port of Gothenburg. This was made in order to see how well these indicators were adapted to fit in the developed causal network. The indicators already used by the Port are mostly well established in the organization and the possibility to include these in the new indicator set was therefore seen as beneficial. When these indicators were considered the scanning for indicators were made by reviewing literature primarily by using online data bases with access through the Chalmers library but also by making interviews with different stakeholder. The interactions with the stakeholder will be described below.

During the scanning for indicators, numerous indicators were considered however most of the suggested indicators could be neglected since they did not possess a high relevance for our specific case. In order to determine which indicators to evaluate further, evaluation criteria was developed based on the qualities discussed in the theoretical framework. In the theoretical framework several suggestions of qualities were discussed and since there was no major contradiction between the different suggestions the evaluation of the individual indicators was made with primarily five aspects in mind which was considered to summarize the different suggestions in a good way. These properties were flexible (adaptable), cost-effective (realistic), sensitive user-driven and policy relevant. These properties was also agreed upon with the supervisor at the Port of Gothenburg. By having these aspects in mind while doing the scanning for indicators, a large amount of indicators could be neglected relatively easy in the selection process. The indicators that were seen as the most appropriate were investigated more in detail and evaluated in the discussion part of this report which finally lead to a recommendation.

3.3 Stakeholder Interactions

In order to give the selection process of indicators more legitimacy and relevance, the Bellagio STAMP argues for broad participation and stakeholder interactions (Pintér, et al., 2012). Due to the fact that the Port of Gothenburg is owned by the municipality of Gothenburg and thereby in fact owned by the citizens of Gothenburg, the legitimacy of its action is of extra importance. Furthermore, indicators developed in this report will have a link to decision making which increases the need for broad participation even further.

Due to the benefits of stakeholder interactions, contacts were made on several occasions both for information gathering but also in a validation purpose. The validation was made in accordance with the suggested method from Bockstaller & Girardin (2003) and was therefore conducted in three steps including design, output and end-use validation, however the main focus was on the third step which involved the end-user i.e. primarily The Port of Gothenburg.

This in turn was made continuously in order to give the end-user the possibilities to ask for changes and to direct the indicator development in the requested direction.

The two first validation steps, design and output validation, was made due to the required working procedure for master thesis at Chalmers University of Technology. In this procedure the report was reviewed by the examiner and also the opponents of the master thesis. Furthermore the design and output validation was also assessed by the potential end-user of the report. This was made continuously in collaboration with representatives from the Port of Gothenburg

The end-user of the indicators is not only The Port of Gothenburg. As a municipality owned company, there is several benefits if the developed indicators also is applicable for the municipality and other companies owned by the municipality. Hence interactions also needed to be made with representatives from the municipality. Except for the municipality, several other stakeholders are to be effected in the long term by the indicator selection. In particular stakeholder supplying data to the indicators are of high importance since they will be highly influential and have knowledge regarding the data collection.

The selection of possible stakeholders for contact was primarily made in discussion with representatives from the Port of Gothenburg. This have in turn resulted in a relatively narrow selection of stakeholders, however it also give the indicators more relevance since the current suppliers of data is a possible supplier also for new kinds of data. The contacts with different stakeholders was made continuously during the work and the different stakeholders represented can be seen in table 6.

Table 6 - Stakeholder interactions

Order of Execution	Stakeholders	Type of interaction
1	The Port of Gothenburg, Senior Manager Port Development	Interview
2	University of Gothenburg, Professor Systematics and Biodiversity	Interview
3	Chalmers University of Technology, Assistant Professor, Biopollution	Interview
4	The Port of Gothenburg, Environmental Coordinating Group	Group discussion
5	Marine Monitoring, Consultant	Interview
6	Environmental Department Municipality of Gothenburg	Interview
7	Gothenburg Ornithology Association, Chairman	Interview
8	Institute of Ecology and Botany, Hungarian Academy of Sciences, PhD	E-mail
9	City of Stockholm, Ecologist	E-mail
10	Municipality of Gothenburg, Coordinating Group Water Issues	Group discussion

As can be seen in table 6 the interactions with the different stakeholder was mainly carried out as interviews which were semi-structured. The interviews were adjusted according to the circumstances in which the interview was conducted. Most of the interviews were conducted in a relatively formal way and began with a short presentation of the case, the method used for indicator selection, and the results so far. This was followed by an opportunity for the stakeholder to ask questions in order to ensure that the stakeholder had understood the information correctly. During the following semi-structured interview, relatively few questions were asked since the discussion following the introduction answered most of the prepared questions. At the end of each interview, a short summary was made in order to ensure that the main discussion had been understood correctly. An example of interview questions can be seen in appendix IV. All interviews were not conducted in a formal way. The interview with the chairman of the Gothenburg Ornithology Association, as an example, was relatively informal. This interview was conducted while walking and driving in the surroundings of Torslandaviken which made the interview was very informal. However, questions were prepared and before ending the meeting these questions were checked in order to ensure that they were answered.

The first interviews in the study was recorded with permission from the respondent. However, after a while the recording was abandoned since it was realized that the information of importance was not the details in the discussion but the conclusion that was agreed upon in the end of each interview. After the interviews the information given was used to develop the network and suggestions for possible indicators were further investigated. During this work new questions arose, often regarding other stakeholders. Therefore new contacts were taken with other stakeholders and the procedure was repeated. This is illustrated in figure 7.

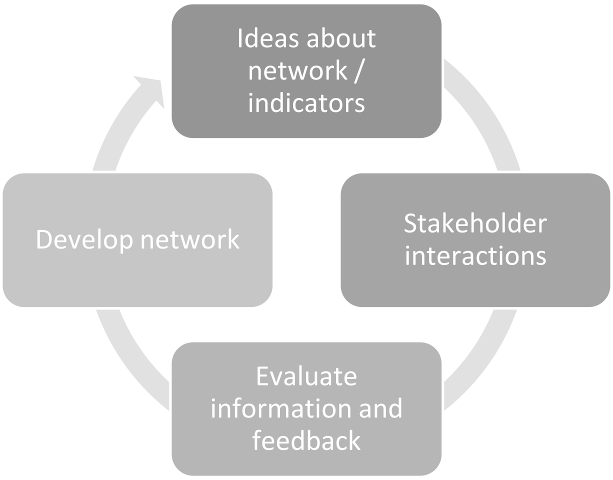

Figure 7- Cycle of Stakeholder Interactions

In addition to the stakeholder interactions presented above, continuous contacts were made with the supervisor of the thesis, Edvard Molitor, Senior Manager Environment at the Port of Gothenburg. These contacts were made in a relatively informal way, mostly in the form of discussions regarding the work and preliminary results. As the manager of environment, Molitor can also be considered as the most important end-user. Therefore these continuous contacts were important to make the result useful and applicable for the Port of Gothenburg.

3.4 Three Different Scenarios

All companies need to adapt to their owner and in the case of the Port of Gothenburg the owner is a municipality, which is a relatively common owner of local ports. However, this is not always the case and even if a port is owned by the municipality it can act highly independently of its owner. In order to enable a general result without compromising the applicability of the indicators for the Port of Gothenburg, three different scenarios were investigated where the degree of collaboration with the owning municipality varies;

1. The Port of Gothenburg uses the indicators for internal use, independent from the municipality of Gothenburg.
2. The Port of Gothenburg uses the indicators in collaboration with the municipality of Gothenburg.
3. The Port of Gothenburg uses the indicator in collaboration with the municipality of Gothenburg as a mean both to assess biodiversity and to involve citizens and create social projects.

These different scenarios were primarily used in the discussion and recommendation part of the thesis however they were also held in mind when searching for indicators for the different levels.

4 Results

The following section will is divided into four main parts; Interviews, Causal Network, Possible Indicators and Data Sources. These results will then be discussed in the discussion part and the final result will be stated in the recommendation section of this report.

4.1 Interviews

Below follows descriptions the process and main conclusions from the different stakeholder interactions, which were made during the study. The interactions will only be described briefly since most of the information given appears elsewhere in this report. Especially in the *Possible Indicators* section. The interviews are presented in the order they were made.

<u>The Port of Gothenburg, Senior Manager Port Development</u>

In the interview with the Senior Manager Port Development in the Port of Gothenburg (Ternström, 2015), the current biodiversity in the Port was discussed. The manager also presented their current work related to biodiversity. Future expansion plans were also presented and what the Port is obliged to do in order to compensate for the resulting impacts on nature. Furthermore, some ideas of indicators for biodiversity were given. Finally the manager could conclude that there are differences in how marine and terrestrial environments are seen both regarding general thoughts and legislation.

<u>University of Gothenburg, Professor Systematics and Biodiversity</u>

During the interview with the professor in systematics and biodiversity at the University of Gothenburg (Sundberg, 2015), the main discussion regarded different pressures and impacts on marine environments. Areas such as effects from dredging and the release of toxic substances were explained and discussed. The professor also highlighted the importance of actually assessing the real biodiversity and not only look at different pressures from the Port. Finally it was suggested that Benthic Quality Index, see section 4.3.3.6, could be a suitable method for assessment of the biodiversity in sediment bottoms.

<u>Chalmers University of Technology, Assistant Professor, Biopollution</u>

In the interview with the assistant professor in biopollution at Chalmers University of Technology (Granhag, 2015), the main topic was impacts and spreading of invasive species. The interview led to a deeper understanding for the topic and especially regarding the different assessment methods for biopollution. A final recommendation from the interviewee was to look deeper into the Biopollution level index (section 4.3.3.2) in order to see if that index could be suitable for the Port of Gothenburg.

<u>The Port of Gothenburg, Environmental Coordinating Group</u>

The group discussion with the environmental coordinating group were made in accordance with a regular meeting of the group (The Port of Gothenburg, 2015). The preliminary results were presented and discussed around. The group showed a particularly high interest in different kind of indices. Especially if this enabled comparison over time internally or comparison with other ports. Furthermore, it was also discussed briefly that it could be of interest that the indicators could be connected to the municipality of Gothenburg.

Marine Monitoring, Consultant

As a company working partly to develop BQI and BHQ the purpose with the interview at Marine Monitoring was to learn about the two indices and see if they could be implemented in the Port of Gothenburg (Magnusson, 2015). More information given can be seen in section 4.3.3.6 and 4.3.3.7. Except for these two indices a discussion were also made regarding assessment of other marine environments.

Environmental Department, Municipality of Gothenburg

At the interview with representatives from the environmental department at the municipality of Gothenburg (Hagberg & Toth, 2015), the main discussion was regarding the current indicators used by the municipality and future possibilities of implementing different indices. The problem with limited resources and the need of cost efficiency was raised and discussed. Furthermore, it was noted that the representatives showed an interest for different indices and possibilities of citizen involvement.

Gothenburg Ornithology Association, Chairman

During the interview Torslandaviken was present on site and a discussion was made regarding the biodiversity in the area (Ström, 2015). Furthermore, it was also discussed how the Gothenburg Ornithology Association could be involved in data collection and which data that exists for the area today. The main conclusions from the interview was regarding the difficulties of creating a reference area for Natural Capital Index based on species abundance and that there was an interest in social projects. Finally the interview also gave several insights regarding Artportalen, which is developed further in section 4.4.1.1.

Institute of Ecology and Botany, Hungarian Academy of Sciences, PhD

The questions was send via E-mail to the PhD at the Institute of Ecology and Botany of the Hungarian Academy of Science (Biro, 2015). The questions regarded a school project mentioned in an article written by Bölöni et.al (2008). Since no results had been compiled yet the main information given was different links to webpages used in the project. This answers will be developed further in section 4.4.1.2.

City of Stockholm, Ecologist

The E-mail interview with the responsible ecologist for implementation of Singapore Index for Cities' Biodiversity in Stockholm gave several important insights (Hjorth, 2015), especially regarding the implementation and the possibilities in using the index in a city similar to Gothenburg. The interviewee also provided recommendations where more information and data regarding the test in Stockholm could be found. The inputs from the interview can be seen in section 4.3.3.1.

Municipality of Gothenburg, Coordinating Group Water Issues

In connection with a meeting for the coordinating group of water issues at the municipality of Gothenburg (The Municipality of Gothenburg, 2015), the preliminary result from the report were presented. The participants showed a particularly high interest in the Singapore Index of Cities' Biodiversity but also for the Natural Capital Index (section 4.3.3.3) and possibilities of citizen science. Different aspects of the indices were discussed especially regarding the pre-industrial level in the Natural Capital Index and the creation of a reference area. A general conclusion from the discussion was that the coordinating group was interested in the result of the thesis, which confirms that the selected indicators were policy relevant.

4.2 Causal Network

In this part of the report the work with the causal network is presented. As Niemeijer & de Groot (2008 A) state there is no such thing as "the network" of something and networks can always be changed. During the work procedure the network was changed frequently and the network presented below in figure 8 and 9 is a final suggestion of how a network reflecting local impacts on biodiversity from the Port of Gothenburg can be built. Due to the complexity of the network some parts of minor importance have been removed in order to ease the readability. Possible nodes where indicators could be implemented are developed in the next part of the result chapter, *possible indicators*.

In the network below some more concrete indicators have been suggested these are stated in the respective box written in italic text. Furthermore, an attempt to also include the existing environmental indicators of the Port was made. However, it turned out that only one indicator was suitable to use in the network. This indicator, oil spills, is written with underlined text. The other environmental indicators used by the Port of Gothenburg can be seen in appendix V.

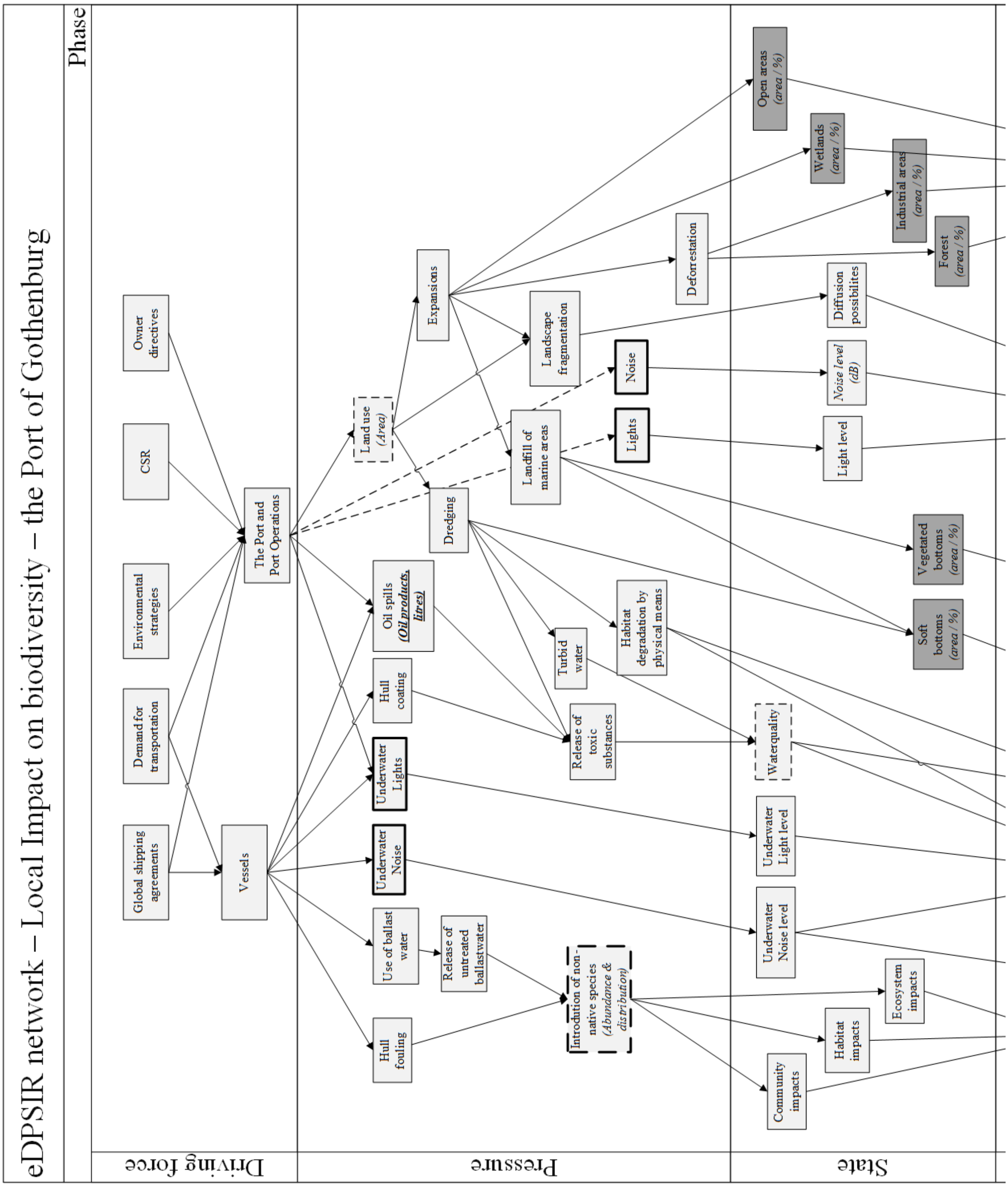

Figure 8 - Causal Network Part 1

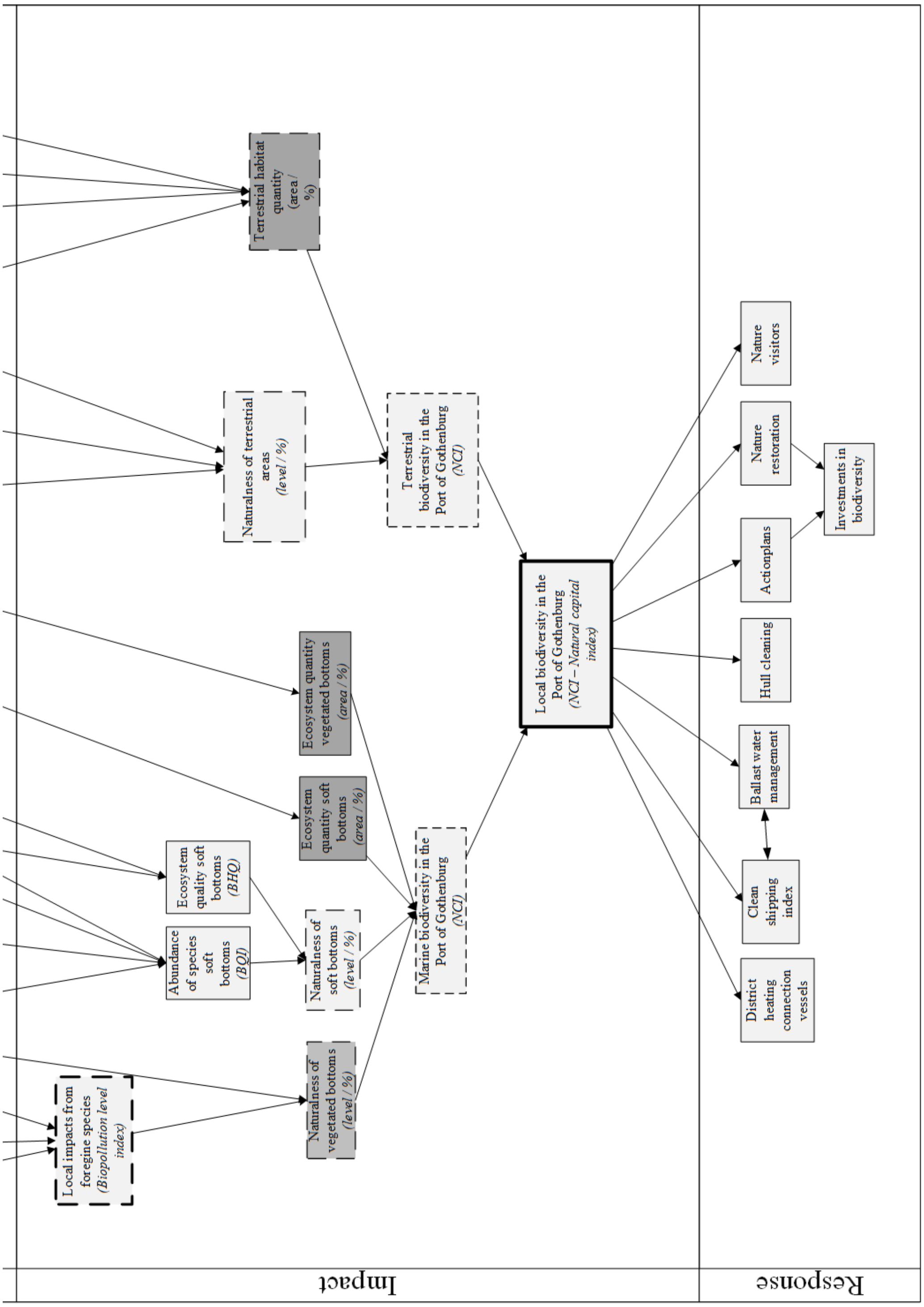

Figure 9 - Causal Network Part 2

4.3 Possible Indicators

Below follows descriptions of the indicators that is possible to use at the different levels in the DPSIR network. The indicators presented below can also be seen in table 7. Already existing environmental indicators used at the Port of Gothenburg can be seen in appendix V.

Table 7 - Possible indicators that will be presented more in detail in this section.

Pressure level	State level	Impact level	Response level
Noise	Coverage of Protected Areas	Singapore Index of Cities' Biodiversity	Investments in Biodiversity
Underwater Noise	Area under Sustainable Management	Biopollution Level Index	
Non-Indigenous Species	Fragmentation of Ecosystems	Natural Capital Index	
Light Pollution		Abundance of species	
		Habitat Quality and Naturalness	
		Benthic Quality Index	
		Benthic Habitat Quality	
		Quality Vegetated Bottoms	
		Living planet index	

4.3.1 Pressure level

Below follows descriptions of indicators possible to use at the pressure level in the DPSIR network.

4.3.1.1 Noise

Sound is commonly measured in the decibel (dB) scale (Hughes & Barham, 2013). The dB scale uses a logarithmic scale which is the case since a doubling in noise will not be received as a doubling in loudness. The sound level is calculated as shown in equation 1:

$$Level = 10 \times \log_{10}\left(\frac{Q}{Q_{ref}}\right) \qquad \text{(Eq.1)}$$

The reference value in the equation is needed since the dB scale is expressed as the ratio between the reference value and the sound quantity. For measurements of sound in air Q_{ref} is usually set to 20 micro Pascal (µPa) which is the threshold of human hearing. Thereby the value will always be positive. The common unit for assessing noise is a bit different from assessing sound. The measurements are mostly made in the unit dB(A) which is a weighted unit only including the frequencies humans can hear (Lindblad, 2015). When noise varies over time it is common to use the unit called equivalent level (dB LAeq) and can be seen as an average value of sound over time.

The current measurements made in the Port of Gothenburg only focus on the conditions in nearby residential areas hence not including any noise level in the surrounding natural areas. In these measurements they are reporting in the units dB(A) for momentary noise and dB LAeq for the general noise level. One example of suggested level of noise in green urban areas has been made by the City of Gothenburg who suggests 50 dB(A) as a maximum level in the major part of the main parks in the city (Göteborgs stad, 2014).

4.3.1.2 Underwater Noise

Underwater noise is mostly assessed with similar units as for noise in air however the reference value for underwater noise is typically one µPa (Hughes & Barham, 2013). As described in the theoretical framework section different marine species uses different frequencies for their communication and therefore the measurements of underwater noise needs to also include the distribution between different frequencies. Furthermore the area of underwater noise is not yet that investigated and will probably rise in interest during the coming years (Hagberg & Toth, 2015).

4.3.1.3 Non-Indigenous Species

The abundance and distribution of non-indigenous species is a complex issue since there several different kinds of species that is released (Granhag, 2015). Especially the transport of non-indigenous species by ballast water have gained attention due to the upcoming Ballast water convention. When the convention enters into force there will be requirements for vessels to clean their ballast water when they are going from one Port to another. However, if the two ports have the same abundance of species, exceptions can be made since the vessels in that case do not risk to transport non-indigenous species. In order for different ports to get approval for these exceptions they need to investigate the abundance of different species in the port. The methods for these investigations needs to be synchronized in order to make comparisons between different ports reliable. These methods are currently being developed and will in the future be a possible way of assessing the abundance of non-indigenous species in port areas.

The NIS needs to be transported and released in the Port in some way to get there. The two main divers are by releases of untreated ballast water and by hull fouling. Assessments of the amount of released untreated ballast water can be made and estimates of the current rates have been made (Gibson & Johansson, 2013). However, according to representatives from the Port of Gothenburg the data assembling can be difficult and there is no available data today. For spreading with hull fouling no examples of indicators used today have been found.

4.3.1.4 Light Pollution

Today there is no widely and commonly used assessment method for quantifying light pollution. Overall the assessments of light pollutions turns out to be relatively few. The most used and known indicator is assessment of the night sky brightness (Cinzano & Falchi, 2013). This indicator is however relatively wide and do not give a very accurate assessment of the actual light pollution.

4.3.2 State level

Below follows descriptions of indicators possible to use at the state level in the DPSIR network.

4.3.2.1 Coverage of Protected Areas

The creation of protected nature areas have for a long time been one of the most important measures for conservation of biodiversity (EASAC, 2005). The importance of the areas are easy to understand and many of the areas with the highest nature values are today protected. The goal set in the CBD is that 17 percent of the land areas are going to be protected and 10 percent of the oceans by 2020 (CBD, 2010). The indicator is used in the Port of Antwerp, a fact that was highlighted during the group discussion with the Environmental Coordinating Group at the Port of Gothenburg.

4.3.2.2 Area under Sustainable Management

Assessing the quantity or percentage of area under sustainable management is made according criteria set by developed under the convention of biological diversity (CBD) (EASAC, 2005). To use area of forest, agricultural and fishery in a sustainable way is important since its contradiction, unsustainable use or over exploitation, is one of the main drivers for biodiversity loss. Originally the indicator developed by CBD does not include fisheries, however EU is developing methodologies in order to include this aspect as well. The criteria used for assessment have been agreed upon in a multinational context.

4.3.2.3 Fragmentation of Ecosystems

Fragmentation of ecosystems are, as described in section 2.2.1.2, an increasing problem with adverse effects on both global and local biodiversity. Assessment of the fragmentation can be complicated, however attempts have been made in the Singapore Index of Cities' Biodiversity, see below. By looking at the fragmentation some conclusions can be made also regarding species abundance by comparing with the habitat selection of species (EASAC, 2005).

4.3.3 Impact level

Below follows descriptions of indicators possible to use at the impact level in the DPSIR network.

4.3.3.1 Singapore Index of Cities' Biodiversity

Singapore Index of Cities Biodiversity also called City biodiversity index (CBI) was developed in order to support the convention of biological diversity (CBD, 2010). The index was initiated by, as the name indicates, the city of Singapore in order to support cities around the world with an evaluation tool for biodiversity. The index gives cities different scores based on 23 indicators which are categorized into three different categories; native biodiversity in the city, ecosystem services provided by biodiversity, and governance and management of biodiversity. The index has been applied by several cities around the world including Stockholm, London and Tokyo. For the full list of indicators see appendix VI.

According to the responsible ecologist for the implementation in Stockholm, the major benefit with the index is that cities start to measure and assess their biodiversity (Hjorth, 2015). For most of the large cities in the northern part of Europe this is however already the case and these cities tend to have relatively high awareness of their biodiversity. Therefore CBI will not make the cities start with assessment and measurements since this is already done. In Stockholm the implementation has also been problematic since the indicators suggested by the CBI are different in several ways from the ones used by Stockholm today, and it has therefore been time consuming to adapt to the index. Another issue that has been recognized at the implementation is what some of the indicators in CBI actually says. One example is the indicators measuring the changes is number of species in the city. The number of species probably changes more slowly that population sizes of respective species, a fact that will be described more below. In order to assess the changes in the number of species from year to year Stockholm have chosen to use data from Artportalen, see below (Hjorth, 2015).

4.3.3.2 Biopollution Level Index

The Biopollution level index (BLI) uses the abundance and distribution of non-indigenous species (NIS) in combination with their impacts on species and communities, habitats and ecosystem functioning (Olenin, et al., 2010). Depending on how the distribution and impacts correlates the investigated area is given an index value from zero to four where zero represents a scenario with low impacts and low distribution.

The assessment of the abundance and distribution of NIS is made in relation to the relevant local ecological group such as macro algae or fishes. The abundance and distribution is then classified between A and E where A represents a scenario where NIS occurs in low numbers in one or several localities in the studied area and E represents a scenario where the NIS occurs in high numbers in all localities.

In figure 10 the classification of abundance and distribution is combined with the impacts on communities (Cx), habitats (Hx) and ecosystem functioning (Ex). Each one of these three impacts are graded between no impact and massive impact which is translated into a number between zero and four e.g. H1 or E3.

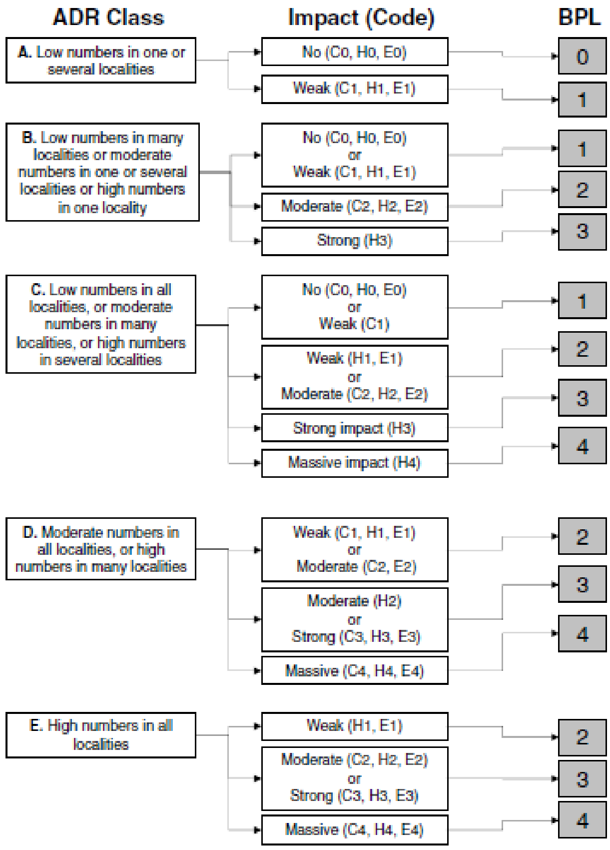

Figure 10 – Biopollution Level Index Matrix - (Olenin, et al., 2007)

4.3.3.3 Natural Capital Index

The Natural Capital Index (NCI) was developed in order to support the implementation of the Convention on Biological Diversity (CBD) (ten Brink, 2007). The purpose of the index is to assess the anthropogenic influences on biodiversity around the world and can especially answers the question of how much biodiversity that remain. NCI is designed in order to be flexible and applicable in different context and scales. It is a straight forward index that is calculated by multiplying the quantity (a) of an ecosystem with the quality (q) of the same ecosystem (Czúcz, et al., 2012). The calculation is shown in equation 2.

$$NCI = \ ecosystem\ quantity(\%) \times ecosystem\ quality\ (\%) = a \times q \quad \text{(Eq.2)}$$

The quantity is represented by the percentage of remaining natural area and the quality is represented by an assessment of the quality of the remaining habitat and the percentage of biodiversity that remains in the area. This function gives an index value which represents how much of the natural capital that remains. As an example if 50% of an area remains uninfluenced by humans and the quality in that subarea is assessed to 50% the NCI will be 25%. If the NCI is applied for large areas with different types of nature it will be more accurate to divide an area into subareas and assess the quality of the different subareas individually. In that case the calculation of the NCI will be as in equation 3:

$$NCI = \sum_{i=1}^{n} q_i a_i \qquad \text{(Eq.3)}$$

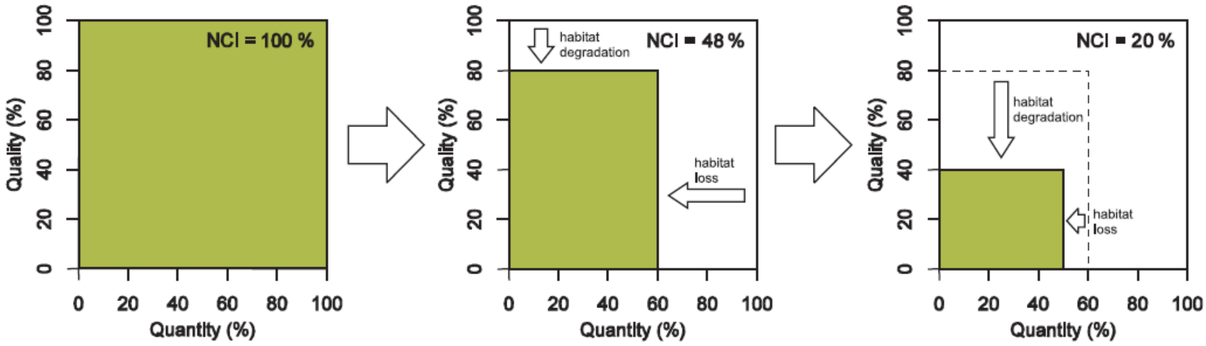

Figure 11 - Natural Capital Index, (ten Brink, 2007)

In order to decide how much percentage of the biodiversity that remains, the calculations of NCI requires a baseline (ten Brink, 2007). The baseline can be decided in different ways, however it is recommended to use a reference area that is under low human impact and can be seen as an area from pre-industrial times. The use of a baseline has some important benefits since it enables comparison within and between countries, makes NCI relevant for all habitat types, is fair when comparing countries of different economic development, and allows aggregation to a high level. With a reference area of some kind, the quality will be calculated as in equation 4;

$$\frac{Quality_i}{Quality_{Ref}} = q_i \qquad \text{(Eq.4)}$$

The quality assessment of the ecosystem in an area can be made in different ways often including assessment of species in some way including abundance of species, distribution of different species and populations of different species. There is also a possibility to assess an ecosystem based on its structure or its naturalness which have a high correlation with the abundance of species. These different ways will be described more in detail below.

4.3.3.4 Abundance of Species

Abundance of species means the presence of different species. In order to assess quality of biodiversity it is common to use abundance of species in some way. However it can sometimes be hard to understand what different kinds of species abundance actually implies and the indicator should be handled with caution (Ström, 2015; Hjorth, 2015).

Ten Brink (2007) argues that the different population sizes is to prefer rather than species richness since the former often is more sensitive, more measurable and a more accurate indicator of biodiversity loss. This is explained by the fact that in an area that just recently has been influenced by human impact the species-richness tend to remain stable or even increase while the number of the individuals of different species can vary drastically. These changes will not be seen if species richness is used as an indicator. This reasoning is also made by Hjorth (2015) who argues that the populations, especially sensitive species, often are changed more rapidly than the species richness. In order to make a more accurate assessment the populations needs to be investigated in detail which is often relatively costly. On the other hand ten Brink (2007) means that it is neither necessary and in many cases nor possible to monitor all species in an area and that a selection of characteristic species is sufficient enough.

When assessing abundance of species it is also important to consider which impacts that can create variations in the abundance from year to year (Ström, 2015). One example is areas used as rest area for migratory birds. The abundance of species can vary due to many different impacts such as weather conditions and negative impacts in the overwintering site.

4.3.3.5 Habitat Quality and Naturalness

Naturalness as a concept can be used to assess the status of an ecosystem. The European Environment Agency (EEA) defines naturalness as *"the similarity of a current ecosystem state to its natural state"* (EEA, 2014, p. 9). Furthermore they exemplifies the concept by comparing a virgin forest, which is considered to have a high naturalness value, with a plantation that mainly consists of one species of tree all within the same age.

The assessment of naturalness can be made in several different ways and there many suggestions have been put forward (Machado, 2004) (Saudytë, et al., 2005). The suggestions consists of many different indicators however common for many suggestions are that the assessment is made with a list of characteristics as a base for the assessment. The list can be made in different levels of detail one example of a relatively detailed lists of description is put forward by Saudytë et al (2005). They present a relatively extensive list of 20 characteristics criteria for each one of the six level of forest stand naturalness which are presented in appendix VII. Another suggestion for characteristics of naturalness is presented by Machado (2004) who uses a more general approach for classification of large areas. The index presented involves 10 different levels which is mainly classified according to human influence. The model enables a relatively efficient assessment of large areas, however the level of detail is low in contrast to the suggestion from Đaudytë et.al. The categories suggested by Machado can be seen in appendix VIII.

4.3.3.6 Benthic Quality Index

In order to assess the biodiversity level at Swedish soft bottoms on depths below 5 meters, a method called Benthic Quality Index (BQI) is widely used. The method was developed by Rosenberg et.al (2004) and is built upon three factors; abundance, species diversity and tolerance scores for each species. In order to calculate the index samples of bottom sediments are taken and the abundance of species are investigated. Most of the species in Swedish coastal waters have been given a sensitivity value which corresponds to how sensitive the respective species are for disturbances. Species with high sensitivity value will not be found in highly disturbed areas and vice versa. One examples is the Norwegian lobster who is easily disturbed and therefore have a high tolerance score of 15.8 compared to a maximum of 16.0. With the inventory of the species in accordance with their respective sensitivity value and their relative abundance compared to other species, the quality of the bottoms can be calculated with equation 5:

$$BQI = \left(\sum_{i=1}^{n}\left(\frac{A_i}{totA} \times ES50_{0.05i}\right)\right) \times {}^{10}\log(S+1) \qquad \text{(Eq.5)}$$

Where:

$$ES50_{0.05i} = Sensitivity\ value$$

$$A = Relative\ abundance$$

$$S = Mean\ nuber\ of\ species$$

The BQI value for each sample will be given on a scale between zero and 20 where values are seen as high if they are above 15.7 is for depths below 20 m, and above 13.9 for depths less than 20 meter (Magnusson & Hammar, 2011). During a recent research project at the University of Gothenburg called WATERS, BQI is developed further and the differences in quality assessments for depths over or under 20 meter will be overbuilt hence will there only be one scale for all depths (Magnusson, 2015). Furthermore, the scale will also be adjusted to be between zero and one instead of zero and 20. WATERS also aims to make BQI less sensitive to changes in salinity and sediment types (WATERS, 2011).

The method is adapted in order to be used in the European Water Framework Directive (WFD). The WFD requires five samples of BQI per water body (Magnusson, 2015). Thereby, the number of samples required by the Port of Gothenburg depends on which waterbodies that is considered to be affected by the Port. As can be seen in figure 12 there are mainly two water bodies in connection to the port. However, effects from the port can possibly also occur in other waterbodies as well and the areas of responsibility therefore needs to be agreed upon with other stakeholders. For the municipality of Gothenburg there are eight water bodies within the borders of the municipality which will require 40 samples in order to meet the requirements from the WFD.

Since the BQI have been developed under Swedish conditions, the tolerance values for different species are only developed for species on a regional level. However the BQI can be used in other geographical areas if regional datasets is developed with sensitivity values for the occurring species in the region.

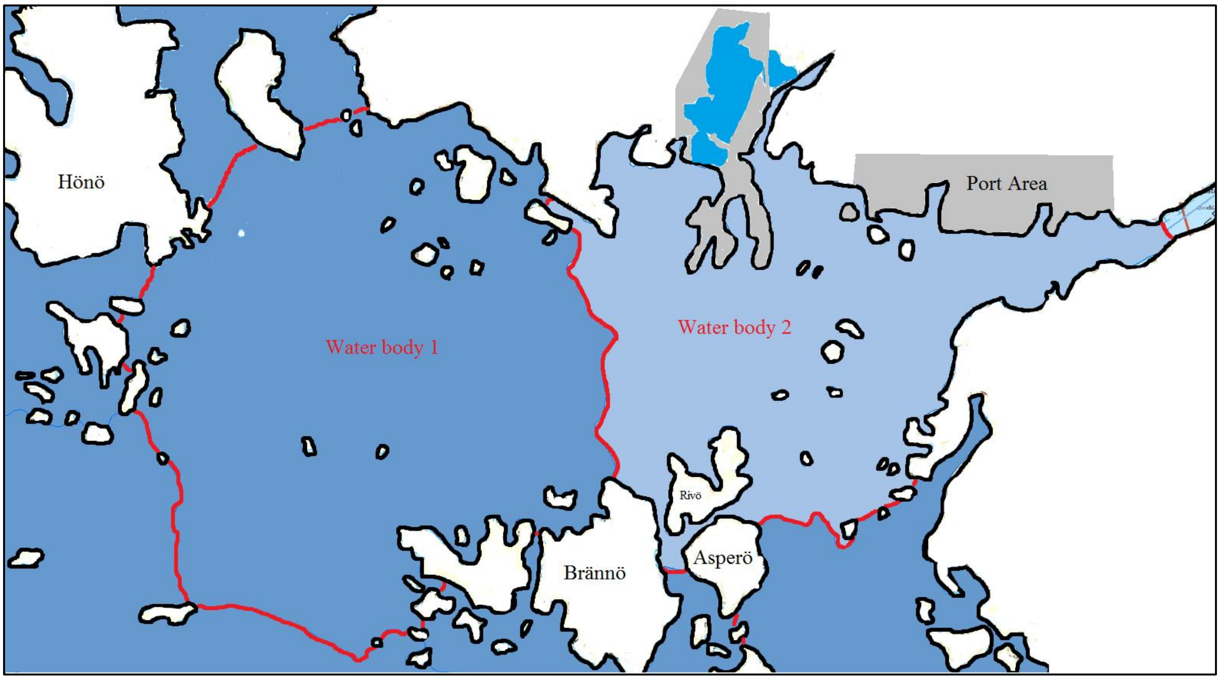

Figure 12 - Water bodies in connection to the Port of Gothenburg

4.3.3.7 Benthic Habitat Quality

One cost efficient and relatively easy way of assessing the status of the benthic habit quality is to use a benthic habitat quality index (BHQ) (Magnusson & Hammar, 2011). The BHQ is in contrast to many other biodiversity related indexes not assessing the actual abundance of different species in an area. The index is instead based on Sediment Profile Images (SPI) which is taken by a camera sunken into the bottom sediment (Nilsson & Rosenberg, 1997). The pictures are analyzed digitally according to the surface structures, subsurface structures and mean depth of apparent Redox Potential Discontinuity (RPD). The structures in the surface and the subsurface mainly comes from animal activities and there is therefore a correlation to the abundance of different species in the sediments (Magnusson & Hammar, 2011). Furthermore the Redox Potential Discontinuity gives us information about the chemical properties of the sediments and in particular the oxygen level in the sediment. The combination between animal movements and oxygen levels gives a relatively accurate description of the biodiversity in the sediment especially since the deeper the oxygen reaches in the sediment the more functional animal groups can exist (Nilsson & Rosenberg, 2000). This implies that BHQ can be directly compared with benthic quality index (BQI). In order to quantify the different categories different properties are set based on the different criteria in table 8 and based on these scores the BHQ is calculated with equation 6:

$$BHQ = \sum A + \sum B + C \quad \text{(Eq.6)}$$

The SPI technology and BHQ have been applied under many different circumstances around the world including USA, Scotland and the Mediterranean Sea (Rosenberg, et al., 2003) (Magnusson & Hammar, 2011). This wide applicability can be put in contrast to BQI which requires tolerance values for local species if it should be possible to adapt.

Despite the differences in assessment method between BHQ and BQI, Magnusson (2015) suggested that the two methods can be used together in order to complement each other. Since BQI is approved by the water directive but has relatively high cost for analyzing samples it can be complimented with BHQ that has low costs for analyzing. In that way, Magnusson means that you will both work in accordance with the water directive and get an extensive picture of the sediment bottoms in a relatively cost efficient way.

Table 8 - Criteria for assessment of BHQ

A: Surface structures	Faecal pellets	1
	Tubes ≤ 2mm in diameter	1
	or Tubes > 2 mm in diameter	2
	Feeding pit or mound	2
B: Subsurface structures	In fauna	1
	Burrows #1-3	1
	or Burrows # > 3	2
	Oxic void at ≤ 5 cm depth	1
	or Oxic void at > 5 cm depth	2
C: Mean depth of apparent RPD*	0 cm	0
	0.1 - 1.0 cm	1
	1.1 - 2.0 cm	2
	2.1 - 3.5 cm	3
	3.6 - 5.0 cm	4
	5 cm	5

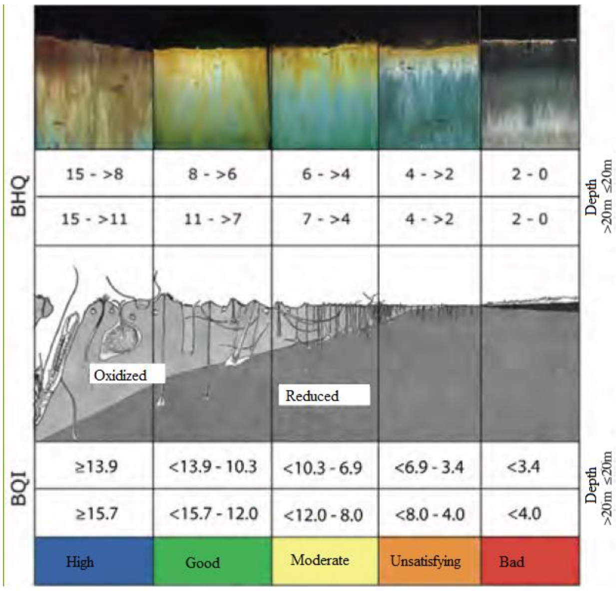

Figure 13 - BHQ and BQI. Used with permission from Marine Monitoring (Magnusson & Hammar, 2011)

4.3.3.8 Quality Vegetated Bottoms

Assessment of the quality of vegetated bottoms can be made in different ways and assessment of different types of vegetation are usually assessed based on different criteria. In the research project MARBIPP, criteria for assessment of the five most common marine environments in Swedish coastal waters were developed and guidelines for assessment of each one of the habitat types were stated (MARBIPP, 2012). The project was made in collaboration with different agencies and financed by the Swedish Environmental Protection Agency (EPA). The recommendations for assessment was partly made as a development of the Swedish EPA's prevailing criteria for environmental quality. These criteria was suggested as a possible way of assessment by Magnusson (2015). Two of the most common marine habitats are sea grass meadows and sea weed belts. These two habitat types are classified according to a scale between one and five where one is seen as "insignificant effected" and five represents a complete degradation of the habitat. The criteria for the two highest levels of sea grass meadows can be seen in table 9. For a full description and criteria for sea grass meadows and sea weed belts see appendix IX

Tabel 9- MARBIPP criteria for Sea grass meadows.

Class	Suggested Naturalness Level	Level of Disturbance	Description
1	100%	Insignificat affected	Sea grass common until 8 m depth
			The biomass of a sea grass leaf is close to 400g dry weight/m2
			No algal mats exists
			Adults amphipods (*Gammarus locusta)* are numerous (100 indiv./m^2)*
			Very high number of seagrass associated animals
2	75%	Slightly affected	Sea grass common until 6 m depth
			The biomass of a sea grass leaf is close to 200 g dry weight/m^2
			Small algal mats exists sporadically
			Adults amphipods are common (50 ind/m^2)*
			High number of seagrass associated animals

4.3.3.9 Living Planet Index

The living planner index (LPI) was initially developed by the World Wide Fund for Nature (WWF) and is an index measuring the state of the global biodiversity (WWF, 2015). Based on population trends for a large number of species, terrestrial, freshwater and marine, an index is calculated that shows average changes of the species and the global biodiversity (EASAC, 2005). The purpose of the index is that it should be used as a communication and policy tool for different kinds of organizations.

4.3.4 Response Level

Below follows descriptions of indicators possible to use at the response level in the DPSIR network.

4.3.4.1 Investments in Biodiversity

Conservation measures for biodiversity is connected to investments of some kind (EASAC, 2005). The interest in making donation to conservation measures is relatively high and comes from a wide range of companies, private persons and organizations and the level of investment can be seen as a good indicator for commitment to the issue of biodiversity loss. However the indicator can be relatively vague and a clear definition is needed before the indicator is used. Investments in biodiversity is an indicator that the Port of Gothenburg have considered (Ternström, 2015). Primarily in the form of percentage of investments in expansion projects.

4.4 Data Sources

For the different indicators described above the data collection can be made in different ways. For all indicators it is possible to use some kind of internal expert or consultancy firm to collect the data. Regarding nature investigations and data collection the Port of Gothenburg are using several different companies (Ternström, 2015). Except for using experts, the municipality of Gothenburg also expressed an interest in involvement of citizens in the data collection (Hagberg & Toth, 2015). An approach that also could be of interest for companies such as the Port of Gothenburg. Therefore, the concept of citizen science will be described below including two examples of ongoing projects.

4.4.1 Citizen Science Projects

Citizen science is a term that have no generally accepted definition however EU express the concept of citizen science as; *Citizen Science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources* (Socientize, 2014, p. 6). The use of citizen science have during recent years gained more interest due to the new possibilities of involvement which have come with the digital revolution. Around the world a large amount of citizen science projects have been initiated (Wikipedia, 2015) and the outcomes is a wide range of values including scientific, social economic, educational and inspirational (Socientize, 2014). Below follows a description of two different citizen science projects the Swedish Artportalen and the Hungarian MÉTA program.

4.4.1.1 Artportalen

One potential data source for abundance of species in Sweden is the online species observation system Artportalen. At this webpage all registered users can report findings of animals, plants and fungi (Artportalen, 2015). The portal is administrated by the Swedish University of Agricultural Sciences (SLU) and the users includes amateurs as well as professionals. The report of findings require as a minimum name of the species found, number, time and location. Except for creating a large dataset one other purpose with Artportalen is to stimulate increased interest and understanding towards different species. Thereby SLU also hopes to encourage trips into the countryside or nearby nature area to search for and report the abundance of different species and thereby contribute to nature conservation programs.

The fact that anyone can report their findings at Artportalen have benefits but also some disadvantages. The main benefit is the incomparable large dataset that it provides which results in a high cost-effectiveness of the measurements (Artportalen, 2015). Furthermore it also enables broad participation and thereby it can result in increased involvement of common citizens. However both representatives from the municipality of Gothenburg and from the ornithology association of Gothenburg highlights some problems with Artportalen. Since there is no coordination between the observers it is common that several observers reports the same findings, therefore, few conclusions regarding the number of individuals can be drawn (Ström, 2015) (Hagberg & Toth, 2015). Furthermore since many observations is reported by amateurs the possibilities of errors within the data is relatively high it is also possible that some observations can be incorrect. Due to differences in popularity of different types of species the number of reports differ highly between different types of species (Artportalen, 2015). Birds for example are very popular, while vascular plants are reported considerably less often.

Despite the disadvantages with Artportalen it is still widely used in several different contexts. One common user is municipalities who uses Artportalen as a tool to assess the biodiversity. In the interviews with representatives from the municipality of Stockholm respectively Gothenburg the respondents states that they are using Artportalen in their current assessment. Regarding reports of findings citizens can, so far, only make reports on the webpage. However, according to the administrator of Artportalen they will soon enable development of reporting applications for smartphones (Artportalen, 2015). A measure that can make the reporting easier and more convenient.

4.4.1.2 The Hungarian System

In Hungary a project called the MÉTA program have been tried out where habitats around the country where assessed based on naturalness (Bölöni, et al., 2008). As a proceeding of this program it was investigated how the instructions for assessment could be made simple enough to enable small scale assessment even by pupils in primary school (Czúcz, et al., 2012). This project is still ongoing and according to the coordinator of the project the results will soon be published (Biro, 2015). However, the general experience of the project have been positive. Recently a website for reporting naturalness assessment have been published which is called természetesség-mero, “the naturalness meter”, and which partly have been financed by the Swedish company IKEA. At the webpage simple descriptions for assessment of naturalness for different kinds of habitat types are available and registered users can report their findings (Természetesség-Mero, 2015).

5 Discussion

In the coming section three different areas will be discussed. Firstly, the indicators suggested in the result section of this report will be discussed and compared with characteristics of a good indicator. Secondly discussion regarding the use of different data sources and indicators in general will be presented. Thereafter, the different scenarios described in the methodology chapter will be discussed individually. Finally the methodology will be discussed regarding how well it worked out, what could have been made differently and which impacts certain choices made.

5.1 Indicators

Below follows a discussion regarding which indicators that are seen as the most suitable for assessing the biodiversity in the Port of Gothenburg. The different indicators presented in the result section of this report will be considered regarding how well they meet the criteria; flexible and adaptable, cost-effective and realistic, sensitive, user-driven, and policy relevant. Furthermore the indicators will be considered as a part in the recommendation for an indicator set for the Port of Gothenburg.

5.1.1 Indicators at a Pressure Level

Regarding indicators at a pressure level it can be seen that the Port of Gothenburg have few indicators focusing on direct effect at the local biodiversity such as habitat loss and degradation. The indicators effecting biodiversity on a more global scale, such as emissions of CO_2 and SO_x, is on the other hand rather well developed. Due to the complexity of biodiversity this is not highly surprising and this scenario is probably common also in other ports and companies.

Some of the impacts identified in the causal chain can be assessed relatively easy. One example is noise in green areas which is assessed in the same way as noise in residential areas which is assessed already today. The impacts from noise can possibly have considerable effects in the green areas in and in connection to the port and an assessment can easily show if different measures are efficient.

For assessment related to the spreading of non-indigenous species (NIS) both the spreading by ballast water and hull fouling need to be considered. Ballast water seems to be the easier of the two to start assessing due to close connection between the amount of released untreated ballast water and the NIS released. This measurement will however only need to include vessels travelling long distance since nearby ports often have the same fauna. The indicator only requires relatively easy calculations however the in order to receive data communication with the vessels entering the port is needed which can be complicated since no such communication exists today. Nevertheless, these communications can be started and it would be particularly interesting to see which effects and implementation of the Ballast Water Convention will have.

Regarding light pollution there is no yet widely used indicator to use for assessment at a local scale. Night sky brightness can possibly be a solution for the municipality of Gothenburg while the Port operations most likely cannot be distinguished. Therefore assessment of the impacts related to light pollution from the Port of Gothenburg will be hard to make and future investigations will be needed.

5.1.2 Singapore Index on Cities' Biodiversity

As an index assessing biodiversity in cities the Singapore index on Cities' Biodiversity is not perfectly suitable for use in The Port of Gothenburg. However, since the Port of Gothenburg is owned by the municipality of Gothenburg it can be of interest for the Port to adapt their indicators to CBI in order to support the municipality with data. This depends however on the interest from the municipality and how well CBI can fulfil their needs. Therefore, this part of the discussion will see the municipality of Gothenburg as the end-user.

CBI can be of interest for the municipality of Gothenburg especially since several other cities, including Stockholm in particular, are adopting to the index. The wide range of cities using the index also shows that the index is adoptable and relatively flexible. Furthermore the index can also be relatively cost effective since most of the information probably are available. In particularly if Gothenburg do as Stockholm and use Artportalen for data regarding abundance of species. Hence an implementation of CBI can be made relatively smooth.

Even if an implementation of CBI can be relatively cost-efficient it can be argued that the efforts put into applying the index is wasted. This is the case since the municipality of Gothenburg already have a relatively extensive monitoring program for biodiversity and since one of the purposes with CBI is to make the first assessment, an advantage Gothenburg cannot take part of. It can also be argued that CBI will not provide any new information or insights to the municipality since most of the data already exists and the aggregation into an index does not give any new knowledge that can be of use in order to reach operational targets for biodiversity. Hence an implementation of CBI will not be cost effective since it is not policy relevant.

Regarding the 23 indicators in CBI most of them are highly relevant for assessing biodiversity and the efforts made for protection. However in some cases it is hard to determine what an appropriate level of effort actually is. If we as an example look at two of the inputs, the proportion of natural areas in the city and budget allocated to biodiversity, it is hard to determine how large they should be in order to achieve a high score. The decision is full of valuations and it is therefore hard to set an appropriate level for scoring. Furthermore if a city already have higher values for than what is required for highest score, CBI can justify a lowering of the budget or the nature areas will have a negative effect at the biodiversity efforts. Furthermore the relatively few different levels for scoring makes small changes hard to see which gives CBI a relatively low sensibility.

The overall impression of CBI is positive since it contributes to create an overall picture of the biodiversity efforts in a city. However the municipality of Gothenburg probably have higher ambitions than the implementation of CBI implies and therefore the index is not very policy relevant. Finally the index is of little usage for the Port of Gothenburg and will need to be complimented with something else in order to serve the objectives of the Port.

5.1.3 Biopollution Level Index

The Biopollution Level Index (BLI) fulfils several of the stated criteria of a good indicator. As a broad indicator with relatively open criteria for the assessment it is possible to implement BLI in many different contexts and locations and the index can therefore be considered as flexible and adoptable. It will be perfectly possible to use the index in most ports in the world and it can therefore be a tool to use for comparison of different ports around the world. BLI is also adoptable in different scales and can also be used by the municipality of Gothenburg in order to assess the biopollution in the archipelago of the municipality.

A disadvantage with the indicator is that it will not be very sensitive to changes. The relatively wide assessment criteria of the index makes it hard to see small differences in an area and thereby it will be hard to act proactively in order to avoid further spreading of NIS. Due to the relatively low sensibility in the index it can be discussed whether the index is policy relevant or not since biopollution can be hard to act upon when NIS already have spread in an ecosystem. Furthermore the index have its main benefits in assessing relatively large areas which is not the case for the Port of Gothenburg.

A future implementation of the Ballast Water Convention with demand for cleaning of ballast water will probably include an exception for vessels traveling between ports with the same marine fauna. In order for ports to be approved for this exception NIS need to be investigated and reported. This work will probably be made in the Port of Gothenburg and also other ports with short sea shipping. This implies that data regarding the abundance of NIS will be generated and therefore abundance of NIS as an indicator will be cost-effective. However the parts of the index regarding impacts on communities, habitats and ecosystem functioning will not have data and the cost effectiveness of these parts will therefore be lower.

5.1.4 Natural Capital Index

The Natural Capital Index (NCI) has many advantages and can be of usage for both the Port of Gothenburg and the municipality of Gothenburg. This is the case since NCI is developed in order to be flexible and thereby be able to use in in different contexts. By assessing the quality of a selected area and multiplying this with the share of the total area the index can be used in any scale and can also add the products from different areas together. Thereby it is possible for the Port of Gothenburg to not only use NCI in their internal work but also to contribute with data in order to make assessment of the entire municipality.

Due to the possibility of using NCI in different context it is not valid to say anything general about cost efficiency of the index since this highly depends on the data collection method that is being used. In a small scale as for a port area it can be reasonable to involve some kind of expert in order to assess the quality of the area however in a large scale such as the entire area of a municipality the cost will probably be unrealistic. However there is still a possibility to use different assessment methods in different areas since amateur assessment will not be as precise as expert assessment but still most likely be relatively accurate. One can also argue that a too detailed quality assessment is impossible since the theoretical reference area representing an original state is too uncertain and hard to assess and an exact value therefore is misleading.

The sensitivity of NCI varies depending the scale of which it is used. In a small scale such as a minor part of a city an exploitation of a natural area will have high effects on the index however in a regional scale the same exploitation will hardly be noticed. In order to make NCI sensitive it is therefore necessary to enable insight into the different compounds of a large scale NCI.

Already in the formulation of the task from the Port of Gothenburg there was an interest to find some kind of indicator that cold summarize the biodiversity in a port area. Thereby a recommendation of NCI will be in accordance with the wishes from the future user of the indicator witch probably will make the implementation of the indicator easier.

Before applying NCI there are several issues that needs to be decided especially regarding the quality assessment of an area. As discussed above this can be made in several different ways however regardless of the assessment method there is a need to either find a reference area or develop a theoretical reference area which can be difficult. Depending on the assessment method the content of the reference area can differ, if ecosystem structure is used a reference model of ecosystem structure need to be developed and this can be made in the as it was done in the Hungarian vegetation based model or as with the BHQ index. It can also be developed by looking at the species abundance as with BQI or simply just comparing species richness or abundance with a theoretical value for the certain area. However it can be hard to assess the original level of species abundance in an area.

In the definition of a reference area it needs to be decided what the original state actually was and what kind of nature an area represents today. Over the time areas can have been changed rather drastically and an area that once was a marine area can today be filled out and be a forested area. In the same way it needs to be decided which time period that should be seen as representing the original state. Ten Brink suggests a pre-industrial time which seems to be relatively suitable especially since many of the threaten species today are threatened due to reforestation of former agricultural land. By using a pre-industrial baseline a certain level of non-industrialized agriculture is needed and the indicators can also be suitable for the goal of the municipality of Gothenburg to have a rich agricultural landscape.

An interesting aspect of the original state is how handle the new types of habitats that cities have created. With growing cities around the world more and more land will be occupied by cites and there will therefore be a need to find out ways to have a certain degree of biodiversity also in areas with high anthropogenic pressure. However the original state of an urban ecosystem can be hard to decide.

5.1.5 Quality of Biodiversity

In order to use Natural Capital Index there is a need for quality assessment of the ecosystem in the assessed area. Depending on whether a habitat is marine or terrestrial there are different possibilities of quality assessment primarily due to differences in the data availability but also due to differences in available methodologies. Generally one can say that the current data availability for marine areas are lower than for terrestrial areas. Artportalen which is one of the main sources for species abundance is not developed for marine areas which seems reasonable due to the fact that relatively few people have knowledge and skills to make inventories in marine areas. However for marine areas there are several scientifically developed methodologies for assessment of the status of the marine environment including BHQ and BQI.

In general assessment methods for the naturalness or habitat quality can be divided into two categories; assessment of habitat characteristics or assessment of species abundance. Assessment of habitat characteristics can be made in different ways however in our case the most relevant method is based on a standardized descriptions as used in the MARBIPP method, the Hungarian method, and BHQ. The primarily benefit with an assessment based on habitat characteristics is that the methods are policy relevant since the habitat characteristics is something that can be directly affected in contradiction to abundance of species. The abundance of species depends on several aspects out of control from the Port, especially in areas such as Torslandaviken where many migratory birds are resting. As described by Ström (2015) the level of migratory birds are influenced by many aspects, such as weather conditions, which is seen as negative if it is used as an indicator.

Quality assessments based on abundance of species can be made in several different ways. As the Brink (2007) argues the number of individuals of species is to prefer rather than species richness since the former often is a more sensitive and accurate indicator and have the possibility to notice early changes. However this implies that the data collection needs to be made by experts or a number of coordinated persons, hence Artportalen as a data source is not possible to use due to the high probability of double counting. Without this opportunity the cost efficiency will be lowered which probably disables assessment over large areas. However in the case of the Port of Gothenburg large parts of the port area is well investigated and assessment based on the number of individuals of different species can therefore still be an opportunity on the local scale.

Regarding the possibility of creating a theoretical reference area this will be made easier with a use of habitat characteristics than species abundance. This is the case since it is hard to determine what an appropriate level of individuals of certain species actually is and also which species that naturally occur in an area. Regarding habitat characteristics it is easier to create a theoretical reference area since an area unaffected by anthropogenic pressure usually have certain characteristics. However even if the characteristics of an area implies that the biodiversity should be high it is not necessarily the case. The ecosystem can also be effected by things not visible in the ecosystem structure such as effects from landscape fragmentation etcetera.

5.1.5.1 Naturalness

Naturalness as a method of assessing ecosystem have the possibility to be used in many different scales and contexts. This wideness of the term is showed by the relatively large differences between the suggestions for criteria given by Machado respectively Đaudytë et.al. However this wideness also implies that the term need to be handled with caution and it has to be clearly stated which characteristics that are being used for the assessment. Depending on the criteria selected the usefullness of the indicators can differ and it is therefore hard to discuss the usefulness in general.

If apropirate criterias are selectet naturalness as an assessment method have many good properties. Firstly it can be considerd as policy relevant since it acturally is something that a organisation can affect directly. Thereby it can also be claimed that it is user-driven since the indicator is easily understood and clear and therefore useful in a context of management. With easy instructions, with or without citizen invlvement, the assment can be made realtively fast and therefore the cost efficiency will be realtvely high. Also the fact that the assessment can be confirmed by others since the base for the assessment do not change rapidly, naturalness as an indicator can be considerd to have a high transparency in accordance with the recommendation in Bellagio STAMP.

The aspects considered when assessing naturalness differs and this can make the cocept to vague and unceratain. However the wideness in the concept also gives the possibility to include aspects that is not included in ecosystem structure. One example is landscape fragmentation for which have considerable effects on biodiversity and could therefore be included - an isolated patch of virgin forrest can not really can be seen as fully natural. This is the case for Rya Skog as an example. Furthermore it is also resonable to include the abundace of non-indeginous species since they do not occure when the ecosystem is fully natural.

5.1.5.2 Benthic Quality Index

By using species abundance in soft bottoms BQI gives a relatively accurate picture of the biodiversity of the benthic fauna. Since it possess the ability to translate the, for common people, relatively unknown area of benthic fauna into a clear value in a scientific way the index clearly fulfills the criteria of being policy relevant.

A disadvantage with BQI is that analyzing of the samples is relatively time consuming with about one working day per sample. If a detailed information of a large area is required BQI will be relatively expensive methodology. However if only the minimum requirement from the water directive of five samples per water body is followed the cost will be reasonable. However the information will also be limited and perhaps not give the full picture. If a more detailed description is wanted BQI can be combined with BHQ which is less time consuming.

The fact that BQI requires regional datasets makes the index relatively inflexible and adaptations to other regions is relatively time consuming. However from a Swedish perspective it is adoptable to most parts of the western coast. In a future however BQI have the potential to be developed and used worldwide. The sensibility of the index depends on the number and frequency of the samples taken. Due to its relatively high costs it will probably not be possible to make detailed descriptions of a waterbody and it is therefore possible that the some changes will be missed. However if the samples are wisely chosen the probability of making a good assessment improves.

5.1.5.3 Benthic Habitat Quality

With several similarities to BQI, BHQ have the benefit of being relatively cost efficient compared to other assessment methods of benthic fauna, including BQI. The cost efficiency comes of the fact that it is the ecosystem structure and not the abundance of species that is being assessed. Thereby the outcome of BHQ is not a real assessment of the biodiversity in an area however the correlation has shown to be strong enough to enable BHQ as an indicator for benthic fauna. Furthermore the indicator can also be considered as flexible since it has been applied in different areas including both the Baltic Sea and the Mediterranean Sea. Regarding policy relevance, demand from the user and sensibility the BHQ are in many ways a method to assess ecosystem structure or naturalness and therefore these criteria already have been discussed above.

5.1.5.4 Quality of Vegetated Bottoms

The assessment method for quality of vegetated bottoms suggested by the MARBIPP project mainly assess the quality of the habitat rather the actual biodiversity in the area. However the correlation between these two aspects are naturally high and the habitat quality will reflect the biodiversity in a good way. The assessment can be made relatively fast and will therefore be cost-efficient alternative compared to a more detailed investigation.

The similarities with assessment of naturalness is high and one can say that the criteria for the assessment actually is criteria for the naturalness of the different vegetation types. In that sense the MARBIPP criteria will be both policy relevant and user driven especially if naturalness is selected as an indicator. The sensibility of the indicator can however be relatively low due to the few levels of assessment and small changes can therefore be missed. Furthermore due to the relatively detailed description for the different criteria the assessment is available for relatively few areas, otherwise it needs to be adapted to the local environment.

The assessment method will however not be highly sensitive due to the relatively broad criteria for assessment. Therefore small changes in the conditions of the respective habitats will probably not be noticed.

5.1.6 Other Indicators

Coverage of Protected Areas as an indicator for biodiversity will be straight forward and easily understood by both common citizens and policymakers. Since protection is one a common and important measure for biodiversity conservation the indicator have a close connection to real biodiversity. However in a relatively small area such as the port area in Gothenburg it can be discussed what the indicator actually says. Especially since the importance of the protected area is decided by the current value of the nature. If nature areas in the port will be protected it will not directly imply that the value of the biodiversity will increase. Furthermore it can also give indirect effects when the port is developing elsewhere. However on a national level or even at a municipality level the indicator can both be interesting and important.

Area under Sustainable Management as a way of assessing biodiversity have many of the same properties as coverage of protected areas. And the issues discussed above will also be valid for this indicator. However the area under sustainable management will include many areas that is not protected hence including a more general view of the biodiversity around the world. The benefits of the indicator depends highly on the criteria suggested for assessment of sustainable management and it can be discussed if these criteria is enough. The indicator can be highly suitable for assessing effects from agriculture and fishery.

Fragmentation of Ecosystems is important to consider in order to get a full view over the biodiversity in an area. For the Port of Gothenburg it is important to consider since the port areas in many cases is working as a barrier between different nature areas. However due to the relatively small scale in of the port the fragmentation as an indicator is not highly applicable. Nevertheless the indicator can be highly useful in a larger scale such as the municipality of Gothenburg. Furthermore the indicator can be included in naturalness assessment and thereby be of usage also for the Port of Gothenburg.

The Living Planet Index measures the global biodiversity by using data series for abundance of different species. The index be useful in many context however both for a local Port and for a single municipality the index is too general and says almost nothing of policy relevance. Therefore the index is not suitable in our case.

Investments in Biodiversity can be used as an indicator of assessing the commitment into the issue of biodiversity loss of a private person or an organization. For the Port of Gothenburg it can be a good indicator to use in connection to expansions of the port however the amount of investments do not necessarily have high effects on the biodiversity. This naturally depends on which measures that are taken and if the investments is made in connection to an expansion is can possibly be connected to a net loss in biodiversity. Furthermore it can be argued that reporting of investments instead of indicators more directly connected to biodiversity can be a way of green washing which possibly can result in negative publicity for the Port of Gothenburg. In summary, investments in biodiversity is important but it needs to be complimented with other measurements in order to be useful as an indicator.

5.2 Data Collection and the Purpose with Indicators

As expressed by Lin et al (2009) there is a contradiction regarding indicator selection between scientists who primarily is “seeking the truth” and managers who are looking for the feasible. This impression have been strengthen during the study since interviews have been made with both managers and experts in the field. Furthermore no biodiversity indicator used worldwide in order to support decision makers have been identified and this gap in research can probably partly be explained that the interest generally is low among scientist to simplify their area of research.

As a complex area, biodiversity is also complex to monitor. Especially since it in order to get a holistic overview of the biodiversity in large areas, extensive inventories are required. In order to enable such an extensive data collection many stakeholders need to be involved and probably also common citizens in some way. There are arguments that involvement of citizens and citizen science projects are mainly social projects with relatively low scientifically value however this is highly dependent how the projects are designed. If they are designed in a good way it is most likely possible to benefit from a range of values including scientific, social economic, educational and inspirational. Furthermore since extensive data is required the possibilities for experts to do the assessment themselves are limited and the only possible way of getting the data is probably involvement and finding ways of assessing data of lower scientific quality.

Indicators should be user-driven however it can sometimes be hard to determine who user actually is. For the indicators of the Port of Gothenburg there can be several different users which is reflected in the three different scenarios selected. By using similar systems regardless of the users indicators can be more cost efficient since multiple purposes can be achieved. With limited resources for biodiversity conservation scalable indicators is a beneficial choice.

5.3 Indicators for Different Scenarios

The Natural Capital index fulfills most of the criteria for a good indicator and will most likely be the most suitable indicator for assessing both the biodiversity in the Port of Gothenburg and in the municipality of Gothenburg. However due to the differences in assessment scale and other prerequisites the available options for quality assessment differs. Below, the three different scenarios will therefore be discussed separately.

First scenario

In the first scenario where The Port of Gothenburg act independently from the municipality of Gothenburg the quality assessment can be made mainly in two different ways in order to get a relatively accurate result. Regarding marine environments and the fact that the indicator is only used internally speaks for a use of BHQ rather than BQI to assess soft bottoms. This is the case since there is need to adopt to the water directive and the fact that BHQ is have a high correlation with the abundance of species while also being more cost efficient. Hence the assessment of the soft bottoms will be made based on ecosystem structure and a reflection of the naturalness of the bottom. For vegetated bottoms such as sea grass meadows and sea weed belts the assessment criteria from the MARBIPP project will reflect the conditions of the ecosystem status or naturalness in a good and cost effective way. The result might not be highly precise however as discussed above this might even be positive due to the high uncertainty regarding the overall quantification of biodiversity.

Regarding assessment of the land areas in scenario one there is manly one area of interest in the port which is Torslandaviken and its surroundings. This area is well explored by ornithologists whom The Port of Gothenburg have collaborations with already. The detailed description of the bird life and the expertise that the local ornithologists possess enables a relatively good quality assessment based on species abundance and distribution. However the creation of a theoretical reference area can be difficult and the abundance of birds can be highly effected by uncontrollable factors which make this assessment method less interesting- Therefore the most efficient way of assessment is due to the naturalness of the ecosystem. However at this moment there is no perfectly suitable assessment method for assessment of the quality as for sea grass meadows or sea weed belt and these methods therefore need to be developed for the prevailing conditions in port and costal environments.

Second scenario

In the second scenario The Port of Gothenburg selects indicators which also can be applied in the municipality of Gothenburg. A considerable difference from scenario one is the scale for which the indicators should be suitable. The large scale limits the level of detail that is possible since a too detailed description will be unrealistic for large areas, nevertheless the indicators used in scenario one could still be functional for the second scenario. Regarding the assessment of marine soft bottoms BHQ is a cost effective solution also in the context of the municipality however the interest in adapting to the water directive is probably higher within the municipality than in the Port and therefore BHQ could be complimented with BQI. According to the water directive this would require five samples of BQI per water body witch in total will be approximately 40 samples. With a combination of the two indices the picture will be both detailed and correct according to the water directive while still being cost efficient. For sea grass meadows and sea weed belts the same assessment can be made as in the first scenario, according to the recommendations from the MARBIPP project. Despite the large scale the assessment will still be relatively cost effective.

For assessment of land areas in the second scenario assessment of naturalness is to prefer rather than species abundance and distribution. The extensive data regarding birds that exists for the areas in The Port of Gothenburg is not available for many other areas in the municipality and therefore it will be unrealistic to use abundance and distribution as the one indicator. Furthermore the difficulties of creating a theoretical reference area will probably increase with a larger area to consider. Since the nature in the municipality consist of many more different types than the port area alone there will be a need to develop templates for assessment of naturalness for several types of ecosystems. However the development will probably be made relatively easy since much of the nature in the municipality consists of different kinds of forest which is a habitat type that is very common in the existing research regarding assessment of naturalness of ecosystems.

In the second scenario Singapore Index on Cities' Biodiversity (CBI) can be considered as an alternative to the Natural Capital Index. However since the municipality of Gothenburg has a relatively extensive and in some areas also award winning environmental work an implementation of the relatively simple CBI will not be a very progressive action and therefore it is probably better to use NCI. This can however be seen differently if the assessment have a more social approach as in the third scenario which will be discussed further below.

Third scenario

In the third scenario the social aspect of sustainability is also considered. The third scenario therefore involve the possibility to use the data collection as a mean to involve citizens and create some kind of citizen science project. Compared to the second scenario the differences in the indicator set do not necessarily need to be considerable however the data collection needs to be adapted to enable citizen involvement. Generally one can say that data gathering is easier for land based habitats than for marine habitats due to the relatively uncommon knowledge required for performing assessment below the water surface. Therefore the initial involvement of citizens is probably limit to land based habitats. Thereby the assessment of marine environment can be made as suggested in the second scenario by use of BQI combined with BHQ for soft bottoms and assessment according to the MARBIPP-project for assessment of sea weed and sea grass meadows.

For assessment of land based habitats there are mainly two options to consider either the use of data from Artportalen or construction of a new reporting system similar to the Hungarian MÉTA program. The later also requires development of instructions enabling quality assessment by amateurs or students. If Artportalen is used the data is already available however there are differences in data availability depending on the location and the animal group. Birds are as an example better documented that amphibious animals. This issue can however be handled with the initiation of projects involving citizens and students. By doing so the data collection will not only be used as a way of assessing the biodiversity but also as a mean to educate citizens and create awareness regarding human effects on biodiversity. (UTVECKLA)

However the use of species abundance with data from Artportalen will not enable an assessment of the number of individuals of respective species due to the high possibility of double counting. Hence the data will only be able to use as a mean to see which species that are present in an area. This information will not be of high validity when assessing the quality of an area and it can be hard to adapt the information to use in Natural Capital Index. Nevertheless the data can be used but it will probably be more relevant to use the Singapore Index on Cities' Biodiversity. As discussed above CBI will, in the case of the municipality of Gothenburg, not be highly useful in order to achieve the objectives of the city however if the main purpose is to involve citizens CBI can be a relatively good option.

Since Artportalen is not providing data perfectly useful for Natural Capital Index the remaining option is inventories based on naturalness or ecosystem structure. This option is not as developed as Artportalen however it have the possibility to be a relatively accurate quality reporting system. By developing simple instructions and models for assessment schools and students can be engaged in the assessment as tried in Hungary and the assessment can be updated on annual basis. In this way the same benefits as for the use of Artportalen can be achieved however it will require initial coordination from the municipality. In return the assessment will both be of higher use and give more accurate information while still being cost efficient.

5.4 Methodology

In the section below the methodology used in the study will be discussed.

5.4.1 Indicator Selection by using a eDPSIR Network

The use of a DPSIR-network was made in order to avoid an indicator selection made on a random manner as argued by Niemeijer & de Groot and others. The method was seen as useful and the connection between the different indicators were made clear. The network also made it easier to see if there was any gaps in the different causal chains and how the different chains were connected to each other. However it was sometimes hard to determine which level of details that were appropriate to include in the network since many of the chains were able to develop much more in detail. Emissions of carbon dioxide have as an example numerous different impacts on the environment however it will be inappropriate to include all the effects even in just costal environment. Still it is important to include the impacts of highest relevance which sometimes can be difficult.

The recommendation of using the different kinds of nodes to find the most suitable places of developing indicators were particularly useful in the cases when the inputs to the indicator came from several diffuse sources where it can be hard to determine which of the sources that have the highest impacts. The nodes was also helpful to make the network more user-friendly since it highlights the part of the network of that is of highest interest. The nodes also make it easier to decide which parts of the network to develop further since they act as clear gates in the network. By enabling comparison between the levels of detail in the different parts of the network the nodes also enabled consideration of the overall context when deciding how well the respective causal chain should be developed.

5.4.2 Stakeholder Interactions

Regarding the indicator selection process the fact that many of the contacted stakeholders were recommended by representatives at the Port of Gothenburg might have affected the result in several ways. A more open scanning for stakeholder might have resulted in new perspectives for the Port and also recommendations of new stakeholders to contact in order to improve the current stakeholder involvement. However it is probably easier to implement new indicators if the stakeholders providing data already have been working with the Port since the contacts already are established. Furthermore this also implies that a stakeholder selection based on recommendations from the Port will make the suggested indicators more realistic which is in line with the aim of this study. A more open minded selection would also have been more time consuming since it would be harder to find the different stakeholders and probably more difficult to establish contacts.

The selection naturally effected the results of the study and in many cases the recommended indicators from a stakeholder could have expected before the interview since the stakeholders mainly represented different organizations that also are working according to and offering certain types of assessments. Therefore it was important to remain objective and assess the different indicators from a scientific base as have been made above.

The different interviews contributed with information in many ways however the main input to the study was not the pure information that was given but the different stakeholders' view of the information. Most of the information given could have been found in other sources primarily literature of different kinds. However literature is mostly written in a more general context, the stakeholder on the other hand were able to adapt their knowledge to the circumstances in the Port of Gothenburg and more exactly how the data collection can be carried out. Since the different stakeholders had the possibility to describe their work and interest more in depth the interviews with the stakeholders gave important insight in which stakeholders to involve and in which ways.

6 Conclusions

In this section a presentation of the main conclusions drawn from the discussion above will presented. Furthermore, recommendations for future research will also be presented.

Regarding the methodology used in the study the use of a causal network was proven to be highly suitable for developing indicators. Especially when working with such a complex topic as biodiversity. By the usage of the causal network it was ensured that the different aspect of biodiversity were connected and thereby a selection on a random manner was avoided.

Regarding indicators at a pressure level it can be concluded that indicators of pressures on a global scale are used, while indicators focusing on effects on biodiversity in a local perspective is few. Some indicators such as noise in green areas and release of untreated ballast water have however the potential to be implemented in relatively short term.

The Natural Capital Index was in comparison with other indicators the most suitable choice for all the three scenarios investigated. The main benefits with the index is that it is highly suitable for several different kinds of originations and scales and thereby enabling both citizen involvement and a relatively high cost efficiency. The difficulties regarding the index was due to the quality assessment of an ecosystem and in particularly the creation of a theoretical reference area.

Quality assessment of ecosystem can be made in several ways, however, assessment of naturalness is probably the most suitable method in order to enable assessment at different scales. The concept is easily understood, is relatively simple, and by setting criteria for both degraded and virgin ecosystems, the creation of a theoretical reference area is unnecessary. Furthermore, with clear descriptions of assessment criteria a relatively accurate assessment can be made by common people enabling citizen participation. The descriptions need to be further developed and preferably agreed upon with different stakeholders preferably on a high decision level.

6.1 Future research

In the study several areas have been identified where future research is needed. The first recommendation regards the development of a Swedish system for reporting of naturalness assessment of habitats in order to use it as input for calculations of Natural Capital Index. This research would involve creation of criteria for assessment of naturalness in Swedish nature types and the criteria would beneficially be developed both for use by professionals but also enable assessment by common citizens or students. Furthermore, the research would also involve the creation of a reporting system which will enable gathering and overviews of the data.

Regarding the spreading of non-indigenous species, ballast water has gained a lot of attention during recent years however hull fouling have the same magnitude of impacts but is less investigated. Therefore, a recommendation is to investigate this area more in detail in order to find means for assessment of the hull fouling and solutions of the problem.

7 Recommendations

In this section the recommendations for the Port of Gothenburg will be presented. Firstly, recommendations for assessment of pressure on biodiversity will be presented and this recommendation is valid regardless of which of the three scenarios the Port chooses to go further with. Finally, three different recommendations regarding assessment of biodiversity depending on which scenario that is chosen.

Due to the complexity of biodiversity it is hard to assess all impacts from the port and its operations however some indicators can be added to the prevailing set of indicators used by the Port of Gothenburg. Firstly, the Port of Gothenburg is recommended to start assessing noise it its nature areas, preferably by assessment in the unit dB(A). Secondly, the Port of Gothenburg is also recommended to start assessment of underwater noise in its area of impact. Thirdly, the Port of Gothenburg is recommended to further investigate the possibilities of using the amount of untreated ballast water from ocean going vessels both in order to see the magnitude of the problem but also to see which effects the coming implementation of the Ballast Water Convention will have.

For assessment of biodiversity the recommendation differs depending on which of the three scenarios that will be chosen to work further with. The recommendations are;

First scenario

If the Port of Gothenburg aims to use the indicator of biodiversity independent from the municipality of Gothenburg the recommendation is an implementation of Natural capital index. The index will be based on naturalness for land areas, Benthic Habitat Quality (BHQ) for soft sediment bottoms and quality assessment of sea grass meadows and sea weed belts according to the MARBIPP assessment criteria. The naturalness assessment of land areas will require a certain level of method development.

An alternative to the naturalness assessment of land areas can be the use data for bird populations in Torslandaviken which will require development of a theoretical reference area.

Second scenario

If the Port of Gothenburg aims to use the indicators of biodiversity in collaboration with the municipality of Gothenburg the recommendation is an implementation of Natural Capital Index. The index will be based on naturalness for land areas, Benthic Quality Index (BQI) complimented with Benthic Habitat Quality (BHQ) for soft sediment bottoms and quality assessment of sea grass meadows and sea weed belts according to the MARBIPP assessment criteria. The naturalness assessment of land areas will require a certain level of method development mainly for coastal areas.

Third scenario

If the Port of Gothenburg aims to use the indicator in collaboration with the municipality of Gothenburg as a mean to both get assess biodiversity and to involve citizens and create social projects the recommendation is an implementation of Natural Capital Index. The quality assessment will be made as in the second scenario with the addition that a creation of a reporting system and instructions inspired by the Hungarian MÉTA project will be necessary.

If the main objective is citizen involvement and not biodiversity assessment Singapore Index of Cities' Biodiversity can be used as an alternative to Natural Capital Index. This will enable citizen involvement by use of data from Artportalen.

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Appendix I - Bellagio STAMP

(Pintér, et al., 2012)

Guiding vision

Assessment of progress toward sustainable development will be guided by the goal of delivering well-being within the capacity of the biosphere to sustain it for future generations.

Essential considerations

Assessment of progress toward sustainable development will consider:
- the underlying social, economic and environmental system as a whole and the interactions among its components, including issues related to governance;
- dynamics and interactions between current trends and drivers of change;
-risks, uncertainties, and activites that can have an impact across boundaries;
- implications for decision making, including trade-offs and synergies

Adequate scope

Assessment of progress toward sustainable development will adopt:
- an appropriate time horizon to capture both short- and long-term effects of current policy decisions and human activities;
- an appropriate geographical scope.

Framework and indicators

Assessment of progress toward sustainable development will be based on:
- a conceptual framework that identifies the domains within which core indicators to assess progress are to be identified;
- standardized measurement methods wherever possible, in the interest of comparability;
- comparison of indicator values with targets, as possible.

Transparency

Assessment of progress toward sustainable development will:
- ensure the data, indicators and results of the assessment are accessible to the public;
- explain the choices, assumptions and uncertainties determining the results of the assessment;
- disclose data sources and methods;
- disclose all sources of funding and potential conflicts of interest.

Effective communication

In the interest of effective communication, to attract the broadest possible audience and minimize the risk of misuse, assessment of progress toward sustainable development will:

- use clear and plain language;
- present information in a fair and objective way that helps to build trust;
- use innovative visual tools and graphics to aid interpretation and tell a story;
- make data available in as much detail as is reliable and practicable.

Broad participation

To strengthen its legitimacy and relevance, assessment of progress toward sustainable development should:
- find appropriate ways to reflect the views of the public, while providing active leadership;
- engage early on with users of the assessment so that it best fits their needs.

Continuity and capacity

Assessment of progress toward sustainable development will require:
- repeated measurement;
- responsiveness to change;
- investment to develop and maintain adequate capacity;
- continuous learning and improvement.

Appendix II – Description Niemejer & de Groot

(Niemeijer & de Groot, 2008 A)

Scientific dimension	
Analytically soundness	Strong scientific and conceptual basis
Credible	Scientifically credible
Integrative	The full suit of indicators should cover key aspects/components/gradients
General importance	Bear on a fundamental process or widespread change
Historic dimension	
Historical record	Existing historical record of comparative data
Reliability	Proven track record
Systemic dimension	
Anticipatory	Signify an impending change in key characteristics of the system
Predictable	Respond in a predictable manner to changes and stresses
Robustness	Be relatively insensitive to expected source of interference
Sensitive to stresses	Sensitive to stresses on the system
Space-bound	Sensitive to changes in space
Time-bound	Sensitive to changes within policy time frames
Uncertainty about level	High uncertainty about the level of the indicator means we can really gain something from studying it
Intrinsic dimension	
Measurability	Measurable in qualitative or quantitative terms
Portability	Be repeatable and reproducible in different contexts
Specificity	Clearly and unambiguously defined
Statistical properties	Have excellent statistical properties that allow unambiguous interpretation
Universality	Applicable to many areas, situations, and scales
Financial and practical dimensions	
Costs, benefits and cost-effectiveness	Benefits of the information provided by the indicator should outweigh the costs of usage
Data requirements and availability	Manageable data requirements (collection) or good availability of existing data
Necessary skills	Not require excessive data collection skills
Operationally simplicity	Simple to measure, manage and analyse
Resource demand	Achievable in terms of the available resources
Time demand	Achievable in the available time
Policy and management dimensions	
Comprehensible	Simply and easily understood by target audience
International compatibility	Be compatible with indicators developed and used in other regions
Linkable to societal dimension	Linkable to socio-economic developments and societal indicators
Links with management	Well established links with specific management practise or interventions
Progress towards targets	Links to quantitative or qualitative targets set in policy documents
Quantified	Information should be quantified in such a way that it significance is apparent
Relevance	Relevance for the issue and target audience at hand
Spatial and temporal scales of applicability	Provide information at the right spatial and temporal scales
Thresholds	Thresholds that can be used to determine when to take action
User-driven	User-driven to be relevant to target-audience

Appendix III – Description Normander et.al

(Normander, et al., 2012)

Number	Criteria	Explenation
1.	Repetative and good coverage	Includes a large enough or representative group of species and has a good spatial coverage
2.	Temporal and up-to-date	Shows temporal trends and can be updated routinely, e.g. annually
3.	Simplifying information	Summarises a complicated phenomenon into a simple and intelligible form
4.	Clear presentation	Possible to display clear messages with eye-catching graphics
5.	Indicative	Indicates changes in a broader scale
6.	Sensitive	Measured qualities are more sensitive to change than their environment (i.e. early warning)
7.	Quantitative and statistically sound	Based on real quantitative observations and statistically sound data collection methods
8.	Relatively independent of sample size	Usable data may be obtained even with relatively small sample sizes
9.	Realistic	Based on existing monitoring programmes. Implementation is economically feasible
10.	User-driven and acceptable	Responds to the needs of stakeholders and is broadly accepted amongst them
11.	Normative and policy relevant	Linked to politically set goals and baselines. Enables assessing progress towards targets.
12.	Not sensitive to background changes	Buffered from natural fluctuations. Measures changes caused by humans
13.	Explainable	The impact and significance of the change measured by the indicator must be known
14.	Predictable	May be forecast and linked to socio-economic models
15.	Comparable	Enables comparison (e.g. benchmarking of countries)
16.	Aggregatable and disaggregatable	Data may be aggregated and disaggregated into different levels (e.g. country vs. community)

Appendix IV – Interview Questions

Example of interview questions. These examples were used at the interview with the Assistant Professor in Biopollution at Chalmers University of Technology.

Allmänna frågor

Hur definierar du främmande eller invasiva arter?

Definition of Non-indigenous species (NIS) (EU-rapport) – inkluderar inte arter som spridits av naturliga skäl ex. via ocean strömmar eller klimatförändringar. Klimatförändring möjliggör etablering för främmande arter är dessa då inte främmande?

Hur omfattande är idag problemen med främmande arter?

Hur stor är problemet med invasiva arter via solid ballast (sten, sand etc)?

Vart tömmer fartyg barlastvatten? I hamnar? I Göteborgs hamn?

Hur ser möjligheterna ut att begränsa spridningen av en art när den väl har hittats i ett område? Exempelvis alger.

Giftiga invasiva alger? Är detta ett nytt fenomen i ex. Östersjön? Hur mycket av problemen med algblomningar bidrar främmande arter till?

Kommentarer på Gurevitch & Padilla? Att invasiva arter i sig inte behöver orsaka utdöende hos arter utan att de kan få sin spridning eftersom ex. markanvändningen ändras eller övergödningen ökar och att det då finns förutsättningarna för spridningen? Då är det inte arten i sig som orsakar utdöende av lokala arter.

Hur ser spridningen av svenska arter ut till andra områden? Har detta skapat några problem?

Vad är de störa ekonomiska inverkningarna från invasiva arter?

Vad finns det för lösningar på problemet med invasiva arter?

Vilka lösningar finns det för påväxt på skrov? Hur är potentialen i exempelvis användningen av robotar för rengöring av skrov? Hur ofta bör detta göras i så fall? (Hur snabb sker påväxt?)

Fungerar det att byta barlastvatten i vissa zoner eller har det bara effekt på vissa arter?

Indikatorer

Vilka indikatorer/metoder används idag för att mäta spridningen av främmande arter? Fördelar/nackdelar?

Vilka indikatorer kan användas i framtiden för att mäta spridningen av främmande arter? Fördelar/nackdelar?

I ex. Göteborg stads miljömål om minskad påverkan från sjöfarten nämns endast barlastvatten som en bärare av invasiva arter. Hur fel är detta? Vad behöver man komplettera med?

Biopollution level index? Vad är det? Hur funkar den? Vad består den största kritiken av?

Appendix V – Indicators Environment, the Port of Gothenburg 2014
(Göteborgs Hamn, 2015)

ENVIRONMENT

Onshore power supply
Percentage of vessels calling that can connect onshore power
Percentage of laytime when onshore power can be used
Quantity consumed, MWh
Environmental benefits:
Sulphur dioxide, tonnes
Nitric oxide, tonnes
Particulates tonnes
Carbon dioxide, tonnes

Environmentally-differentiated port tariff
Number of vessels participating in the sulphur programme
Environmental benefits of the sulphur programme:
Sulphur dioxide, tonnes
Nitric oxide, tonnes
Particulates, tonnes

Shipping emissions in Gothenburg Municipality
Sulphur dioxide, tonnes
Nitric oxide, tonnes
Particulates, tonnes
Carbon dioxide, tonnes
Hydrocarbons, tonnes

Climate and energy consumption
Gothenburg Port Authority’s total emission of greenhouse gases - direct tonnes of carbon dioxide equivalents
Gothenburg Port Authority’s total emission of greenhouse gases – indirect energy tonnes of carbon dioxide equivalents
Total emissions of greenhouse gases – other indirect
tonnes of carbon dioxide equivalents
Diesel working vessels, litres
Diesel production vehicles, litres
Petrol production vehicles, litres
Vehicle gas, Nm3 , production vehicles
Natural gas buildings, MWh
Diesel fire pump, litres
Electricity, MWh
District heating, MWh
Heating of pipes MWh
Electrical efficiency, kWh/m2

Energy Port’s workshop / buiding 510
Amerikaskjulet, HK / building 036
Galären / building 660
Building 642

Key figures relating to our immediate environment
VOC emissions in Energy Port, tonnes
Number of discharges to ground outside safety systems
Estimated amount, oil products, litres
Number of discharges to surrounding water
Estimated amount, oil products, litres

Appendix VI - Singapore Index on Cities´ Biodiversity

(CBD, 2010)

Core components	Number	Indicators	Maximum Score
Native Biodiversity in the City	1.	Proportion of Natural Areas in the City	4
	2.	Connectivity Measures	4
	3.	Native Biodiversity in Built Up Areas (Bird Species)	4
	4.	Change in Number of Vascular Plant Species	4
	5.	Change in Number of Bird Species	4
	6.	Change in Number of Butterfly Species	4
	7.	Change in Number of Species (any other taxonomic group selected by the city)	4
	8.	Change in Number of Species (any other taxonomic group selected by the city)	4
	9.	Proportion of Protected Natural Areas	4
	10.	Proportion of Invasive Alien Species	4
Ecosystem Services provided by Biodiversity	11.	Regulation of Quantity of Water	4
	12.	Climate Regulation: Carbon Storage and Cooling Effect of Vegetation	4
	13.	Recreation and Education: Area of Parks with Natural Areas	4
	14.	Recreation and Education: Number of Formal Education Visits per Child Below 16 Years to Parks with Natural Areas per Year	4
Governance and Management of Biodiversity	15.	Budget Allocated to Biodiversity	4
	16.	Number of Biodiversity Projects Implemented by the City Annually	4
	17.	Existence of Local Biodiversity Strategy and Action Plan	4
	18.	Institutional Capacity: Number of Biodiversity Related Functions	4
	19.	Institutional Capacity: Number of City or Local Government Agencies Involved in Inter-agency Co-operation Pertaining to Biodiversity Matters	4
	20.	Participation and Partnership: Existence of Formal or Informal Public Consultation Process	4
	21.	Participation and Partnership: Number of Agencies/Private Companies/NGOs/Academic Institutions/International Organisations with which the City is Partnering in Biodiversity Activities, Projects and Programmes	4
	22.	Education and Awareness: Is Biodiversity or Nature Awareness Included in the School Curriculum	4
	23.	Education and Awareness: Number of Outreach or Public Awareness Events Held in the City per Year	4
		Native Biodiversity in the City (Sub-total for indicators 1-10)	40
		Ecosystem Services provided by Biodiversity (Sub-total for indicators 11-1	16
		Governance and Management of Biodiversity (Sub-total for indicators 15-	36
		Maximum Total:	92

For more information see Guidelines for Singapore Index for Cities' Biodiversity. (CBD, 2010).

Appendix VII - Levels of Forest Stand Naturalness

(Saudytë, et al., 2005)

	Levels of forest stand naturalness					
Criteria	**Virgin forest (primeval forest)**	**Natural forest**	**Semi natural forest (near natural forest)**	**Semi cultural forest**	**Cultural forest**	**Artificial forest (plantation, park)**
origin	natural	natural	natural, mixed	afforestation, mixed, natural	afforestation, mixed	afforestation
stand tree species composition	species of climax communities is dominant	characteristic to the site species prevail, succession communities tree species might dominate	admixture of singe site type non characteristic but native tree species is possible	domination of natural site type non characteristic native and admixture of non native tree species is possible	domination of site type non characteristic and non native tree species is possible	domination of site type non characteristic and non native tree species is possible
mixture of the stand	mixed, except extreme site conditions	mixed, except extreme site conditions	mixed, except extreme site conditions	unmixed (one tree species) stand possible	unmixed stand possible	usually unmixed
forest continuation (time of forest existence on the particular area)	continuous forest cover	more than two forest stand generations	more than one forest stand generation	more than one forest stand generation	forest is >20 years	no limits
stand age structure	absolutely or conditionally mixed aged	mixed aged or conditionally single aged	mixed aged or conditionally single aged	might be single aged, but in young stands old growth trees should be observed	might be single aged	usually – single aged
stand spatial structure	two or multi-storey with exception of stands on extreme site conditions	multi-storey, young and premature stands might be single storey	might be single storey stand	might be single storey stand	might be single storey stand	usually – single storey stand
impact to the site: drainage	not drained	not drained	might be drained long time > 60 years ago	might be drained > 30 years ago	might be drained recently	might be drained
fertilisation	not carried out	not carried out	might be carried out > 20 years ago	might be carried out recently	might be carried out recently	might be carried out
damage of the upper soil layer	no signs	no signs	not significant signs of soil damage conducted during the cuttings or afforestation works	significant soil damage by scarification is possible	various damages are possible	various damages are possible
border with agricultural lands	not possible	not characteristic	might be possible	might be possible	might be possible	characteristic
impact to the stand: clear cuttings	never carried out	not carried out for >100 years	not carried out for >70 years	not carried out for >10 years	might be carried out recently	carried out
impact to the stand: final non clear cuttings	never carried out	not carried out for >50 years	carried out only selective cuttings	carried out various not clear cuttings	carried out various not clear cuttings	carried out
impact to the stand: sanitary cuttings	not carried out	not carried out for >50 years	carried out leaving number (part) of dead standing trees	carried out intensively	carried out intensively	carried out intensively
impact to the stand: thinning	not carried out	not carried out for >50 years	carried out by forming characteristic of natural stands composition	carried out	carried out	carried out
standing and lying deadwood	dead standing and dead lying wood of various decay stages is abundant	dead standing and dead lying wood of various decay stages is abundant	dead standing and lying dead wood is present	recently died standing trees and single old lying trees might be present	only recently died standing trees might be present	only recently died standing trees might be present
forest community's composition and structure of lower layers	composition and structure characteristic of the site type	composition and structure characteristic of the site type	composition characteristic of the site type	composition characteristic of the forest environment	composition might be not characteristic of the forest environment	not characteristic of the forest environment

Appendix VIII - Index for Naturalness

(Machado, 2004)

[10] Natural virgin system; only natural elements and processes. Possible anecdotal presence of negligible or hardly noticeable anthropic elements, or totally insignicant physical-chemical pollution coming from exterior anthropic sources

[9] Natural system; presence of few exotic biological elements (no qualitative effects); minimal articial infrastructure, temporary or removable. Physical-chemical pollution absent or of no signicance

[8] Sub-natural system; possible extended presence of wild exotic species, but not dominant (low impact); articial elements located, not extensive. Occasional pollution processed by the system (does not go beyond resilience). Possible minor extraction of renewing resources. Fragmentation irrelevant. Natural dynamic little altered

[7] Quasi-natural system; extensive anthropic activities of low physical impact; facilities if present, dispersed, not connected; wild exotic species well established but not dominant; natural structures modied but not distorted (re-location of physical or biotic elements). Moderate extractions, if present. Little alteration of water dynamics

[6] Semi-natural system; anthropic infrastructure scarce or concentrated; possible dominance of wild exotic species; native elements considerably reduced. Occasional addition of energy and/or extraction of renewable resources or of non-relevant materials. General dynamic still controlled by natural processes. It may include abandoned cultural systems undergoing natural recovery

[5] Cultural self-maintained system; processes conditioned by extensive activities of man; biological production not too forced. Native species altered, occasionally managed. Little or no presence of constructions or artefacts. Little or no management of water cycle (passive)

[4] Cultural assisted system; important infrastructures and/or conditioning of the physical environment; forced biological production; moderate addition of matter (usually with pollution associated). Natural elements intermixed, in patches or corridors. Active management of water

[3] Highly intervened system: still areas with biological production (natural/cultivated/breeding) mixed (mosaic) with buildings and infrastructures. Natural biodiversity severely reduced; its elements rather isolated (intense fragmentation). Water dynamic manipulated. Geomorphology usually altered; soils eventually removed

[2] Semi-transformed system; biological production not dominant, disarticulated. Predominance of constructed elements. Occasional moderate vertical development of facilities. Intensive input of energy and matter (food, water) from the outside. Intensive control of water

[1] Transformed system; anthropic processes governing; clear dominance of articial elements; frequent intensive vertical development; vestiges of natural elements; those exotic confined, decorative or not visible. Full dependence of external inputs of matter and energy. Absolute control of waters

[0] Articial system; high closure; without self-maintained macroscopic life; microscopic life absent or in containers

Appendix IX – MARBIPP descriptions

Translation of MARBIPP criteria for sea grass meadows, also including a suggested naturalness level:

Class	Suggested Naturalness Level	Level of Disturbance	Description
1	100%	Insignificat affected	Sea grass common until 8 m depth
			The biomass of a sea grass leaf is close to 400g dry weight/m2
			No algal mats exists
			Adults amphipods (*Gammarus locusta*) are numerous (100 indiv./m^2)*
			Very high number of seagrass associated animals
2	75%	Slightly affected	Sea grass common until 6 m depth
			The biomass of a sea grass leaf is close to 200 g dry weight/m^2
			Small algal mats exists sporadically
			Adults amphipods are common (50 ind/m^2)*
			High number of seagrass associated animals
3	50%	Clearly affected	Sea grass exists until 5 m depth
			The biomass of sea grass leaf is close to 100 g dry weight/m^2
			Large algal mats are common, sulfur bacteria exists
			Adults amphipods are rare (<10 ind/m^2)*
			Reduced number of seagrass associated animals
4	25%	Considerably affected	No sea grass under 3 m deapth
			Only singe sea grass exists (<50 g dry mass/m^2)
			Algmattor dominerar botten, vanligt med svavelbakterier
			Aduld amphipods do not occure*
			Low number of seagrass assoiated animals
			Non or very little living sea grass
			Non of very low number of seagrass associated animals
5	0%	Comunity extinct	The bottom is either covered with algal mats and sulfur bacterial mats, or the sediment is bare and exposed to erosion

Translation of MARBIPP criteria for sea weed belts, also including a suggested naturalness level:

Class	Suggested Naturalness level	Level of disturbance	Description
1	100%	High ecological status	The sea weed vegetation uneffected, or only unsignifically effected.
			Dense stands of bladderwrack (Fucus vesiculosus) and / or knottedwrack (Ascophyllum nodosum).
			Any fouling of brown and red algae only in the rare case of green algae or a few filter feeders.
			The undergrowth is varied.
			On exposed premises the bladderwrack may be without bladders.
			Deeper follow toothed wrack (Fucus serratus), Pod weed (Halidrys siliquosa) and species of kelp (Laminaria spp.).
2	75%	Good ecological status	The sea weed vegetation slightly effected.
			Dense stands of bladderwrack (Fucus vesiculosus) and / or knottedwrack (Ascophyllum nodosum) still exists.
			Existing fouling cosists of brown and red algae and some green algae filter feeders.
			The number of green algae is slightly higher than for high ecological status.
			The undergrowth is varied.
			On exposed premises the bladderwrack may be without bladders.
			Deeper follow toothed wrack (Fucus serratus), Pod weed (Halidrys siliquosa) and species of kelp (Laminaria spp.).
3	50%	Moderate ecological status	The sea weed vegetation significantly effected.
			Sperse stands of bladderwrack (Fucus vesiculosus) and / or knottedwrack (Ascophyllum nodosum) still exists alongside green algae.
			Porphyra (Porphyra purpurea) can be common during parts of the year.
			Seaweed plants are overgrown with green algae and / or filtering animal.
			The deepest growing plants of kelp (Laminaria saccharina) are a depth of 4-5 m.
			The total number of species is lower and more sensitive species have disappeared compared to good ecological status.
4	25%	Unsatisfying	Strongly effected algal communities.
			Few examples of bladderwrack, ofter largly overgrown by algae and filtering animals.
			The most common fouling algae is different green algae species of Chlorophyta (Ulva) and green algae (Cladophora spp.).
			Among filtering fouling animals dominate various bryozoans, mussels and barnacles.
			Drifting algal mats can be common.
			The total number of species are drastically reduced compared to moderate ecological status.
5	0%	Bad ecological status	The annual brown algae community is eliminated.
			Very few species in the community.
			Algae vegetation is dominated by green algae.
			The most common algae is different green algae species of Chlorophyta (Ulva) and green algae (Cladophora spp.).
			Drifting algal mats is common.
			In some cases, only cyanobacteria and other bacteria exists.