The use of the Ecosystem Services approach in Protected Area management

Christiaan Hummel

The artwork on the front and back of the cover represents a landscape. This landscape is composed of photos which I took during my travels through different countries. Represented in the artwork are:

+ Camargue, France
+ La Palma, Spain
+ Oosterschelde, The Netherlands
+ Curonian Snit, Lithuania

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Chapter 1 - General Introduction

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Chapter 1 – General Introduction

1

Motive and outline of this thesis

In a world with advancing climate change and industrialisation, a growing population, and ever- expanding cities, Protected Areas (PA) are often regarded as the best way of stopping many (threatened) species from becoming extinct (Dudley et al., 2013). Protected Areas could be considered as islands of healthy functioning nature in the middle of human disturbance. Sometimes they are even said to be the only hope for humans to survive - (Azoulay, 2021). Although many would not go as far as previous statement, there is agreement that Protected Areas play a key role in the conservation of nature.

Ecosystem Services and Societal Goods & Benefits
Next to nature's intrinsic value, a properly functioning nature is also important to mankind as a resource of Ecosystem Services (ES) that may yield Societal Goods and Benefits (SG&B). Resources and benefits that people derive from nature can be seen as services that nature, or ecosystems, provides us with, hence the term Ecosystem Services. Although there are many different definitions of what Ecosystem Services are and are not, all definitions have in common that Ecosystem Services can be regarded as usable products and benefits to satisfy the needs of society, produced by ecosystems (Daily, 1997; Costanza et al., 1997; De Groot et al., 2002; MEA, 2005; Boyd and Banzhaf, 2007; Fisher and Turner, 2008; Haines-Young and Potschin, 2010; TEEB, 2010; Harrison et al., 2010; Staub et al., 2011; Landers and Nahlik, 2013; Haines-Young and Potschin, 2013).
These usable products and benefits may include goods such as firewood, fish or mushrooms, that may yield direct economic benefits when sold, but also less tangible goods and benefits such as recreation, education, scenery or religious sanctuaries (Liu et al., 2001; Parrish et al., 2003; Brooks et al., 2004; Rodrigues et al., 2004; Chape et al., 2005; Campos & Nepstad, 2006; Coad et al., 2008; Dudley, 2008; Wild & McLeod, 2008; Butchart et al., 2010; Cardelús et al., 2013; Scull et al., 2017).
In the marine field, a continuum is proposed whereby ecosystem structure leads to Ecosystem Functions (EF) that in turn produce Ecosystem Services. Obtaining Societal Goods & Benefits from those Ecosystem Services require an input of time, energy, money and/or skills (Turner and Schaafsma, 2015; Scharin et al., 2016; Elliott et al., 2017; Burdon et al., 2018). For example, a fully functioning sea can produce fish, but it is still necessary for society to learn how to catch and use those fish.

Protected Areas
Protecting what is important to mankind already came to the foreground in ancient history. For example, from 322 BC to 187 BC, Asian elephants were protected by the Mauryan kings, because it was easier and cheaper to capture elephants in the wild and train them, than to raise them in captivity (Rangajaran, 2005).

During the period of colonialism (1600-1800), the colonists realised that degradation of the natural system could seriously threaten the output of the land. After a period of degradation they set about to restore the natural system and in this way diminish further degradation to sustain the economic output of the colonies.
As Grove (1996) writes on page 6 of his book Green Imperialism: "... a coherent and relatively organized awareness of the ecological impact of the demands of emergent capitalism and colonial rule started to develop, to grow into a fully- fledged understanding of the limited nature of the earth's natural resources and to stimulate a concomitant awareness of a need

for conservation".The first Protected Areas founded in more recent times were founded primarily for recreation: Yosemite National Park, in 1864, and Yellowstone National Park, 1872.

The reasons for protecting a certain area may vary greatly. On the one hand, Protected Areas may be set up to protect resources directly needed by humans, such as the Mauryan kings did with elephants. On the other hand, they may exist to protect certain unique land- or seascapes, either for the intrinsic value, or the human recreational value (Adams & McShane, 1996; Draper et al., 2004; Phillips, 2007). Nowadays, Protected Areas are set up and managed for many different reasons: protection of species, habitat protection, catchment protection, tourism, recreation, research, education, or to protect important non-material and aesthetic values such as nice views or sacred places (IUCN, 2004). Although there are many different reasons for protecting nature in a Protected Area, they all have in common the protection of material or non-material aspects that humans need from nature or connect them to nature.

Because Protected Areas are mainly set up to protect natural features that are useful to support a healthy functioning ecosystem as well as a prosperous society, it would seem logical to combine Protected Area management with the Ecosystem Services concept (which includes possibly obtaining Societal Goods and Benefits from Protected Areas). However, not only the use of the Ecosystem Services concept to describe primarily the Societal Goods and Benefits humans can get from nature is frequently debated, but also how this concept may improve our insight and opinions on the importance of nature itself is regularly questioned (McCauley, 2006; Turnhout et al., 2013). Using an Ecosystem Services approach in Protected Area management is sometimes even said to lead the Protected Area management away from protecting the intrinsic value of nature (Sagoff, 2004; Redford and Adams, 2009; McAfee and Shapiro, 2010).Therefore, in this PhD thesis, I investigated whether the protection offered by Protected Areas could benefit from using the Ecosystem Services concept.

The overarching aim of my PhD research, as described in this thesis, is to assess if the use of the Ecosystem Services concept in Protected Area management could help to improve the protection given by Protected Areas. This leads to the overarching research question:

Does the use of the Ecosystem Services concept in Protected Area management help to enhance the protection level of Protected Areas?

To answer this overarching research question, a number of objectives were formulated to investigate during my PhD research.

+ The first objective, discussed in detail in chapter 2, is to indicate the theoretical feasibility of introducing the Ecosystem Services concept in Protected Area management. This led to a number of conclusions and recommendations for the way forward.

+ The second objective, discussed in chapter 3, is to understand whether in daily practice the major stakeholder groups involved in Protected Area research and management speak the same language. A "common" language to jointly discuss issues at stake in a Protected Area is needed to properly introduce any new concept in Protected Area management. This led to recommendations on harmonisation of communication.

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- The first and second objective led to the third objective, to introduce Fuzzy Cognitive Modelling (FCM) as a method to enhance the communication on essential aspects in Protected Areas and to incorporate views of a wide array of stakeholders into Protected Area management. This is discussed in detail in chapter 4.

- The previous objectives led to the fourth objective, to assess what information is required to manage Protected Areas effectively and enhance their protection level. It appeared that a large number of frameworks already existed to measure management effectiveness of a Protected Area, but most of them were installed in a top-down fashion, and (virtually) none for measuring the protection level of a Protected Area with ample inclusion of ecosystem functions and services to society. Therefore, a new Protection Level Index (PLI) was developed in close cooperation with Protected Area managers in a bottom-up process to include essential environmental information. This is discussed in detail in chapter 5.

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The relation between the different chapters in this thesis is also depicted in figure 1.1. The contents of the different chapters will be discussed in more detail after picture 1.1.

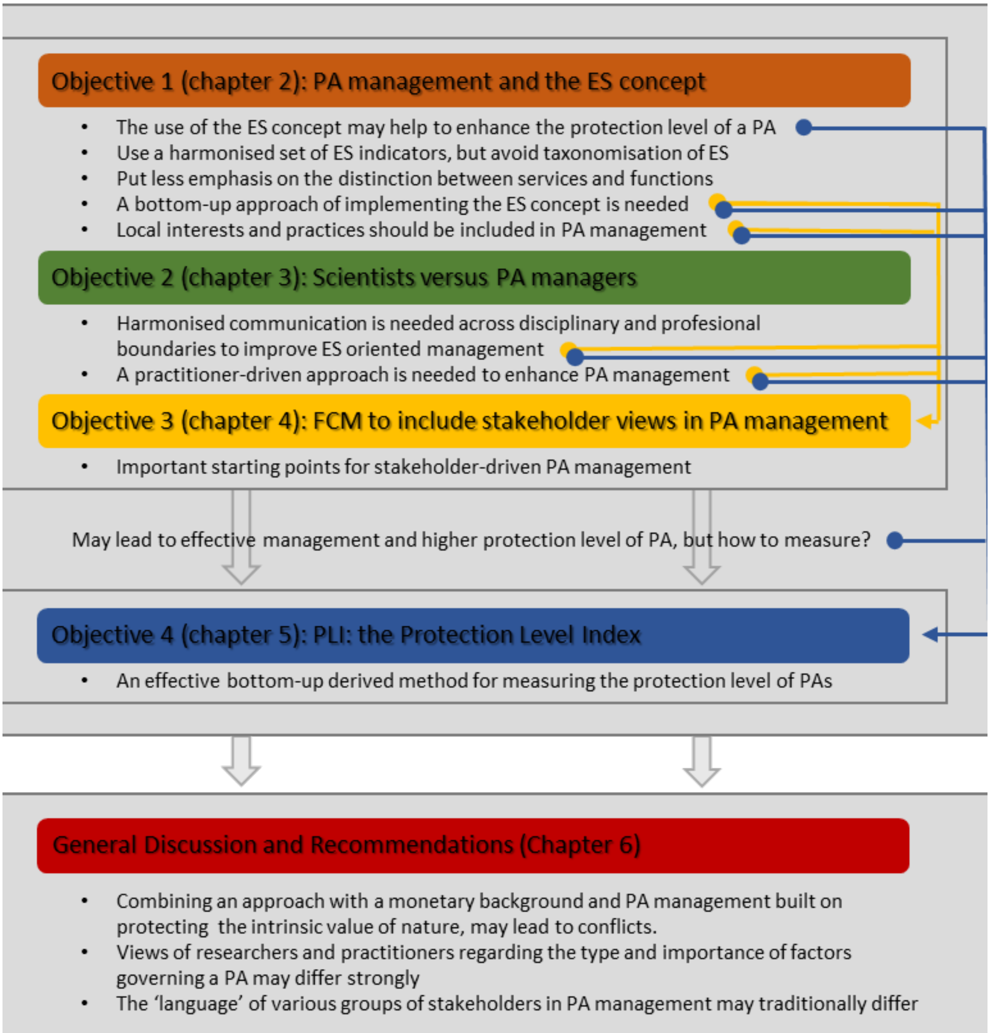

Figure 1.1: The relation between the different chapters of this PhD thesis, (PA = Protected Area; ES = Ecosystem Services; FCM = Fuzzy Cognitive Models; PLI = Protection Level Index)

Chapter 2: Protected Area management and the Ecosystem Services approach

My research started with a literature review concerning the historical background of Protected Areas, Protected Area management, and the Ecosystem Services concept. It includes an extensive discussion on the relevance and applicability of the Ecosystem Services concept for Protected Area management, including the different definitions of Ecosystem Services, different classification methods, and the different ways in which Ecosystem Services can be measured. The conclusion is that including the Ecosystem Services concept in Protected Area management could be useful, because the Ecosystem Services framework makes clear to society that people are highly dependent on nature. Therefore, recommendations for the way forward on the application of the Ecosystem Services approach in Protected Area management are given, as follows:

+ Develop a standardised set of indicators for the assessment of Ecosystem Services in Protected Areas, but avoid trying to systematically classify Ecosystem Services (taxonomisation).
+ Avoid too much distinction between ecosystem functions and services
+ Focus on a bottom-up approach for implementing the Ecosystem Services concept in Protected Area management
+ Include local interests and practices in Protected Area management

Chapter 3: The difference between scientists involved in Protected Area research and Protected Area managers

To be able to enhance the protection of nature it is important that research on Protected Areas is performed in a proper and comprehensible way to yield results that can support effective management decisions. For the optimal protection of a Protected Area it is essential to account for the variables underlying the major ecosystem functions and structures in the area, the Ecosystem Services it delivers, and the threats acting upon them. Therefore, the second chapter of my thesis deals with the commonalities and differences in perception of important variables to measure in Protected Areas among scientists, involved in Protected Area research, and Protected Area managers. The perception of these important variables is, however, shown to differ markedly between scientists and managers, in both mountainous and coastal (transitional waters) Protected Areas. Scientists emphasise variables of abiotic and biotic nature, whereas managers indicate socio- economic, cultural and anthropogenic variables being more important.
Therefore, greater and harmonised communication across disciplinary and professional boundaries is needed to implement and improve Ecosystem Services-oriented management strategies in Protected Areas. To this end, a bottom-up way of approaching Protected Area management is needed.
We conclude that Protected Area managers should be the starting point of this

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bottom-up approach, because scientists tend to have their own “pet subjects”, whereas the managers agree more amongst each other on what is important in Protected Areas.

Chapter 4: A stakeholder driven view of Protected Areas

Since stakeholders may actively oppose or support certain nature conservation actions, they are important in determining the success of Protected Area management activities, (Panda, 1999). Including stakeholders in the development of Protected Area management could help the managing process by elucidating potential conflicts between them that may stand in the way of proper management and protection of the Protected Area. Therefore, the inclusion of stakeholders with regard to management could be essential to the success or failure of a Protected Area. Stakeholder co-design is also helpful to identify aspects and areas where future research should be focused on (Jetter and Kok, 2014).
Fuzzy Cognitive Models (FCM) were used to map the knowledge and perception among various stakeholders regarding the Wadden Sea, one of the most important Protected Areas in the Netherlands. FCM were used since they elucidates the level of importance of the prime governing factors and their positive and negative interactions in a Protected Area in a user-friendly fashion. Thereby FCM yields important starting points for stakeholder co-design, and practitioner driven, Protected Area management.

Chapter 5: Introducing the Protection Level index (PLI), that can be used to uniformly measure the protection level of PA, drawn up in close co-operation with Protected Area managers

To be able to detect changes in the protection level of a Protected Area, it is important to measure it in a way that is both cost effective and easy. There are various ways of measuring the protection level of a Protected Area, but most methods are not generally applicable (Hockings & Phillips, 1999), do not focus sufficiently on the effects of protection regulations in the field (Pomeroy, 2004), or require quite some financial or personnel effort (Stoll-Kleeman, 2010). When managers and policy makers want to keep track of the conservation status of a Protected Area, and determine the effectiveness of their management, they will need a way that is practical, scientifically sound and comparable among different Protected Areas in different realms, such as mountains, transitional waters or lakes.
To this end, the novel Protection Level Index (PLI) was developed in a bottom-up process in close cooperation with Protected Area managers. PLI is easy to use, and does not require extensive resources from the management, and can therefore be used on a yearly basis to keep track of the progress of management activities and conservation status of a Protected Area. PLI is a multimetric indicator as it uses a set of dedicated indicators, and has been tested in seven different Protected Areas across Europe.

Chapter 6: General Discussion and Recommendations

In this chapter of this thesis, the overall outcomes of all studies will be discussed: how society, and particularly managers of Protected Areas, can use the found results. Also recommendations for future research, as well as a critique of the work carried out during this PhD research, are given.

Chapter 2 - Protected Area management: Fusion and confusion with the Ecosystem Services approach

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Chapter 2 - Protected Area management:

Fusion and confusion with the ecosystem services approach

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Abstract

For many years, Protected Areas (PA) have been an important tool for conserving nature. Recently, also societal aspects have been introduced into PA management via the introduction of the Ecosystem Services (ES) approach. This review discusses the historical background of PAs, PA management, and the ES approach. We then discuss the relevance and applicability of the ES approach for PA management, including the different definitions of ES, different classification methods, and the ways in which ES are measured. We conclude that there are still major challenges ahead in using the ES approach in PA management and so recommendations are given on the way in which the ES approach should be integrated into PA management.

Highlights

+ Protected Areas are important in conservation strategies.
+ Protected Areas maintain (species) diversity, landscapes and Ecosystem Service.
+ The Ecosystem Services approach is scarcely used in Protected Area management.
+ Operationalising the Ecosystem Services approach in Protected Area management may prove difficult.
+ The Ecosystem Services approach could be used in Protected Area management with some changes.

Keywords

+ Ecosystem Services
+ Protected Areas
+ Management
+ Nature Conservation

1. Introduction

Protected areas (PAs) are one of the most important tools in conservation science and management (Chape et al., 2005). They have long been regarded as important for maintaining species and habitat diversity, as well as protecting specific landscapes or sacred areas (Brooks et al., 2004; Rodrigues et al., 2004; Coad et al., 2008; Wild & McLeod, 2008; Butchart et al., 2010).

Conservation strategies have traditionally taken the view that biodiversity should be protected because species have both a functional and an inherent value (Wilson, 1988; Kareiva, 2012). More recently, there has been a transformation towards considering Ecosystem Services (ES) and human well-being in the design and management of PAs (Doak et al., 2015). A

s such, there is a transition from focusing on the protection of (threatened) species towards the sustainable use and protection of landscapes and ecosystem complexes against various anthropogenic pressures.

However, an ongoing theoretical debate (although with profound applied implications) raises doubts on the role of humans in natural systems and in particular questions whether humans are primarily a threat to biodiversity, or whether they can be integrated into a PA as managers of biodiversity conservation (Janzen, 1986). In that sense the use of ES in PA management has raised concerns that economic valuation of nature would lead to "selling out on nature" (McCauley, 2006) and commodification (Turnhout et al., 2013).

Focussing only on the outcomes of the system that are important or of value to mankind, often by trying to classify them, would lead to a potential loss of the view on the whole (eco)system, and of the understanding of its importance in sustaining delivery of ES (Kremen, 2005). Therefore, there is an urgent need for a balanced and inclusive combination of the societal-focussed ES approach and the traditional view of conservation, protecting nature, and biodiversity, in order to become adopted in current management strategies.

It is contended here that the ES approach could become a central facet in PA management, when using a holistic assessment of the ecosystem. This means including ES, the ecosystem natural features (biodiversity, structure and functioning), and the natural and socio-economic pressures that act on them. An understanding of this holistic system is then inherent in communication with different stakeholders when designing new PAs (Reid et al., 2006; Cowling et al., 2008; Menzel & Teng, 2010; de Groot et al., 2010)

This review presents concepts and approaches used in, and for, PA and ES, and their use in environmental management. Firstly, we describe the history and evolution of PAs and their designation and management. Secondly, we review the evolution of the ES concept and the way in which ES are defined, classified, measured and assessed.

The synthesis of both concepts will show the advantages and disadvantages of using an ES approach in PA management. The analysis aims to be relevant to terrestrial, freshwater and marine systems although certain aspects are more applicable to only one of these systems.

2. History of Protected Areas & Protected Area Management

The most frequently used definition of a PA is that of the CBD (Convention on Biological Diversity): "A geographically defined area, which is designated or regulated and managed to achieve specific conservation objectives" (CBD, 1992). As such, in 2017, PAs covered in total about 15% of the land surface of the planet and about 7% of the marine environment (ProtectedPlanet, 2017).

Protecting places that are special or of societal use, with the purpose of conserving them, has been a tradition for many centuries. The Mauryan kings in Northern India, from 322 B.C. to 187 B.C., had a system to protect forests in order to maintain and manage wildlife stocks, such as tigers and elephants, including laws and penalties for offenders (Rangajaran, 2001). The Mauryas sought to preserve supplies of elephants since it was cheaper and took less time to catch, tame and train wild elephants than to raise them. The tigers were protected for their skins. In 134 B.C., Roman Emperor Hadrian staked his claim to the mountains of Lebanon to protect its trees, because of their importance for ship-building. Over 200 stones were engraved to delineate his imperial forest with: "IMP(eratoris) HAD(riani) AUG(usti) D(e)F(initio) S(ilvarum) A(rborum) G(enera) IV C(etera) P(rivata)" meaning "Boundary of the forests of the Emperor Hadrian Augustus; four species of trees were reserved under the imperial privilege" (McNeil, 2007; Rich, 2013). Hence, those places were already protected for the ES they delivered to society.

PAs, or a network of PAs, can have many purposes including maintenance of healthy functioning ecosystems (Dudley, 2008), acting as a sanctuary (Liu et al., 2001), saving specific habitats, preserving ecological processes unable to survive in intensely managed land- or seascapes, providing space for assuring normal ecological functions, and preventing ecosystem fragmentation (Parrish et al., 2003; Chape et al., 2005).
PAs can also be managed to promote and preserve valuable cultural ES such as tourism, recreation, research, education and scenery or religious sanctuaries (Campos & Nepstad, 2006, Coad et al., 2008; Cardelus et al., 2013; Scull et al., 2017), providing the base for sustainable development.
PAs can also be used as a benchmark to assess the effects of human interactions with the environment. PAs are well-known for acting as refuges for species and ecological processes that would not persist in intensely managed landscapes and seascapes, and for their ability to provide space for natural evolution and potential ecological restoration (Dudley et al., 2010). This implies that the quality of nature and dependent services is higher in PAs than in the surrounding areas where human influence is present. In this way, the protected and unprotected areas can be compared to determine anthropogenic influence. Dudley (2008) even suggested that they can prevent threatened species (often endemic) from becoming extinct.

The first ‘modern’ PA was Yellowstone National Park, founded in 1872 and protected under United States law as “a public park or pleasuring ground for the benefit and enjoyment of the people”. Similar types of PAs have been set up worldwide during the past 150 years (Bishop, 2004) although for different reasons. In North America, PAs were set up to protect dramatic and sublime scenery, in Africa parks were set up to protect game and their habitats in order to maintain elite hunting traditions, and in Europe PAs were established to protect the landscape and seascape (Adams and McShane, 1996; Draper et al., 2004; Phillips, 2007).
PAs are now considered essential in most national and international conservation strategies. Many public, private, community and voluntary organisations are active in promoting the conservation and sustainable management of particular areas with relevant environmental value. International networks of PAs have been established under global regulations, for example UNESCO World Heritage Sites, UNESCO Global Geoparks, Biosphere Reserves and Ramsar Conventions (Matthews, 1993; Jungmeier et al, 2008). Increasingly, regional agreements create networks of PAs, such as the Natura 2000 network in Europe (EU, 2000; Maiorano, 2007). In total, more than 200,000 sites meet the definition of a PA (Deguignet et al., 2014).

This broad variety of international and national conservation and management strategies, conventions, directives, networks and ownerships leads to a wide-ranging nomenclature for PAs, at different levels, and by many different bodies (IUCN, 2004). However, all these initiatives have in common that they are set up to achieve similar goals, as is shown in Table 2.1(McNeely, 1993).

Table 2.1. Goals to be achieved by Protected Areas

Protection type	Goal
Preserving nature	Safeguard outstanding areas of living richness, natural beauty and cultural significance.
	Maintain the diversity of ecosystems, species, genetic varieties, and ecological processes.
	Protect genetic variation and species which are needed to meet human needs.
Preserving the interaction between nature and humans	Provide homes to human communities with traditional cultures and knowledge of nature.
	Protect landscapes reflecting the history of human interaction with the environment.
To protect societal assets in nature	Provide for scientific, educational, recreational and spiritual needs of societies.
	Provide benefits to local and national economies.

Just as the goals for most PAs have changed with time, their management practices have likewise changed since the establishment of the very first PA, such as most importantly the management of indigenous peo-

ples. Local people living in the territory of the PA were often moved and excluded, with enforcement often carried out through either fences or fines, thus creating so-called “fortress conservation” (Brockington, 2002; Hutton et al., 2005; Busscher, 2007). This top-down “fortress conservation” has been the preferred way of conservation for most of the twentieth century (Hutton et al., 2005), especially in game reserves in Africa, such as the Mkomazi game reserve in Tanzania and the Kruger National Park in South Africa (Brockington, 1999).
De-colonialisation in Africa emphasised that new ways of managing PAs without excluding (native) people were needed. Further, it became clear that a top-down approach for PA management as was used prior to the 1970’s, did not only unjustly disempower local residents, it did not always provide the appropriate protection for biodiversity (Pimbert, 1997). Consequently, since then there has been a more bottom-up inclusive, participatory and sustainable way of managing PAs (Busscher, 2007). Despite this, “fortress conservation” has remained one of the important ways of managing PAs worldwide (Oates, 1999; Terborgh, 1999; Cernea & Schmidt-Soltau, 2006; Buscher, 2007).

The new way of managing PAs has arisen through public awareness of academic ecology. Prior to the 1970’s, ecology was largely viewed as a sub-discipline of biology, but since then has been regarded as an integrative discipline that links both the physical and biological processes and natural and social sciences (Odum, 1977). In the 1990s, a further academic paradigm shift was taking place in which humans and their activities were considered increasingly integral to the ecological research agenda. Such changes were reflected in the European school of landscape ecology (Naveh and Lieberman, 1994, Naveh, 2000) and in the disciplinary evolution of socio-ecology (Collins et al., 2011; Haberl et al., 2006; Singh et al., 2013).
In the marine field, the socio-ecological system has become a driving factor in environmental management (Turner and Schaafsma, 2015; Elliott et al, 2017).

This also means that the assessment of the success of PA or networks of PAs should be evaluated in a more multidisciplinary way. This evaluation should use measures such as coverage of endemic and threatened species or representativeness in terms of their species diversity, genetic diversity and connectivity, but also should include socioeconomic metrics (Rodrigues et al., 2004; Júnior et al., 2016; Corrigan et al., 2017), assuming that PAs provide effective protection once established (Geldmann et al., 2013).
Alternatively, PAs can be evaluated by means of their management measures, i.e. the presence of management plans, boundaries, staffing, and other management systems and processes (Jachmann, 2008). It is assumed that increased levels of management lead to a more successful protection (Geldmann et al., 2013).
However, these managerial-directed analyses may not describe how conditions inside PAs change over time (Craigie et al., 2010). The business adages that you cannot manage anything without measuring it and that management and monitoring need precise goals against which their success is judged become relevant here (Roberts et al., 2003; Leemans, 2017; Pieraccini et al., 2017).
Proper monitoring and evaluation of the goals set by the PA, are required to evaluate the effectiveness of management measures. Inadequate management linked to poor monitoring of outcomes will lead to what are critically called ‘paper parks’.

3. The Concept of ES

The concept of ES was firstly described as “Environmental Services” in SCEP (1970). Then Westman (1977) suggested that the social value of the benefits that ecosystems provide could potentially be quantified so that society can make more informed policy and management decisions, and introduced the term “Nature’s Services” (Fisher, 2009). In the 1980’s the term “Ecosystem Services” (ES) was firstly used by Ehrlich & Ehrlich (1981) (also Mooney & Ehrlich, 1997).
The term ES became more accepted in scientific research in the 1990’s, mainly as an important way to communicate societal dependence on nature as the most important life support system for humans (Costanza et al., 1992; Perrings et al., 1992; Daily, 1997; de Groot et al., 2002).
To show this importance, different methods were developed to value ES economically (Costanza et al., 1997). An important step in introducing ES into policy was made by the Millennium Ecosystem Assessment (MEA, 2003) and since then the ES literature has increased exponentially (Fisher et al., 2009; Gómez-Baggethun et al., 2010).
The original definition of ES as indicated in the MEA is: “The benefits that people obtain from ecosys-

tems". These include provisioning services such as food, water, timber and fibre; regulating services such as those attenuating climate related impacts, floods, diseases, wastes and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits, and supporting services such as soil formation, photosynthesis and nutrient cycling (MEA, 2005). This, however, is just one of many definitions that lead to some ambiguity (see table 2.2). This ambiguity becomes particularly relevant when practitioners attempt to identify, characterise and value ES for a given area. Although there are different interpretations of what are ES, central in most of the definitions is the delivery by ecosystems of usable products and benefits to satisfy the needs of society.

More recently, at least in the marine field, there has been an attempt to reduce this confusion by separating ES from Societal Goods and Benefits (SG&B) (Turner and Schaafsma, 2015; Scharin et al., 2016; Elliott et al., 2017; Burdon et al., 2018). This takes the view that there is a continuum whereby ecosystem structure leads to ecosystem functioning which in turn produces ES. Obtaining SG&B from those ES requires an input of complementary assets or human capital, such as time, energy, money and skills. For example, while a fully functioning sea can produce fish, it is necessary for society to learn how to catch and use those fish. It is contended that such a separation of ES from SG&B helps to prevent definitions such as those in Table 2 where the two concepts are conflated.

Table 2.2. Overview of definitions of ES

Authors	Year	Definition of ES
Daily et al.	1997	A wide range of conditions and processes through which natural ecosystems, and the species that are a part of them, help sustain and fulfil human life
Constanza et al.	1997	The benefits human populations derive, directly or indirectly, from ecosystem functions
De Groot et al	2002	The capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly
MEA	2005	The benefits people obtain from ecosystems
Boyd & Banzhaf	2007	Components of nature, directly enjoyed, consumed, or used to yield human well-being
Fisher & Turner	2008	The aspects of ecosystems utilized (actively or passively) to produce human well-being
Haines-Young & Potschin	2010 +2013	The contributions that ecosystems make to human well-being, and arise from the interaction of biotic and abiotic processes
TEEB	2010	The direct and indirect contributions of ecosystems to human well-being
Harrington et al.	2010	The benefits that humans recognise as obtained from ecosystems that support, directly or indirectly, their survival and quality of life
Staub et al.	2011	Aspects of ecosystems that have a recognisable connection to human welfare and that are used or valued in some form or other by the human population
Landers & Nahlik	2013	The components of nature, directly enjoyed, consumed or used to yield human wellbeing

4. Classifying ES

There have been many approaches to classification systems for ES (de Groot et al., 2002; MEA, 2005; Wallace, 2007; CICES, 2011; Costanza and van den Belt, 2011; Liquete et al., 2013; Landers & Nahlik, 2013; Turner et al., 2014; Rhodes, 2015; Pascual et al., 2017), but none of these classification systems has been universally accepted. Several definitions (Table 2.2) include ecosystem functions and processes but many of these classification systems conflate ES and societal benefits. Due to this conflation of ecosystem functions, ES and benefits, it may be difficult to distinguish between the actual services, related (economic) benefits, and the ecological processes that provide these services and benefits (see Table 2.3).

Authors	Year	Way of classifying	Classification categories						Remarks:
			Ecosystem functions and structures		**Ecosystem elements of societal use**				
De Groot et al.	2002	ES are classified on the basis of related Ecosystem Functions	*Habitat functions:* refuge and reproduction habitat to wild plants and animals	*Production functions:* Photosynthesis and nutrient uptake used by secondary producers to create living biomass	*Regulation functions:* the capacity of ecosystems to regulate essential ecological processes and life support systems			*Information functions:* reflection, spiritual enrichment, cognitive development, recreation and aesthetic experience	Services are not explicitly named as such in the classification system, the ES are classified by the functions they depend upon. In this way the ecosystem delivering certain services is of big importance to the classification of these services.
Millennium Ecosystem Assessment	2005	ES are classified on the basis of the type of benefits humans can obtain from nature	*Supporting services:* those that are necessary for the production of all other ES		*Regulating services:* benefits obtained from the regulatory role of ecosystem processes		*Provisioning services:* products obtained from ecosystems	*Cultural services:* nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences	ES are classified in a more or less similar way as De Groot et al. (2002) classified functions. Ecosystem functions and structures are named *Supporting services*, because they support the delivery of all other services. *Provisioning services* are added to describe explicitly the products humans can get from ecosystems.
Wallace	2007	ES are classified on the basis of the specific human values they support	*Adequate resources:* basic needs that support the life of individuals		*Benign physical and chemical environment:* ES that keep the human physical and chemical environment within the tolerance levels of humans	*Protection from predators, disease and parasites:* the abundance and distribution of harmful organisms is sufficiently low that human well-being is not threatened		*Socio-cultural fulfilment:* ethical positions including those related to intrinsic values	The whole classification is more human oriented then previous systems.
Fisher et al.	2008	ES are categorised by the degree of connection to human welfare	*Intermediate services:* ecosystem structures and processes	*Final services:* services that humans utilise, but indirectly	*Benefits:* end products of the ecosystem utilised by humans				Supporting services are split into two categories. All other services are grouped and named “*benefits*”
TEEB (the Economics of Ecosystems and Biodiversity)	2010	ES are classified based on the direct or indirect benefits they provide to humans	*Habitat services:* the way in which ecosystems provide habitats, and gene pool protection		*Regulating services:* the services that ecosystems provide by acting as regulators		*Provisioning services:* ecosystem services that describe the material or energy outputs from ecosystems	*Cultural Services:* benefits people obtain from ecosystems through spiritual experience, recreation, mental and physical health, tourism and aesthetic appreciation	Largely follows the Millennium Ecosystem Assessment, Supporting services are now called Habitat services to highlight the importance of ecosystems to provide habitats.

Authors	Year	Way of classifying	Classification categories				Remarks:
			Ecosystem functions and structures	Ecosystem elements of societal use			
Haines-Young & Potschin (CICES – the Common International Classification of Ecosystem Services)	2011, 2018	ES are classified by ecosystem outputs that directly affect human well-being		*Regulating and Maintenance services:* ways in which ecosystems control or modify biotic or abiotic parameters that define the environment of people	*Provisioning services:* tangible things that can be exchanged or traded, as well as consumed or used directly by people in manufacture	*Cultural and Social services:* non-material ecosystem outputs that have symbolic, cultural or intellectual significance	Supporting services are not considered to be services, and left out of the classification. Regulating services are renamed in *Regulating and maintenance services*, Provisioning services category is expanded from goods to tangible things.
Liquete et al.	2013	Classification largely follows CICES		*Regulating and Maintenance services*	*Provisioning services*	*Cultural and Social services*	No major changes
Rhodes (NESCS)	2015	ES are classified by the way they affect human welfare	*Environment:* spatial units with similar biophysical characteristics that are located on or near the Earth's surface and that contain or produce "end-products"	*End-Products:* biophysical components of nature that are directly used or appreciated by humans			Core ecosystem processes and beneficial ecosystem processes are grouped to *Environment*, Benefits are renamed to *End Products*, explicitly being biophysical components that are appreciated
Pascual et al. (IPBES)	2017	ES are called Nature's Contributions to People and classified accordingly		*Regulating contributions:* Functional and structural aspects of organisms and ecosystems that modify environmental conditions experienced by people	*Material contributions:* Material elements from nature that sustain people's physical existence and infrastructure	*Non-material contributions:* Contribution to people's subjective or psychological quality of life	Although using different nomenclature, largely resembles CICES

Table 2.3: Comparison of several different ways of classifying ES, and their links, italic headings are the terms used by the authors, green columns refer to Ecosystem Functions and structure, blue columns refer to Regulating ES, yellow columns to Provisioning ES, orange columns refer to Social and Cultural ES. If ES are not divided into different categories the colour grey is used.

De Groot et al. (2002) attempted to classify the ES based on the Ecosystem Functions delivering them. The Millennium Ecosystem Assessment (2005) partly continued this, but was the first to group ES, and added the category provisioning services, making a fourth category next to regulating, supporting and cultural services. Wallace (2007) classified ES based on the human values they support, but omits the provisioning services. TEEB created a new classification to couple ES to the (economic) benefits they provide. CICES is gaining acceptance by scientists and policy makers globally but particularly in Europe. CICES does not include the MEA (2005) “supporting services” (La Notte et al., 2017; Czúcz et al., 2018). More recently, there are proposals in the marine field to separate ES from SG&B given the need to insert human complementary assets between the two (e.g. Scharin et al., 2015). The latest IPBES classification system of Nature’s Contributions to People (NCP) proposes renaming ES and classifying these NCP on the contribution of nature to a good quality of life (Pascual et al., 2017). However, the classification of NCP largely resembles the ES classification by CICES (see also Table 2.3).

As indicated here, there is an increasing “taxonomisation” (hierarchical subdivisions) of ES, i.e. it becomes more important to assign a certain service to a certain category, instead of making it easier practically to measure certain ES. This “taxonomisation” may eventually lead to an incomprehensible categorisation of ordinary attributes as for example “maple syrup collectors” (Landers & Nahlik, 2013). In the American classification systems of Final Goods and ES (FEGS-CS), the Maple Syrup Collectors should firstly be categorised under Food Extractors in Forests and coded 21.0201, being regarded as a service. However, it is suggested here that the collectors are not a service but rather those who benefit from a certain service.

Moreover, most classification systems miss the connection with, on one hand, ecological attributes (e.g. ecosystem functions and structures) that give rise to the ES, and, on the other hand, the socio-economic attributes (e.g. the resulting SG&B and the factors influencing the ES). Knowing the causal connections encompasses the full range of interactions and dependencies from biophysical structures to socio-economy which are important for the existence and sustainable delivery of ES.

The Cascade model for ES (Haines-Young & Potschin, 2010) is a step forward in connecting ecosystem structures, functions, services and economic benefits. It allows linking natural systems to elements of human wellbeing, following a pattern similar to a production chain: from ecological structures and ecosystem functioning (processes), to the ES and SG&B. The advantage of this continuum is to effectively communicate societal dependence on ecosystems. Yet, as a cascade can be considered to be a continuum, there are no direct feedback loops, whereas in nature these feedback loops do exist, some of which may be adverse (Odum & Barrett, 1971). For example, the over-extraction of SG&B such as fish from the sea would adversely affect the ecosystem structure and functioning.

Feedback loops have already since long been used for adaptive risk assessment and risk management as encapsulated in the DPSIR (Driver-Pressure-State-Impact-Response) approach (Patricio et al., 2016). Haines-Young & Potschin (2010) combine DPSIR and ES thus possibly providing a feedback loop (Rounsevell et al., 2010; Kandziora et al., 2013).

However, the proposed cause-effect chain described by Kandziora et al. (2013) with a feedback loop from human well-being to ecosystems and biodiversity still lacks the direct feedback between the various components of the system, i.e. ecosystem structures and functions, ES, threats and socio-economy. Rounsevell et al. (2010) overcomes this anomaly with Ecosystem Service Providers (structures and functions that deliver ES), that are dependent on Ecosystem Service Beneficiaries (socio-economy), so there is a possibility for direct feedback between both. In addition, a Supporting System (structures and functions that do not contribute to ES delivery) is proposed, but it remains unclear what are the effects on this part of the feedback loop.

More recently, anomalies in the DPSIR framework have been corrected using the DAPSI(W)R(M) cycle (Patricio et al., 2016; Elliott et al., 2017) in which **D**rivers of basic human needs (such as for food) require **A**ctivities (such as fishing) which cause **P**ressures (as mechanisms of change to the ecosystem, e.g. scraping a trawl over the seabed). The **P**ressures then can cause a **S**tate Change on the natural system (a loss of fish) leading to **I**mpacts (on human **W**elfare, e.g. no fish for consumption, i.e. a loss of SG&B). Those adverse consequences then require **R**esponses (using management **M**easures; e.g. fish stock

management plans).
A feedback loop allows the management to respond to and control the drivers, activities and pressures and, in turn, to prevent negative consequences. Therefore, we emphasise the need to adopt, both for practitioners and for communication, the linkages of the cyclical adaptive management framework coupled to and encompassing feedback to the ES and SG&B analysis.

5. Assessment of ES

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There are many techniques and approaches for valuing ES and SG&B (see Table 1 in Cooper et al., 2013). As an example here, ES can be assessed in monetary terms (for example using direct market, indirect market, contingent and group valuation terms) and non-monetary terms (Turner and Schaafsma, 2015).

5.1 Monetary assessment of ES

5.1.1. Direct market valuation:
The trade value of ES on the open market (de Groot et al., 2002) is used to assess the economic value of SG&B provided by ES. This method is useful to measure provisioning services and some cultural services that can be traded, for example tourism or seagrass meadows and their value for fisheries (Vasallo et al., 2013; Jackson et al., 2015). An example of direct market valuation is the value of trees for firewood or construction wood which can be priced on the open market.
5.1.2. Indirect market valuation:
When no explicit markets for certain services exist, a more indirect way of assessing the value of ES can be used, see table 2.4.

Table 2.4. Methods for indirect market valuation (from Bishop & Heberlein, 1979; Adamowicz, 1991; Hoevenagel, 1994; Toman, 1997; de Groot et al., 2002; Freeman, 2003)

Method:	Explanation:	Example:
Willingness to Pay	Willingness to pay for the availability of certain ES.	The amount of money you would like to pay to have a nature reserve nearby your house.
Willingness to Accept	Willingness to Accept compensation for the loss of certain ES.	The amount of money you would expect to receive if the wetland near your house would be lost due to bad management.
Avoided Cost	ES allowing society to avoid certain costs that would have been there if these services would have been absent.	Flood control by e.g. dunes, it avoids the costs of property damage or damage to field crops.
Replacement Cost	The value of an ES is related to the costs of replacing it by a man-made system.	Coastal defence by dunes can partly be replaced by building costly dikes or walls.
Factor Income	ES can enhance incomes.	The way in which natural water quality increases commercial fisheries and income of fishermen.
Travel Cost	The use of some ES may require travel to get to them. The travel costs can be seen as a reflection of the value of the service.	The travel costs made to travel by car to the nearest forest for a walk, to enjoy the scenery.
Hedonic Pricing	Demand for ES can be reflected in the prices people will pay for associated goods.	A house near the beach is more expensive than a similar house near less attractive scenery.
Production costs	Costs to get back certain ES that have been lost due to human behaviour.	The costs of cleaning or repair due to pollution.

Dose-response	To what extent changing an ES affects the production costs of a product.	If lumber gets more expensive, because of declining forests.
Averting behaviour	The expenditures to defend against negative impacts of a certain ES.	Sunscreen sales on a beach.

5.1.3. Contingent valuation:
Here, demand for ES is elicited by hypothetical scenarios that involve describing alternatives in a survey or a questionnaire. For example, respondents may be asked to express their preference of increasing the level of water quality in a stream, lake or river so that they might enjoy activities such as swimming, boating, or fishing (Wilson and Carpenter, 1999). In order to obtain realistic values, the respondents must have a good understanding of the ES or environmental quality changes about which they will be asked, of the hypothetical method of payment, and of the social context of the payment.

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5.1.4. Group valuation:
This brings together stakeholders to discuss the values of ES which are regarded as public goods, and decisions regarding them affect many people. Therefore, their valuation should not come from values based on the opinion of individuals, but on public discussion (Sagoff, 1988; Jacobs, 1997; Wilson and Howarth, 2002; de Groot et al, 2002).

5.2 Non-monetary assessment of ES

Some of the ES values are difficult to assess directly, as described by Boerema et al. (2017), “no measures were found for the ES part of the cascade”. In such case, indicators are used as proxies (Layke, 2009; Layke et al., 2012; Muller & Burkhard, 2012; Kandziora, et al., 2013).

There is a plethora of indicators of ES, each of which may differ with ecosystem and be relevant for certain areas, habitats and ecosystems (Dobbs et al., 2011; van Oudenhoven et al., 2012; Atkins et al., 2015). Boerema et al. (2017) give proxies for measuring ES:

- Ecosystem properties: For example, often simple measures or indicators of biodiversity and population size are used for all ES that depend on biodiversity, such as Genetic Resources, Biological Control, Pollination and Life Cycle Maintenance,.

- Ecosystem functions: The functions and processes underpinning each ES are diverse and often composed of different components (Smith et al., 2013). Proxies for pollination may, for example, be intraspecific diversity, pollination effectiveness, visit rate, plant growth rate and infestation rate.

Non-monetary assessments of ES are particularly important given the persistent criticism of the ES assessment process that it could treat nature as a commodity, increasing economic discrepancies and question underlying philosophies that ecosystems and their biodiversity should be protected for their intrinsic value (Kosoy and Corbera, 2010; Spangenberg and Settele, 2010). This can be countered by jointly using both economic and ecological valuation (e.g. Pascual et al., 2012). Non-monetary assessments can aim to define a more aesthetic and less-tangible view of nature, ecosystems and biodiversity and their influence on social relationships, cultural evolution and spirituality (Chan et al. 2012; Raymond et al., 2013).

There are many social research methodologies for carrying out such assessments (Christie et al., 2008; Cooper et al., 2013). These range from spatially-oriented participatory GIS (Fagerholm et al., 2012; Brown and Fagerholm, 2015), to traditional social methods – both qualitative and quantitative – including interviews, surveys, observational studies and focal group discussions (Tengberg et al., 2012; Orenstein et al., 2015; Eizenberg et al., 2017). While the findings from such studies can be more challenging to convey to policy makers who may prefer economic valuations and quantitative data, these studies can help to characterise the intensity to which ES contribute to human well-being in both tangible and intangible ways, and compensate for the shortcomings of economic assessments.

6. Discussion

The confusion regarding the delineation, classification and categorisation of ES shows an inconsistency between approaches, and has blurred borders between ecosystem functioning, the services and the goods and benefits. Despite increasing approaches and a wealth of literature in the last 15 years, there has not yet been any agreement. Moreover, PA management is lagging behind in the introduction and use of the ES concept.[1] This discussion aims to link the different aspects of the ES approach in PA management, the confusion, commonalities and differences, connected to the classification and use of the ES approaches.

2

6.1 The inclusion of ES in international management frameworks

Since the Millennium Ecosystem Assessment (2003, 2005) there has been an exponential growth of literature on ES (Fisher et al., 2009; Gómez-Baggethun et al., 2009). This should have increased international interest in the use of ES in management and decision-making in general. In addition, an increased interest in an ES approach should be observed within PAs, given that PAs can be more effective in supplying ES, in comparison to exploited areas. People and society can benefit from an array of goods and services, including basic life-support goods, such as drinking water, or processes that regulate water and air quality, prevent natural hazards such as flooding, or mitigate climate change by storing carbon. PAs may even deliver sustainably produced crops or timber (Costanza et al., 1997; Daily, 1997; Dudley & Stolton, 2003; Sohngen & Brown, 2006; Campbell et al., 2008). Moreover, PAs provide cultural services such as recreation, tourism, research opportunities and maintaining cultural identity (Butcher, 2005; Eagles & Hillel, 2008).

A proper delivery of ES in PAs is dependent on a healthy and resilient ecosystem, since ES delivered by PAs are fundamentally supported by, and have to be in balance with, key ecosystem processes (Stolton et al., 2008; Dudley et al., 2010).
These healthy and natural resources in PAs may, because of connectivity between ecosystems, positively reflect on the bordering areas thereby increasing the importance and spill-over of ES delivery within PAs to a much larger area (Di Lorenzo et al., 2016). Therefore again, it might have been expected that the ES concept is included in the various aspects and strategies of PA management and nature conservation. However, the use of an ES approach in biodiversity conservation is not explicitly mentioned in the Convention on Biological Diversity (CBD, 1992).
Only later was it included explicitly in the ‘‘2020 Aichi targets’’, thereby complementing the CBD (Maes et al., 2012).

A similar policy has been followed in the past 2 decades by the European Union as part of its commitment to the CBD. Protecting, valuing and appropriately restoring natural resources will help not only to conserve biodiversity for its intrinsic value, but also for its essential contribution to human wellbeing and economic prosperity (European Commission, 2011). Consequently, the strategies and directives commissioned by the European Commission (EC), such as the Natura2000 framework (incorporating the Wild Birds and Habitats Directives, aiming for Favourable Conservation Status), the Water Framework Directive (for Good Ecological and Chemical Status), and the Marine Strategy Framework Directive (MSFD, for Good Environmental Status) aim not only to halt the loss of biodiversity, but also to halt the degradation of ES in the EU by 2020.

PAs are therefore key to achieving sustainability, maintaining biodiversity, ecosystem health, and delivering ES. As PA management currently is still strongly oriented towards sustainability, maintaining biodiversity, and maintaining ecosystem health, the ES framework should enhance current conservation strategies and management approaches in PA (Chan et al., 2006; Daily and Matson, 2008; Nelson et al., 2009; Egoh et al., 2009).
However, the ES frameworks remain poorly explored across Europe (Haslett et al., 2010; Harrison et al., 2010), let alone implemented (Cowling et al., 2007; Daily and Matson, 2008). Similarly, although appeal-

[1] For instance, at a recent academic seminar in Israel, where the nearly-concluded Israel National Ecosystem Assessment was presented, several of a panel of stakeholders (representatives of land management agencies and conservation organisations) suggested that the ES concept was administratively too complicated, irrelevant, or in contradiction to the values the organisation promotes (in reference to the NGO).

ing to decision makers and implicitly included in top-level EC, UN and UNESCO documents, such as the Sustainable Development Goals (e.g. Cormier and Elliott, 2017), ES are not yet anchored in environmental legislation (Maes et al., 2012).
Hence there is no legislative instrument requiring the ES framework in practice. This absence of legislation of course does not alleviate, and may indeed be the cause of the mismatch between the advanced theoretical outline of ES, increasing uptake in (inter)national directives and the lack of practical implemen tation and operationality of the ES framework in PAs.

6.2 Definition and Classification systems of ES and use in PA management

2

A commonality in all ES definitions is that ES are the elements delivered by ecosystems that satisfy societal needs (Table 2.1). However, most of the definitions of ES tend to be broad which can cause confusion (Fu et al., 2011), even with the separation of ES from SG&B (Elliott et al., 2017). Hence the emphasis in this review on the increase of separating and making a distinction between the several elements in the continuum from ecosystem structure via ecosystem functions and ES to SG&B.
For example, where the Millennium Ecosystem Assessment includes ecosystem functions and structures as supporting services, the CICES classification of ES omits them (see also Table 2.2, section comments). It is acknowledged in this review that several functions are simultaneously services, hence the use of the term 'continuum'. Ecosystem functions refer to the physical, chemical, and biological rate processes that maintain an ecosystem—including material circulation, energy flow, information connections, and their dynamic evolution, and are considered intrinsic properties of ecosystems (Odum & Barrett, 1971; Wallace, 2007).

Turner (1999) originally considered ecosystem structures as a service, because the "infrastructure" is of value that its prior existence and maintenance is necessary for service provision. More recently, Turner and Schaafsma (2015) acknowledge the 4-step continuum from ecosystem structure to SG&B described above.

The confusion in the definition of services versus functions or benefits may even lead to contradictive constructions as observed by Fisher et al. (2009) who pondered the role of ES if there were no humans to benefit from them. If ES are defined as the benefits to humans then the planet could have ecosystem structures and processes, but no services. Fisher et al. (2009) and later collaborators (Turner and Schaafsma, 2015; Scharin et al., 2015) use the term "intermediate services", as pollination, primary productivity, water regulation and soil formation, and "final services" such as clean water, storm protection and constant stream flow are mentioned on the 'humanless planet'. Yet, following Fisher's initial reasoning in their thought experiment, it would have been logical not to call any of the mentioned structures and processes as intermediate or final services, since these processes would also occur on the planet without humans, and thus are according to Fisher's own definition normal functions and processes.
What Fisher and co-workers further describe as benefits (drinking water, property protection, recreation, etc.) would have been ES only in case of human presence. The transition between the natural system and anthropogenic system, i.e. where ecosystem structures and functions become ecosystem services, is not clearly defined and causes confusion. This confusion is only to be overcome if we accept humans on the planet as an integral part of ecology, and then by separating ES from SG&B (Elliott et al., 2017) whereby the planet can produce ES as long as the ecosystem structure and functions are maintained, but that SG&B can thus only be achieved after the introduction of humans and complementary assets and human capital.
More confusion in classifying ES comes from the use of their economic valuation. Many environmental economists deem the MEA classification not fit-for-purpose as including supporting services may increase the risk of double counting of services (Boyd & Banzhaf, 2007; Wallace, 2007; Fisher et al., 2009; Fu et al., 2011). With ES, this usually occurs when processes ('means') and benefits (so-called 'ends') are mixed. For example, "nutrient cycling" is a supporting service, "water flow regulation" is a regulating service, and "recreation" is a cultural service, depending on "surface water for non-drinking purposes", a provisioning service. If a PA manager contemplates creating a wetland using a cost-benefit analysis, including these three services, there would be double counting, as "nutrient cycling" and "water flow regulation" help to provide the same service "surface water for non-drinking purposes " on which the service "recreation" depends. A solution to this problem can be found in Turner and Schaafsma (2015), by looking at the final SG&B, i.e. what is valued by society in financial or non-financial terms. Despite this, another solution can be not to classify each ES to fit into one of the possible categories, but to acquire its value by summing its different values to society.

6.3 Assessment methods for ES and use in PA management

Maintaining ES is becoming an ever-growing priority in sustainability science, and conservation plans increasingly emphasise joint protection or improvement of ES and biodiversity (Graves et al., 2017). To achieve this requires a harmonised and consistent monitoring scheme linked to pre-defined indicators and with an agreed action plan of measures if the indicator is breached or not reached (Borja et al., 2017). The monitoring has to be harmonised and quality controlled especially if the data from different areas are to be combined for a holistic assessment.

Direct market valuation is a straightforward method of valuation which relates to the trade value on the open market. Its major disadvantage is that many ES are not traded directly on markets (Koetse et al., 2015). The extraction of materials is usually forbidden in PA, this means that any ES that would normally be traded on the open market has no direct monetary value at all. For example, you cannot put a direct monetary value on trees in a PA, because you are not allowed to cut those trees, so you cannot trade them on the open market. Also if markets for ES are highly distorted, for example by taxes, subsidies, or government control, this method does not yield a proper value (Koetse et al., 2015). In addition, the market value of a certain service does not reflect the real capacity of a system to deliver this service, for example, if a good is in high demand, the market price goes up, without the stocks of the service going up.

Other valuation techniques such as non-market methods are necessary to evaluate societal appreciation of a certain ES. The downside is that the values are often subjective. Willingness to pay (WTP) values may be sensitive to context, or task given (Mitchell & Carson, 1989; Boyle et al., 1994), or how the method handles non-compliance, refusal to value or protest bids (Spash & Hanley, 1995). There are also questions regarding whether WTP values for non-economic, non-traded goods are valued by participants as consumers, or as citizens (Sagoff, 1988; Keat, 1994; Blamey & Quiggin, 1995). A good example of the questionable character of these methods is the contingent valuation approach on UK nature conservation policy, where some participants emphasised the difficulty of putting a monetary value on nature (Clark et al., 2000). There are also doubts over these methods as shown by questioning the difference between ‘willingness to pay’, which can be dependent on household income, social setting, etc., from ‘willingness to accept’ (Hanemann, 1991; Bateman & Turner, 1993). Some methods even discard responses such as zero or infinite values on the grounds that they are unreasonable, without making clear why they are unreasonable (Diamond & Hausman, 1994; Ludwig, 2000).

Both market and non-market valuation of ES have the difficulty that some in society tend to regard nature as something that should exist in its own right, without having an explicit value (Costanza et al., 1997; Ludwig, 2000). Nevertheless, if we keep the above-mentioned limitations in mind, market and non-market valuation methods can be valuable as they yield straightforward, easy to interpret values, until more reliable, less biased methods of measuring ES are developed.

The interest in non-monetary ES quantification has led to numerous ecological assessments of ES. These assessments typically identify indicators or proxies for ES, attempt their quantification, or try to spatially map them (Burkhard et al., 2012; Crossman et al., 2013; Hattam et al., 2015). However, in spite of growing policy and scientific interest, non-monetary valuation of ES still does not have a formalised methodology (Nieto-Romero et al., 2014). Despite the latter, it is still useful to perform these assessments, as they often provide supplementary information that cannot be captured through monetarisation, even if sometimes more coarse or arbitrary indicators/proxies are used. The added information can often address values that are not captured, or cannot be captured using monetary approaches (Layke, 2009; Seppelt et al., 2011). It has, however, to be taken into account that when using different measures per PA, the outcomes will be less comparable and therefore for the management of networks of PA (such as Natura 2000 sites in Europe) less accurate. Establishing at international, e.g. EU, scale a standardised set of harmonised practical measures for ES, both monetary and non-monetary, is therefore necessary for a proper implementation of the ES framework in PA management (see below).

Assessing cultural services is difficult as monetary methods often cannot be used, thereby creating a challenge for both scientists and PA management. PAs may exist for their biota (biological components) or just their land- or seascape (physical and habitat components) – for the latter, cultural services can be translated into societal benefits irrespective of the organisms present, i.e. natural landscapes that are particularly enjoyed by onlookers, e.g. water bodies, green and diverse vegetation, or orderly nature (e.g.

Nassauer, 1995; Dramstad et al., 2006). Charismatic species, such as whales or giant pandas, may be the focus of ecotourism (Small, 2011) although recreational, inspirational or spiritual enjoyment of the landscape (cultural ES) is seldom attributed to a single organism or species (Sagie et al. 2014; Orenstein and Groner, 2015), and the latter can be even immaterial; hence, this feature is difficult to capture in a concrete attribute. Landscape preference is more often the result of the sum of many biological (and geological) parts. As such, the "value" of a particular organism or species cannot be considered independently of its ecosystem and surroundings. One potential solution to this quandary is the adoption of the concept of landscape services instead of ES (Termorshuizen and Opdam, 2009).

A complication in properly connecting ecological indicators/proxies to services is that ecosystem functions that provide ES often rely on a minimum level of ecosystem health, whereby the decline of ES delivery in a degrading system and their recovery in a recovering system are often not linear (Layke, 2009, Tett et al., 2013). This makes it difficult to couple ecosystem functioning to the delivery of ES. Determining the best indicators to represent ES remains then a crucial challenge (Anderson et al., 2009; Feld et al., 2009; Eigenbrod et al., 2010; Müller & Burkhard, 2012; Graves et al., 2017).
Nevertheless for the future, establishing a harmonised and standardised set of valid ecological indicators (e.g. see Cormier and Elliott, 2017) will be the way forward to increase the perception of the direct connection between an ES and its underlying ecological processes, and thus giving insight in the functioning and potential impacts of/on(changes in) the ecosystem.
It will also deliver the right tools to manage the environmental quality and simultaneously the sustainable use of (potential) ES.

A further complication is that the valuation is often benefit or beneficiary dependent (Boyd and Banzhaf, 2007), which means that the benefits of interest will change your appreciation of what is an ES, and what is not. For example, when used in PA management, water regulation services can be seen as an input to the final service of clean water provision, for example for recreational swimmers, and a benefit may be higher water quality.
From the point of view of a recreational fisherman, however, clean water provision would no longer be a final service, but an intermediate one, leading to fish production as a final service. This means that whether a service is considered final or intermediate, and even what its economic value might be, will change depending on what is being valued, monitored or measured, as well as on who are the beneficiaries (Fisher et al., 2009).

The complication with benefit or beneficiary dependency is in fact an artificial problem, because to be able to use an ES approach it is necessary to measure or value a certain service, and whether this service is a primary function or an intermediate or final service is immaterial. This complication results from the scientist's tendency to deconstruct systems as a way to understand and manage them.
However, it is often forgotten that these pieces or categories are artificial, and were only created for the better and easier understanding of a system.
The appreciation and understanding of the whole system reconstructed from these artificial pieces is, however, often lacking or forgotten (Tansley, 1935). This occurs in many ES studies and although the classification of ES could be valuable in understanding a system, it is only the starting point for measuring the ES attributes themselves. T
he remaining confusion therefore prevents the use of the ES concept in the management and conservation strategy. It is therefore recommended that time should be spent on measuring the ES (or their proxies) relevant for stakeholders rather than on further classification.

6.4 The use of the ES approach in PA management

The ES concept is the route towards delivering the significant goods and benefits that ecosystems (natural, semi-natural, and human-dominated systems) supply to human society. This may emphasise the value of nature to different stakeholders, and in this way may assist the management of PAs. It has, however, to be taken into account that monetary assessments of ES must be used with considerable caution as many in society may regard nature of intrinsic value irrespective of its explicit human value (Costanza et al., 1997; Ludwig, 2000). In addition, many PA were founded to protect nature, so putting a value on something that should exist in its own right may seem odd. Therefore, a monetary assessment of ES might be less useable for the PA management practice. Non-monetary valuation methods might give a better fit to the aims of the PA management, but there are still no widely adoptable and standardised methods (Nieto-Romero et al., 2014). Because of this, there is a danger of using different measures in each PA, making the outcomes between sites non-comparable, and unsuitable for the management of networks of PA. Moreover, the decline of services delivery in a degrading system is often not linear (Layke, 2009; Tett et al., 2013). This makes it difficult to couple ecosystem functioning to the delivery of ES. Determining the best indicators to represent ES remains a crucial challenge (Eigenbrod et al., 2010; Anderson et al., 2009; Feld et al., 2009; Müller & Burkhard, 2012; Graves et al., 2017), but will eventually yield a way of looking at ES that is compatible with PA management.

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The absence of one agreed, clear and harmonised classification system for ES in PA management (Daily, 1997; de Groot, 1992; de Groot et al., 2002; MA 2005, Liquete et al., 2013) makes the ES approach difficult to use in management, as a lack of methodological standardisation could hamper (cross-site) comparability and scalability across different spatial and temporal scales (Pereira & Cooper, 2006; Haase et al., 2018). As Nahlik et al. (2012) concluded, to be able to move the concept of ES into practice, there is a need for a (more) unified approach.

A test of suitability of the ES approach in a decision-making context has been done for the Millennium Ecosystem Assessment by Wallace (2007). He concluded that the classification of ES as described in the MEA cannot be used in decision making as it mixes 'means' (how to achieve a goal) with 'ends' (the goal that needs to be achieved). For providing an effective decision making context, as is needed in PA management, the classification of ES must show a PA manager the planning implications of certain decisions, through the diverse interactions between functions, structures, services, and pressures.

Moreover, the current ES concept has a high reliance on economic value, partly caused by the absence of fully operational non-monetary measurement systems for ES, making monetary valuation currently the best method available.
This, however, may lead to, or even force, the management of PAs to drift away from the intrinsic value of protection of, and thus to a reduced focus on, nature and/or biodiversity per se (Sagoff, 2004; McAfee & Shapiro, 2010; Redford & Adams, 2009).
During interviews with PA managers, Fisher & Brown (2014) found that the ES concept was used in PA management already, but far from whole-heartedly, and some of the respondents even replied with "I wouldn't say there has been any change in the central mission…nor how it looks on the ground, but there has been a lot of change in how we package it, promote it…the biggest change in that has been the ES stuff …." or "… I view with horror the idea that the way you protect nature is through communicating about it just in terms of services ….".
Continuing this, interviews with managers of 26 different European PAs within the EcoPotential project (Hummel et al., 2018) showed that only 2 out of 26 used the concept of ES in the management of their PA, although both managers did not know which framework (CICES, TEEB, etc.) was used.
Nine of the managers replied that they are still considering whether to use the ES framework, and 15 respondents did not use the ES framework in their management at all; one of them even replied: "The ES framework is a capitalistic way of preserving nature, how can you put a value on nature?"

This indicates that the usage of the ES framework in PA management is not yet common practice, and when used, it is not always greeted with enthusiasm. This might be overcome by a bottom-up ES approach understood by the management, given that conflicts emerge when conservation strategies for PAs follow a top-down approach that excludes local practices or interests (West et al., 2006).

7. Conclusions and recommendations

The discussion here suggests that using an ES approach could possibly lead to commodification of nature, enlarging economic inequalities, or undermine the protection of nature and biodiversity for its intrinsic value (Kosoy and Corbera, 2010; Spangenberg and Settele, 2010).
The strong focus in ES literature on the ES categorisation ('taxonomy') instead of measuring ES in practical terms, the lack of a harmonised system, and the lack of systematic insight in the relation of ES with underlying ecosystem functions and structures or socio-economic pressures, makes the ES framework not yet suitable for use in PA management.

As suggested by Tansley (1935), it is not useful to look at single elements of a system other than for simplifying the system for research purposes. It is important to consider the whole ecosystem including its attributes and interactions. Hence, it is argued that following the continuum from ecosystem structure and functioning, through ES to SG&B, is central for successful and sustainable PA management.

The ES framework is by definition highly anthropocentric (McCauley, 2006; Sagoff, 2008; Redford & Adams, 2009), and is nowadays mostly used as a tool to consider how to maximise profit and benefits from nature. Hence it has resonance with policy makers and implementers concerned with economic benefits, but the challenge is to ensure that such benefits can be accrued while also protecting the natural system. The ES framework could also make clear to society that people are highly dependent on nature, not only for tangible goods, but also for (spiritual) well-being. As PAs are considered to be the “building blocks” of healthy land and seascapes and are central to achieve several important global targets (Juffe-Bignoli et al., 2014), it is beneficial to incorporate the ES approach into their management.
This incorporation of the ES approach in PA management would need ES to become one of the central objectives in adaptive management, next to protecting and maintaining natural structures and functions, and at the same time deliver ES from which SG&B can be obtained (Elliott 2011; Elliott et al, 2017).
As such, there are several recommendations for the way forward in the application of the ES approach in PA management:

+ *Reduce taxonomisation of ES:* Less emphasis on classifying and categorising ES, and more emphasis on developing (ecologically or socio-economically-based) methods to measure the proxies for a core-set of ES in a standardised way is needed.

+ *Focus on a bottom-up approach on implementing the ES concept in PA management:* A stronger bottom-up way of implementing an ES approach that is understood by PA management is needed. Conflicts will emerge when conservation strategies for PAs follow a top-down approach that excludes local practices or interests. The PA management community should be incorporated in implementing the ES approach in a way that is practical and suitable for their purposes.

+ *Avoid too much distinction between ecosystem functions and services:* There should be less emphasis on trying to find a distinction between ecosystem functions and services, as several functions are simultaneously services. Healthy ecosystem functions refer to a good status of the physical, chemical, and biological processes, and they all together contribute to the proper functioning of PAs and the sustainable maintenance of ES.

+ *Develop a standardised set of indicators for ES - assessment in PA:* A standardised set of indicators for ES should be developed, established at international and transboundary scale, using monetary and non-monetary ES assessment methods, together with measures of the related ecosystem functions and structures and relevant pressures in and on the system, that are for practitioners easy to measure and understandable to use.

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References

Adamowicz, W. L. (1991). Valuation of environmental amenities. Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 39(4), 609-618.

Adams, J.S. and T.O. McShane. (1996). The Myth of Wild Africa: Conservation without Illusion. University of California Press, Berkeley, CA, USA.

Anderson, B. J., Armsworth, P. R., Eigenbrod, F., Thomas, C. D., Gillings, S., Heinemeyer, A., ... & Gaston, K. J. (2009). Spatial covariance between biodiversity and other ecosystem service priorities. Journal of Applied Ecology, 46(4), 888-896.

Atkins, J.P., Burdon, D. & Elliott, M., (2015). Chapter 5: Identification of a practicable set of indicators for coastal and marine ecosystem services. In: Turner, R.K. & Schaafsma, M. (Eds.) Coastal zones ecosystem services: from science to values and decision making. Springer Ecological Economic Series, Springer Internat. Publ. Switzerland, ISBN 978-3-319-17213-2; p79-102.

Bateman, I. J., & Turner, R. K. (1993). Valuation of the environment, methods and techniques: the contingent valuation method. Sustainable environmental economics and management: principles and practice, Belhaven Press, London, 120-191.

Bishop, R. C., & Heberlein, T. A. (1979). Measuring values of extramarket goods: Are indirect measures biased?. American journal of agricultural economics, 61(5), 926-930.

Bishop, K. (2004). Speaking a common language: The uses and performance of the IUCN system of management categories for protected areas. IUCN.

Blamey, R. K., Common, M. S., & Quiggin, J. C. (1995). Respondents to contingent valuation surveys: consumers or citizens?. Australian Journal of Agricultural and Resource Economics, 39(3), 263-288.

Boerema, A., Rebelo, A. J., Bodi, M. B., Esler, K. J., & Meire, P. (2017). Are ecosystem services adequately quantified?. Journal of Applied Ecology, 54(2), 358-370.

Borja, A., Elliott, M., Uyarra, M. C., Carstensen, J., Mea, M., eds. (2017). Bridging the Gap Between Policy and Science in Assessing the Health Status of Marine Ecosystems, 2nd Edition. Lausanne: Frontiers Media. doi: 10.3389/978-2-88945-126-5; pp548; downloaded from http://www.frontiersin.org/books/Bridging_the_Gap_Between_Policy_and_Science_in_Assessing_the_Health_Status_of_Marine_Ecosystems_2nd/1151

Boyd, J., & Banzhaf, S. (2007). What are ecosystem services? The need for standardized environmental accounting units. Ecological economics, 63(2), 616-626.

Boyle, K. J., Desvousges, W. H., Johnson, F. R., Dunford, R. W., & Hudson, S. P. (1994). An investigation of part-whole biases in contingent-valuation studies. Journal of Environmental Economics and Management, 27(1), 64-83.

Brockington, D. (1999) Conservation, displacement, and livelihoods: the consequences of the eviction for pastoralists moved from the Mkomazi Game Reserve, Tanzania. Nomadic Peoples, 3, 74–96.

Brockington, D. (2002). Fortress Conservation: the Preservation of the Mkomazi Game Reserve, Tanzania. In: Hulme, D., & Murphree, M. African wildlife and livelihoods: the promise and performance of community conservation. James Currey Ltd.

Brooks, T. M., Da Fonseca, G. A., & Rodrigues, A. S. (2004). Protected areas and species. Conservation Biology, 616-618.

Brown, G. and Fagerholm, N., (2015), "Empirical PPGIS/PGIS mapping of ecosystem services: A review and evaluation", Ecosystem Services, Vol. 13 No., pp. 119-133.

Burdon, D., Boyes, S.J., Elliott, M., Smyth, K., Atkins, J.P., Barnes, R.A. & Wurzel, R.K., (2018). Integrating natural and social marine science to sustainably manage vectors of change: Dogger Bank transnational case study. Estuarine, Coastal and Shelf Science 201: 234-247, http://dx.doi.org/10.1016/j.ecss.2015.09.012.

Burkhard, B., Kroll, F., Nedkov, S., & Müller, F. (2012). Mapping ecosystem service supply, demand and budgets. Ecological Indicators, 21, 17-29.

Buscher, B. and Whande, W., (2007). Whims of the winds of time? Emerging trends in biodiversity conservation and protected area management. Conservation and Society, 5(1), p.22.

Butcher, J. (2005). The moralisation of tourism: sun, sand... and saving the world?. Routledge.

Butchart, S. H., Baillie, J. E., Chenery, A. M., Collen, B., Gregory, R. D., Revenga, C., & Walpole, M. (2010). National Indicators Show Biodiversity Progress—Response. Science, 329(5994), 900-901.

Campbell, A., Clark, S., Coad, L., Miles, L., Bolt, K., & Roe, D. (2008). Protecting the future: Carbon, forests, protected areas and local livelihoods. Biodiversity, 9(3-4), 117-121.

Campos, M. T., & Nepstad, D. C. (2006). Smallholders, the Amazon's new conservationists. Conservation Biology, 20(5), 1553-1556.

Cardelús, C. L., Scull, P., Hair, J., Baimas-George, M., Lowman, M. D., & Eshete, A. W. (2013). A Preliminary Assessment of Ethiopian Sacred Grove Status at the Landscape and Ecosystem Scales. Diversity, 5(2), 320-334.

CBD (1992) 8. Convention on biological diversity. Rio de Janeiro, 5 June 1992

Cernea, M.M. and K. Schmidt-Soltau. (2006). Poverty risks and national parks: Policy issues in conservation and resettlement. World Development 34(10): 1808–1830

Chan, K. M., Shaw, M. R., Cameron, D. R., Underwood, E. C., & Daily, G. C. (2006). Conservation planning for ecosystem services. PLoS biology, 4(11), e379.

Chan, K. M. A., Guerry, A. D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., Bostrom, A., Chuenpagdee, R., Gould, R., Halpern, B. S., Hannahs, N., Levine, J., Norton, B., Ruckelshaus, M., Russell, R., Tam, J. and Woodside, U., (2012), "Where are Cultural and Social in Ecosystem Services? A Framework for Constructive Engagement", BioScience, Vol. 62 No. 8, pp. 744-756.

Chape, S., Harrison, J., Spalding, M., & Lysenko, I. (2005). Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1454), 443-455.

Christie, M., Fazey, I., Cooper, R., Hyde, T., Deri, A., Hughes, L., Bush, G., Brader, L., Nahman, A., Delange, W. and Reyers, B. (2008). An Evaluation of Economic and Non-economic Techniques for Assessing the Importance of Biodiversity to People in Developing Countries. DEFRA, London

Clark, J., Burgess, J., & Harrison, C. M. (2000). "I struggled with this money business": respondents' perspectives on contingent valuation. Ecological economics, 33(1), 45-62.

Coad, L., Campbell, A., Miles, L., & Humphries, K. (2008). The costs and benefits of protected areas for local livelihoods: a review of the current literature. UNEP World Conservation Monitoring Centre, Cambridge, UK.

Collins, S. L., Carpenter, S. R., Swinton, S. M., Orenstein, D. E., Childers, D. L., Gragson, T. L., Grimm, N. B., Morgan Grove, J., Harlan, S. L., Kaye, J. P., Knapp, A. K., Kofinas, G. P., Magnuson, J. J., Mcdowell, W. H., Melack, J. M., Ogden, L. A., Robertson, G. P., Smith, M. D. and Whitmer, A. C., (2011). "An Integrated conceptual framework for long-term social-ecological research". Frontiers in Ecology and the Environment, Vol. 9 No. 6, pp. 351-357.

Cooper, K., Burdon, D., Atkins, J.P., Weiss, L., Somerfield, P., Elliott, M., Turner., RK, Ware, S., Vivian, C. (2013). Can the benefits of physical seabed restoration justify the costs? An assessment of a disused aggregate extraction site off the Thames Estuary, UK. Marine Pollution Bulletin 75(1-2): 33-45. http://dx.doi.org/10.1016/j.marpolbul.2013.08.009).

Cormier, R., Elliott, M. (2017). SMART marine goals, targets and management – is SDG 14 operational or aspirational, is 'Life Below Water' sinking or swimming? Marine Pollution Bulletin 123: 28-33; https://doi.org/10.1016/j.marpolbul.2017.07.060.

Corrigan, C., J. Robinson, C., Burgess, N. D., Kingston, N. and Hockings, M. (2017). Global Review of Social Indicators used in Protected Area Management Evaluation. Conservation Letters. doi:10.1111/conl.12397

Costanza, R., Daily, G., & Ehrlich, P. (1992). Population, sustainability and the earths carrying capacity. A framework for estimating population sizes and lifestyles that could be sustained without undermining future generations. Journal of Bioscience, 1-19.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., ... & Raskin, R. G. (1997). The value of the world's ecosystem services and natural capital. Nature, 387(6630), 253-260.

Costanza, R., van den Belt, M (Eds) (2011) Volume 12: Ecological Economics of Estuaries and Coasts. In: Treatise on Estuarine and Coastal Science Editors-in-Chief: E Wolanski and DS McLusky, Elsevier, Amsterdam, ISBN: 978-0-08-087885-0

Cowling, R. M., Egoh, B., Knight, A. T., O'Farrell, P. J., Reyers, B., Rouget, M., ... & Wilhelm-Rechman, A. (2008). An operational model for mainstreaming ecosystem services for implementation. Proceedings of the National Academy of Sciences, 105(28), 9483-9488.

Craigie, I. D., Baillie, J. E., Balmford, A., Carbone, C., Collen, B., Green, R. E., & Hutton, J. M. (2010). Large mammal population declines in Africa's protected areas. Biological Conservation, 143(9), 2221-2228.

Crossman, N. D., Burkhard, B., Nedkov, S., Willemen, L., Petz, K., Palomo, I., ... & Alkemade, R. (2013). A blueprint for mapping and modelling ecosystem services. Ecosystem services, 4, 4-14.

Czúcz, B., Arany, I., Potschin-Young, M., Bereczki, K., Kertész, M., Kiss, M., ... & Haines-Young, R. (2018). Where concepts meet the real world: A systematic review of ecosystem service indicators and their classification using CICES. Ecosystem Services, 29, 145-157.

Daily, G. (Ed.). (1997). Nature's services: societal dependence on natural ecosystems. Island Press.

Daily, G. C., & Matson, P. A. (2008). Ecosystem services: from theory to implementation. Proceedings of the national academy of sciences, 105(28), 9455-9456.

De Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological economics, 41(3), 393-408.

De Groot, R. S., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological complexity, 7(3), 260-272.

Deguignet M., Juffe-Bignoli D., Harrison J., MacSharry B., Burgess N., Kingston N., (2014) 2014 United Nations List of Protected Areas. UNEP-WCMC: Cambridge, UK

Diamond, P. A., & Hausman, J. A. (1994). Contingent valuation: Is some number better than no number?. The Journal of economic perspectives, 8(4), 45-64.

2

Di Lorenzo, M., Claudet, J.,Guidetti, P., (2016) Spillover from marine protected areas to adjacent fisheries has an ecological and a fishery component Journal for Nature Conservation, 32: 62-66.

Doak, D. F., Bakker, V. J., Goldstein, B. E., & Hale, B. (2015). What is the future of conservation?. In Protecting the Wild (pp. 27-35). Island Press/Center for Resource Economics.

Dobbs, C., Escobedo, F. J., & Zipperer, W. C. (2011). A framework for developing urban forest ecosystem services and goods indicators. Landscape and urban planning, 99(3-4), 196-206.

Dramstad, W. E., Tveit, M. S., Fjellstad, W. J. and Fry, G. L. A., (2006), “Relationships between visual landscape preferences and map-based indicators of landscape structure”, Landscape and Urban Planning, Vol. 78 No. 4, pp. 465-474.

Draper, M, M. Spierenburg and H. Wels. (2004). African dreams of cohesion: Elite pacting and community development in transfrontier conservation areas in Southern Africa. Culture and Organization 10(4): 341–353.

Dudley, N. & Stolton, S., eds. (2003). Running pure: the importance of forest protected areas to drinking water. Gland, Switzerland, WWF/World Bank Alliance for Forest Conservation and Sustainable Use.

Dudley, N. (Ed.). (2008). Guidelines for applying protected area management categories. Iucn.

Dudley, N., Stolton, S., Belokurov, A., Krueger, L., Lopoukhine, N., MacKinnon, K., ... & Sekhran, N. (2010). Natural solutions: Protected areas helping people cope with climate change. Natural solutions: protected areas helping people cope with climate change.

Eagles, P., & Hillel, O. (2008). Improving protected area finance through tourism. In Second meeting of the Ad Hoc Open□ended Working Group on Protected Areas (WGPA□2), Rome, Italy

Egoh, B., Reyers, B., Rouget, M., Bode, M., & Richardson, D. M. (2009). Spatial congruence between biodiversity and ecosystem services in South Africa. Biological conservation, 142(3), 553-562.

Ehrlich, P., & Ehrlich, A. (1981). Extinction: the causes and consequences of the disappearance of species.

Eigenbrod, F., Armsworth, P. R., Anderson, B. J., Heinemeyer, A., Gillings, S., Roy, D. B., ... & Gaston, K. J. (2010). The impact of proxy□based methods on mapping the distribution of ecosystem services. Journal of Applied Ecology, 47(2), 377-385.

Eizenberg, E., Orenstein, D. E. and Zimroni, H., (2017), “Back to the (Visualization) Laboratory”, Journal of Planning Education and Research, Vol. No., pp. 0739456X17700252.

Elliott, M. (2011). Marine science and management means tackling exogenic unmanaged pressures and endogenic managed pressures – a numbered guide. Marine Pollution Bulletin, 62: 651-655.

Elliott, M., Burdon, D., Atkins, J.P., Borja, A., Cormier, R., de Jonge, V.N., and Turner, R.K. (2017). “And DPSIR begat DAPSI(W)R(M)!” - a unifying framework for marine environmental management. Marine Pollution Bulletin, 118 (1-2): 27-40. http://dx.doi.org/10.1016/j.marpolbul.2017.03.049

European Commission (EU). (2000). Natura 2000. Managing our heritage. EU, Luxembourg.

European Commission. (2011). Our life insurance, our natural capital: an EU biodiversity strategy to 2020. COM (2011), 244.

Fagerholm, N., Käyhkö, N., Ndumbaro, F. and Khamis, M., (2012), “Community stakeholders’ knowledge in landscape assessments – Mapping indicators for landscape services”, Ecological Indicators, Vol. 18 No. 0, pp. 421-433.

Feld, C. K., Martins da Silva, P., Paulo Sousa, J., De Bello, F., Bugter, R., Grandin, U., ... & Pärtel, M. (2009). Indicators of biodiversity and ecosystem services: a synthesis across ecosystems and spatial scales. Oikos, 118(12), 1862-1871.

Fisher, B., & Turner, R. K. (2008). Ecosystem services: classification for valuation. Biological conservation, 141(5), 1167-1169.

Fisher, B., Turner, R. K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. Ecological economics, 68(3), 643-653.

Fisher, J. A., & Brown, K. (2014). Ecosystem services concepts and approaches in conservation: Just a rhetorical tool?. Ecological economics, 108, 257-265.

Freeman, A. M. (2003). Economic valuation: what and why. A primer on nonmarket valuation, 1-25.

Fu, B. J., Su, C. H., Wei, Y. P., Willett, I. R., Lü, Y. H., & Liu, G. H. (2011). Double counting in ecosystem services valuation: causes and countermeasures. Ecological research, 26(1), 1-14.

Geldmann, J., Barnes, M., Coad, L., Craigie, I. D., Hockings, M., & Burgess, N. D. (2013). Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. Biological Conservation, 161, 230-238.

Graves, R. A., Pearson, S. M., & Turner, M. G. (2017). Species richness alone does not predict cultural ecosystem service value. Proceedings of the National Academy of Sciences, 114(14), 3774-3779.

Gómez-Baggethun, E., De Groot, R., Lomas, P. L., & Montes, C. (2010). The history of ecosystem services in economic theory and practice: from early notions to markets and payment schemes. Ecological economics, 69(6), 1209-1218.

Haase, P., Tonkin, J. D., Stoll, S., Burkhard, B., Frenzel, M., Geijzendorffer, I. R., ... & Mirtl, M. (2018). The next generation of site-based long-term ecological monitoring: Linking essential biodiversity variables and ecosystem integrity. Science of the Total Environment, 613, 1376-1384.

Haberl, H., Winiwarter, V., Andersson, K., Ayres, R. U., Boone, C., Castillo, A., Cunfer, G., Fischer-Kowalski, M., Freudenburg, W. R., Furman, E., Kaufmann, R., Krausmann, F., Langthaler, E., Lotze-Campen, H., Mirtl, M., Redman, C. L., Reenberg, A., Wardell, A., Warr, B. and Zechmeister, H., (2006), "From LTER to LTSER: Conceptualizing the Socioeconomic Dimension of Long-term Socioecological Research", Ecology and Society, Vol. 11 No. 2

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. Ecosystem Ecology: a new synthesis, 110-139.

Haines-Young, R., & Potschin, M. (2011). Common international classification of ecosystem services (CICES): 2011 Update. Nottingham: Report to the European Environmental Agency.

Haines-Young, R., & Potschin, M. (2013). CICES V4. 3–Revised report prepared following consultation on CICES Version 4, August-December 2012. EEA Framework Contract No EEA (p. 34). IEA/09/003.

Hanemann, W. M. (1991). Willingness to pay and willingness to accept: how much can they differ?. The American Economic Review, 81(3), 635-647.

Harrison, P. A., Vandewalle, M., Sykes, M. T., Berry, P. M., Bugter, R., de Bello, F., ... & Jongman, R. H. (2010). Identifying and prioritising services in European terrestrial and freshwater ecosystems. Biodiversity and Conservation, 19(10), 2791-2821.

Haslett, J. R., Berry, P. M., Bela, G., Jongman, R. H., Pataki, G., Samways, M. J., & Zobel, M. (2010). Changing conservation strategies in Europe: a framework integrating ecosystem services and dynamics. Biodiversity and Conservation, 19(10), 2963-2977.

Hattam, C., Böhnke-Henrichs, A., Börger, T., Burdon, D., Hadjimichael, M., Delaney, A., ... & Austen, M. C. (2015). Integrating methods for ecosystem service assessment and valuation: Mixed methods or mixed messages?. Ecological Economics, 120, 126-138.

Hummel, H., Bienfait, L., Kalle, V., Boyer, Y., De Wit, R., Hummel, C.A. (2018). Essential Environmental and Socio-Economic Variables for future and current Protected Areas, EcoPotential deliverable 9.1, https://doi.org/10.5281/zenodo.1404042

Hoevenagel, R. (1994). An assessment of the contingent valuation method. In Valuing the environment: Methodological and measurement issues (pp. 195-227). Springer Netherlands.

Hutton, J., W.M. Adams and J.C. Murombedzi. (2005). Back to the barriers? Changing narrativesin biodiversity conservation. Forum for Development Studies 2: 341–370.

IUCN. (2004). Speaking a Common Language, The uses and performance of the IUCN System of Management Categories for Protected Areas, ISBN: 1-902647-48-3

Jachmann, H. (2008). Illegal wildlife use and protected area management in Ghana. Biological Conservation, 141(7), 1906-1918.

Jackson, E. L., Rees, S. E., Wilding, C., & Attrill, M. J. (2015). Use of a seagrass residency index to apportion commercial fishery landing values and recreation fisheries expenditure to seagrass habitat service. Conservation Biology, 29(3), 899-909.

Jacobs, M. (1997). Environmental valuation, deliberative democracy and public decision-making institutions. Valuing nature, 211-231.

Janzen, D. H., Mantell, M., & Burley, F. W. (1986). Can National Parks Survive?. BioScience, 36(8), 512-512.

Juffe-Bignoli, D., Burgess, N.D., Bingham, H., Belle, E.M.S., de Lima, M.G., Deguignet, M., Bertzky, B., Milam, A.N., Martinez-Lopez, J., Lewis, E., Eassom, A., Wicander, S., Geldmann, J., van Soesbergen, A., Arnell, A.P., O'Connor, B., Park, S., Shi, Y.N., Danks, F.S., MacSharry, B., Kingston, N. (2014). Protected Planet Report 2014. UNEP-WCMC: Cambridge, UK

Jungmeier, M., Velik, I., Wagenleitner, S., Zollner, D., (2008): PANet 2010: PANet Protected Area Networks. WP1: Project Management and overall coordination, Klagenfurt, 177.

Júnior, J. G. C. O., Ladle, R. J., Correia, R., & Batista, V. S. (2016). Measuring what matters–Identifying indicators of success for Brazilian marine protected areas. Marine Policy, 74, 91-98.

Kandziora, M., Burkhard, B., & Müller, F. (2013). Interactions of ecosystem properties, ecosystem integrity and ecosystem service indicators—A theoretical matrix exercise. Ecological Indicators, 28, 54-78.

Kareiva, P.M. (2012). In: Wijkman, A., & Rockström, J. Bankrupting nature: Denying our planetary boundaries. Routledge.

Keat, R. (1994). Citizens, Consumers and the Environment: Reflections on the Economy of the Earth. In Cultural Goods and the Limits of the Market (pp. 52-69). Palgrave Macmillan, London.

Koetse, M. J., Brouwer, R., & van Beukering, P. J. (2015). Economic valuation methods for ecosystem services. Ecosystem services: From concept to practice, 108-131.

Kosoy, N. and Corbera, E., (2010), "Payments for ecosystem services as commodity fetishism", Ecological Economics, Vol. 69 No. 6, pp. 1228-1236.

Kremen, C. (2005). Managing ecosystem services: what do we need to know about their ecology?. Ecology letters, 8(5), 468-479.

Landers, D. H., & Nahlik, A. M. (2013). Final ecosystem goods and services classification system (FEGS-CS). Anonymous EPA United

States Environmental Protection Agency. Report Number EPA/600/R-13/ORD-004914.

La Notte, A., D'Amato, D., Mäkinen, H., Paracchini, M. L., Liquete, C., Egoh, B., ... & Crossman, N. D. (2017). Ecosystem services classification: A systems ecology perspective of the cascade framework. Ecological Indicators, 74, 392-402.

Layke, C. (2009). Measuring nature's benefits: a preliminary roadmap for improving ecosystem service indicators. World Resources Institute: Washington.

Layke, C., Mapendembe, A., Brown, C., Walpole, M., & Winn, J. (2012). Indicators from the global and sub-global Millennium Ecosystem Assessments: An analysis and next steps. Ecological Indicators, 17, 77-87.

Leemans, S. (2017). Preventing Paper Parks: How to Make the EU Nature Laws Work. WWF, UK.

Liquete, C., Piroddi, C., Drakou, E. G., Gurney, L., Katsanevakis, S., Charef, A., & Egoh, B. (2013). Current status and future prospects for the assessment of marine and coastal ecosystem services: a systematic review. PloS one, 8(7), e67737.

Liu, J., Linderman, M., Ouyang, Z., An, L., Yang, J., & Zhang, H. (2001). Ecological degradation in protected areas: the case of Wolong Nature Reserve for giant pandas. Science, 292(5514), 98-101.

Ludwig, D. (2000). Limitations of economic valuation of ecosystems. Ecosystems, 3(1), 31-35.

Maes, J., Egoh, B., Willemen, L., Liquete, C., Vihervaara, P., Schägner, J. P., ... & Bouraoui, F. (2012). Mapping ecosystem services for policy support and decision making in the European Union. Ecosystem Services, 1(1), 31-39.

Maiorano, L., Falcucci, A., Garton, E.O. and Boitani, L., (2007). Contribution of the Natura 2000 network to biodiversity conservation in Italy. Conservation Biology, 21(6), pp.1433-1444.

Matthews, G.V.T., (1993). The Ramsar Convention on Wetlands: its history and development. Gland: Ramsar convention bureau.

McAfee, K., & Shapiro, E. N. (2010). Payments for ecosystem services in Mexico: nature, neoliberalism, social movements, and the state. Annals of the Association of American Geographers, 100(3), 579-599.

McCauley, D. (2006). Selling out on nature. Nature. 443. 27-8. 10.1038/443027a.

McNeely, J. A. (1993). Parks for Life: Report of the Fourth World Congress on National Parks and Protected Areas, 10–21 February 1992. IUCN, Protected Areas Programme, WWF, IUCN, Gland.

McNeill, J. R. (2007). The Mediterranean: An Environmental History.

MEA. (2003). Assessment: Ecosystems and human well-being: A framework for assessment. Island Press, 1718 Connecticut Avenue, N.W., Suite 300, Washington, DC 20009

MEA. (2005). Ecosystems and human well-being: wetlands and water. World resources institute, Washington, DC, 5.

Menzel, S., & Teng, J. (2010). Ecosystem services as a stakeholder-driven concept for conservation science. Conservation Biology, 24(3), 907-909.

Mitchell, R. C., & Carson, R. T. (1989). Using surveys to value public goods: the contingent valuation method. Resources for the Future. Rff press.

Mooney, H. A., Ehrlich, P. R., & Daily, G. E. (1997). Ecosystem services: a fragmentary history. Nature's Services: societal dependence on natural ecosystems, 11-19.

Müller, F., & Burkhard, B. (2012). The indicator side of ecosystem services. Ecosystem Services, 1(1), 26-30.

Nahlik, A. M., Kentula, M. E., Fennessy, M. S., & Landers, D. H. (2012). Where is the consensus? A proposed foundation for moving ecosystem service concepts into practice. Ecological Economics, 77, 27-35.

Nassauer, J. I., (1995), "Messy Ecosystems, Orderly Frames", Landscape Journal, Vol. 14 No. 2, pp. 161-170.

Naveh, Z., (2000), "What is holistic landscape ecology? A conceptual introduction", Landscape and Urban Planning, Vol. 50 No., pp. 7-26.

Naveh, Z. and Lieberman, A. S., (1994), Landscape Ecology: Theory and Application, Springer-Verlag. New York.

Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, D., ... & Lonsdorf, E. (2009). Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Frontiers in Ecology and the Environment, 7(1), 4-11.

Nieto-Romero, M., Oteros-Rozas, E., González, J. A., & Martín-López, B. (2014). Exploring the knowledge landscape of ecosystem services assessments in Mediterranean agroecosystems: insights for future research. Environmental Science & Policy, 37, 121-133.

Oates, J.F. (1999). Myth and Reality in the Rain Forest: How Conservation Strategies Are Failing in West Africa. University of California Press, London, UK.

Odum, E. P., & Barrett, G. W. (1971). Fundamentals of ecology (Vol. 3). Philadelphia: Saunders.

Odum, E. P. (1977). The emergence of ecology as a new integrative discipline. Science, 195(4284), 1289-1293.

Orenstein, D. E., Zimroni, H. and Eizenberg, E., (2015), “The Immersive Visualization Theater: A new tool for ecosystem assessment and landscape planning”, Computers, Environment and Urban Systems, Vol. 54 No., pp. 347-355.

Orenstein, D. and Groner, E., (2015), “Using the Ecosystem Services Framework in a Long-Term Socio-Ecological Research (LTSER) Platform: Lessons from the Wadi Araba Desert, Israel and Jordan”, in: ROZZI, R., CHAPIN III, F. S., CALLICOTT, J. B., PICKETT, S. T. A., POWER, M. E., ARMESTO, J. J. & MAY JR, R. H. (eds.) Earth Stewardship. Springer International Publishing, pp. 281-296
Parrish, J. D., Braun, D. P., & Unnasch, R. S. (2003). Are we conserving what we say we are? Measuring ecological integrity within protected areas. BioScience, 53(9), 851-860.

Pascual, M., Borja, A., Franco, J., Burdon, D., Atkins, J.P. & Elliott, M. (2012). What are the costs and benefits of biodiversity recovery in a highly polluted estuary? Water Research, 46: 205-217.

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., ... & Maris, V. (2017). Valuing nature’s contributions to people: the IPBES approach. Current Opinion in Environmental Sustainability, 26, 7-16.

Patrício J., Elliott M., Mazik K., Papadopoulou K.-N. and Smith C.J. (2016). DPSIR—Two decades of trying to develop a unifying framework for marine environmental management? Front. Mar. Sci. 3:177. doi: 10.3389/fmars.2016.00177.

Pereira, H. M., & Cooper, H. D. (2006). Towards the global monitoring of biodiversity change. Trends in Ecology & Evolution, 21(3), 123-129.

Perrings, C., Folke, C., & Mäler, K. G. (1992). The ecology and economics of biodiversity loss: the research agenda. Ambio, 201-211.

Phillips, A. (2007). A short history of the international system of protected area management categories. WCPA Task Force on protected area categories.

Pieraccini, M., Coppa, S., & De Lucia, G. A. (2017). Beyond marine paper parks? Regulation theory to assess and address environmental non compliance. Aquatic Conservation: Marine and Freshwater Ecosystems, 27(1), 177-196.

Pimbert, M.P. and Pretty, J.N., (1997). Parks, people and professionals: putting ‘participation’ into protected area management. Social change and conservation, 16, pp.297-330.

ProtectedPlanet (2017). https://protectedplanet.net/c/increased-growth-of-protected-areas-in-2017

Rangajaran, M. (2005). India’s Wildlife History: an introduction, Orient Blackswan, 135 pp.

Raymond, C. M., Singh, G. G., Benessaiah, K., Bernhardt, J. R., Levine, J., Nelson, H., Turner, N. J., Norton, B., Tam, J. and Chan, K. M. A., (2013), “Ecosystem Services and Beyond: Using Multiple Metaphors to Understand Human–Environment Relationships”, BioScience, Vol. 63 No. 7, pp. 536-546.

Redford, K. H., & Adams, W. M. (2009). Payment for ecosystem services and the challenge of saving nature. Conservation Biology, 23(4), 785-787.

Reid, W.V., Mooney, H.A., Capistrano, D., Carpenter, S.R., Chopra, K., Cropper, A., Dasgupta, P., Hassan, R., Leemans, R., May, R.M., Pingali, P., Samper, C., Scholes, R., Watson, R.T., Zakri, A.H., Shidong, Z. (2006). Nature: the many benefits of ecosystem services. Nature 443 (7113), 749–750

Rhodes, C. R. (2015). National Ecosystem Services Classification System (NESCS): Framework Design and Policy Application. EPA-800-R-15-002.

Rich, S. (2013). Ship Timber as Symbol? Dendro-Provenancing and Contextualizing Ancient Cedar Ship Remains from the Eastern Mediterranean/Near East. Unpublished Ph. D. dissertation. KU Leuven. Leuven.

Roberts, C.M., Fiona R. Gell, F.R., Hawkins, J.P. (2003). Protecting nationally important marine areas in the Irish Sea Pilot Project Region. Unpublished Report for the JNCC, Environment Department, University of York, York, YO10 5DD, UK.

Rodrigues, A. S., Andelman, S. J., Bakarr, M. I., Boitani, L., Brooks, T. M., Cowling, R. M., ... & Long, J. S. (2004). Effectiveness of the global protected area network in representing species diversity. Nature, 428(6983), 640-643.

Rounsevell, M. D. A., Dawson, T. P., & Harrison, P. A. (2010). A conceptual framework to assess the effects of environmental change on ecosystem services. Biodiversity and Conservation, 19(10), 2823-2842.

Sagie, H., Morris, A., Rofè, Y., Orenstein, D. E. and Groner, E., (2013), “Cross-cultural perceptions of ecosystem services: A social inquiry on both sides of the Israeli–Jordanian border of the Southern Arava Valley Desert”, Journal of Arid Environments, Vol. 97 No. 0, pp. 38-48.

Sagoff, M. (1988). Some problems with environmental economics. Environmental Ethics, 10(1), 55-74.

Sagoff, M. (1998). Aggregation and deliberation in valuing environmental public goods: A look beyond contingent pricing. Ecological Economics, 24(2), 213-230.

Sagoff, M. (2004). Price, principle, and the environment. Cambridge University Press.

Sagoff, M. (2008). On the economic value of ecosystem services. Environmental Values, 239-257.

SCEP [Study of Critical Environmental Problems] (1970) Man’s impact on the global environment. Cambridge, Massachusetts: MIT Press.

Scharin, H., Ericsdotter, S., Elliott, M., Turner, R.K., Niiranen, S., Rockström, J., Blenckner, T., Hyytiäinen, K., Ahlvik, L., Heini Ahtiainen, H., Artell, J., Hasselström, L., Söderqvist, T. (2016). Processes for the sustainable stewardship of marine environments. Ecological Economics. 128: 55-67.

Scull, P., Cardelús, C. L., Klepeis, P., Woods, C. L., Frankl, A., and Nyssen, J. (2017) The Resilience of Ethiopian Church Forests: Interpreting Aerial Photographs, 1938–2015. Land Degrad. Develop., 28: 450–458. doi: 10.1002/ldr.2633.

Seppelt, R., Dormann, C. F., Eppink, F. V., Lautenbach, S., & Schmidt, S. (2011). A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. Journal of applied Ecology, 48(3), 630-636.

Singh, S. J., Haberl, H., Chertow, M., Mirtl, M. and Schmid, M., (2013), “Introduction”, in: SINGH, S. J., HABERL, H., CHERTOW, M., MIRTL, M. & SCHMID, M. (eds.) Long Term Socio-Ecological Research. Springer, Dordrecht, pp. 1-28

Small, E., (2011), “The new Noah’s Ark: beautiful and useful species only. Part 1. Biodiversity conservation issues and priorities”, Biodiversity, Vol. 12 No. 4, pp. 232-247.

Smith, P., Ashmore, M. R., Black, H. I., Burgess, P. J., Evans, C. D., Quine, T. A., ... & Orr, H. G. (2013). The role of ecosystems and their management in regulating climate, and soil, water and air quality. Journal of Applied Ecology, 50(4), 812-829.

Sohngen, B., & Brown, S. (2006). The influence of conversion of forest types on carbon sequestration and other ecosystem services in the South Central United States. Ecological Economics, 57(4), 698-708.

Spangenberg, J. H., & Settele, J. (2010). Precisely incorrect? Monetising the value of ecosystem services. Ecological Complexity, 7(3), 327-337.

Spash, C. L., & Hanley, N. (1995). Preferences, information and biodiversity preservation. Ecological economics, 12(3), 191-208.

Staub, C., Ott, W., Heusi, F., Klingler, G., Jenny, A., Hacki, M., & Hauser, A. (2011). Indicators for Ecosystem Goods and Services: Framework, methodology and recommendations for a welfare-related environmental reporting. Federal Office for the Environment, Bern. Environmental studies, (1102), 17.

Stolton, S., Dudley, N., & Randall, J. (2008). Natural Security: Protected Areas and Hazard Mitigaton. WWF.

Tansley, A. G. (1935). The use and abuse of vegetational concepts and terms. Ecology, 16(3), 284-307.

TEEB, (2010). The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. In: Pushpam Kumar (Ed.), Earthscan, London and Washington

Tengberg, A., Fredholm, S., Eliasson, I., Knez, I., Saltzman, K. and Wetterberg, O., (2012), “Cultural ecosystem services provided by landscapes: Assessment of heritage values and identity”, Ecosystem Services, Vol. 2 No. 0, pp. 14-26.

Terborgh, J. (1999). Requiem for Nature. Island Press/Shearwater Books, WA, DC, USA.

Termorshuizen, J. and Opdam, P., (2009), “Landscape services as a bridge between landscape ecology and sustainable development”, Landscape Ecology, Vol. 24 No. 8, pp. 1037-1052.

Tett P., Gowen R., Painting S., Elliott M., Forster R., Mills D., Bresnan E., Capuzzo E., Fernandes T., Foden J., Geider R., Gilpin L., Huxham M., McQuatters-Gollop A., Malcolm S., Saux-Picart S., Platt T., Racault M.-F., Sathyendranath S., Molen J.v.d. and Wilkinson M. (2013). Framework for understanding marine ecosystem health. Marine Ecology Progress Series 494: 1–27 + suppl. material.

Toman, M. A. (1997). Ecosystem valuation: an overview of issues and uncertainties. In Ecosystem Function & Human Activities (pp. 25-44). Springer, Boston, MA.

Turner, K., Schaafsma, M., Elliott, M., Burdon, D., Atkins, J., Jickells, T., Tett, P., Mee, L., van Leeuwen, S., Barnard, S., Luisetti, T., Paltriguera, L., Palmieri, G., Andrews, J. (2014). UK National Ecosystem Assessment Follow-on. Work Package Report 4: Coastal and Marine Ecosystem Services: Principles and Practice. UNEP-WCMC, LWEC, UK.

Turner, R.K. (1999). Markets and environmental quality. In: Clark, G.L., Feldman, M.P., Gertler, M.S. (Eds.), The Oxford Handbook of Economic Geography, pp. 585–606

Turner, R.K., Morse-Jones, S., Fisher, B., (2010). Ecosystem valuation: A sequential decision support system and quality assessment issues. Ann. N.Y. Acad. Sci. 1185 (2010) 79–101

Turner, R.K. & Schaafsma, M. (Eds.) (2015) Coastal zones ecosystem services: from science to values and decision making. Springer Ecological Economic Series, Springer Internat. Publ. Switzerland, ISBN 978-3-319-17213-2.

Turnhout, E., Waterton, C., Neves, K., & Buizer, M. (2013). Rethinking biodiversity: from goods and services to “living with”. Conservation Letters, 6(3), 154-161.

Van Oudenhoven, A. P., Petz, K., Alkemade, R., Hein, L., & de Groot, R. S. (2012). Framework for systematic indicator selection to assess effects of land management on ecosystem services. Ecological Indicators, 21, 110-122.

Vassallo, P., Paoli, C., Rovere, A., Montefalcone, M., Morri, C., & Bianchi, C. N. (2013). The value of the seagrass Posidonia oceanica: A natural capital assessment. Marine pollution bulletin, 75(1-2), 157-167.

Wallace, K. J. (2007). Classification of ecosystem services: problems and solutions. Biological conservation, 139(3), 235-246.

West, P., Igoe, J., & Brockington, D. (2006). Parks and peoples: the social impact of protected areas. Annu. Rev. Anthropol., 35, 251-277.

Westman, W. E. (1977). What are nature's services worth?. Sciences, 197, 960-963.

Wild R., McLeod C. (2008). Sacred natural sites: Guidelines for protected area managers. IUCN, Gland, Switzerland, pg. 106

Wilson, E. O. (ed.) (1988), Biodiversity, National Academies Press, Washington D.C.

Wilson, M. A., & Carpenter, S. R. (1999). Economic valuation of freshwater ecosystem services in the United States: 1971–1997. Ecological applications, 9(3), 772-783.

Wilson, M. A., & Howarth, R. B. (2002). Discourse-based valuation of ecosystem services: establishing fair outcomes through group deliberation. Ecological economics, 41(3), 431-443.

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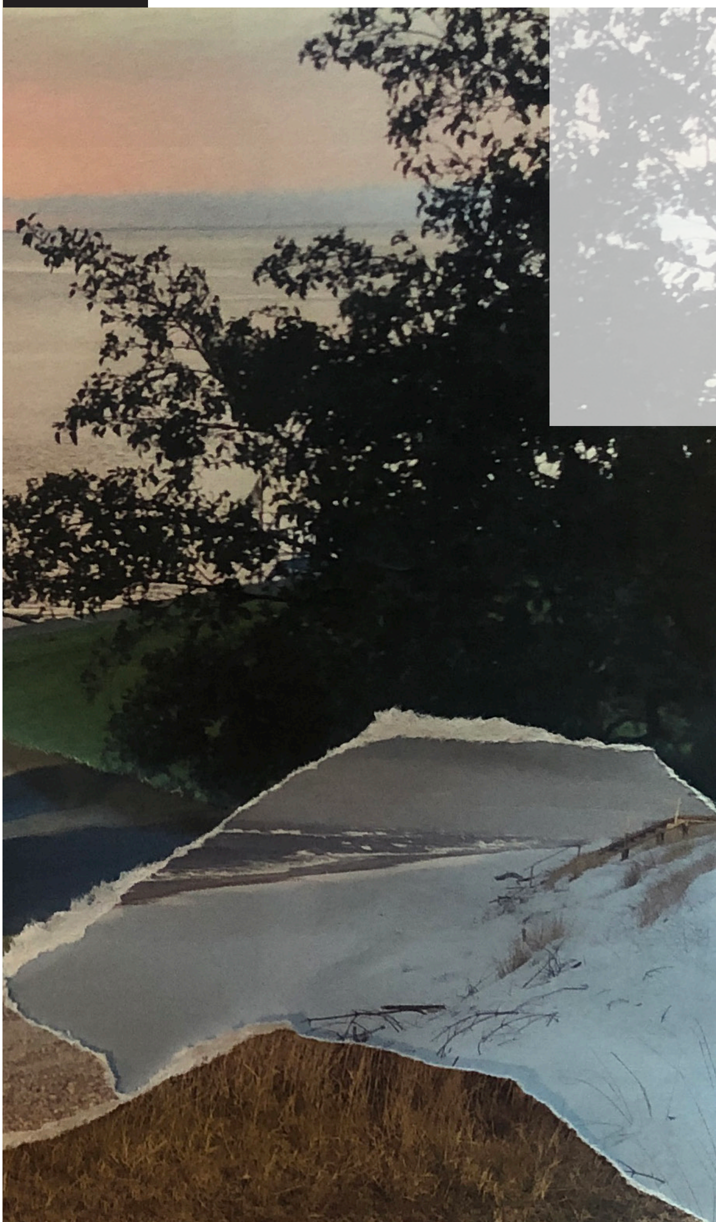
Chapter 3 - Ecosystem services in European protected areas: Ambiguity in the views of scientists and managers?



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Chapter 3 - Ecosystem services in European protected areas:

Ambiguity in the views of scientists and managers?

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Abstract

Protected Areas are a key component of nature conservation. They can play an important role in counterbalancing the impacts of ecosystem degradation. For an optimal protection of a Protected Area it is essential to account for the variables underlying the major Ecosystem Services an area delivers, and the threats upon them. Here we show that the perception of these important variables differs markedly between scientists and managers of Protected Areas in mountains and transitional waters. Scientists emphasise variables of abiotic and biotic nature, whereas managers highlight socio-economic, cultural and anthropogenic variables. This indicates fundamental differences in perception. To be able to better protect an area it would be advisable to bring the perception of scientists and managers closer together. Intensified and harmonised communication across disciplinary and professional boundaries will be needed to implement and improve Ecosystem Service oriented management strategies in current and future Protected Areas.

3

Keywords

+ Ecosystem services
+ Protected Areas
+ Marine coastal waters
+ Wetlands
+ Transitional waters
+ Mountains
+ Threats
+ Essential Variables
+ Indicators
+ Climate change
+ Nature conservation
+ Biodiversity loss

1. Introduction

Marine and terrestrial ecosystems play a vital and ever increasingly important role in providing essential Ecosystem Services to humanity and society (MEA, 2005). Ecosystem Services (ES) are the benefits that humans derive from ecosystems, ranging from material benefits such as food or fuel, to non-material benefits such as soil formation, water purification, recreation or aesthetics (MEA, 2005; Fitter et al., 2010; Hattam et al., 2015).
Due to their societal relevance and their close link to the state of ecosystems and the broader environment (Honrado et al., 2013), ES have increasingly been used as an assessment and policy communication tool (van der Biest et al., 2014; Maes et al., 2015; Paruelo et al., 2016).

Over the course of the last century strong anthropogenic pressures have caused widespread habitat degradation and a noticeable decline in the environmental quality across many ecosystems, potentially leading to biodiversity loss and an increased risk of declining or even collapsing ecosystem functions, and subsequent loss of ES (MEA, 2005; UNEP, 2016; Diaz et al., 2006; Hector & Bagchi, 2007; Ridder, 2007; Atkins et al., 2011; Vassallo et al.,2013)

The very first Protected Areas (PAs) in the form as we now know them can be traced back to the nineteenth century. The first 'modern' protected area was Yellowstone National Park, founded in 1872, as "a public park or pleasuring ground for the benefit and enjoyment of the people" (Bishop, 2004). Around the globe similar types of protected areas have been set up ever since.
The reasons to protect the environment through PAs however were of a different nature in several regions around the globe.
In North America they were set up to protect dramatic and sublime scenery, in Africa to protect game and their habitats in order to maintain elite hunting traditions (Adams & McShane, 1992; Draper et al., 2004) and in Europe to protect the landscape (Phillips, 2007).
This means that already from the beginning PAs were installed to protect specific ES and (bio)diversity, although the aims of these PA were not meant specifically to protect ES or (bio)diversity. The focus in using the terms biodiversity and ES with regard to the management of PA arose only in the eighties and nineties of the last century with the Convention on Biological Diversity (ISCBD, 1994) and the onset of ES studies (Costanza et al., 1997; Daily, 1997).

Nowadays, Protected Areas have become a key component of nature conservation, human well-being and also of management and policy strategies from regional to global scales (Bonet-Garcia et al., 2015; Coad et al., 2008; Upton et al., 2008). They can play an important role in counterbalancing the impacts of ecosystem degradation (Tittensor et al., 2014), avoiding collapse of ecosystem function, and also mitigating the associated loss of ES, not only inside but also outside the PA (Vitousek et al., 1997; Daily et al., 2000; Palmer et al., 2004; Haines-Young & Potschin, 2010; Potts et al., 2014; Sil et al., 2016).
The European network of PAs can make a substantial contribution to fulfil the requirements of various conventions and directives, including the Convention on Biological Diversity (CBD) through maintaining the natural heritage of European ecosystems.
This is supported by the diversity and the spatial distribution of PAs across the whole continent. However, direct and indirect human pressures on biodiversity such as climate and land use change have wide reaching impacts (Vermaat et al., 2016) especially affecting mountains and transitional coastal ecosystems, which are particularly sensitive to environmental changes (Pachauri et al., 2014).
Therefore, for an optimal protection of a PA and a better environmental quality, thereby strengthening a sustainable delivery of current services and for the future, it is essential to account for the pressures that may pose major threats to the system (Nagendra et al., 2015; Carvalho-Santos et al., 2015).

In the pursuit of identifying the most important variables in European PAs, the EcoPotential project (www.ecopotential-project.eu) surveyed the state-of-art view on the services and pressures in a representative selection of areas covering a variety of European regions.
This survey elicited responses from environmental scientists as well as PA managers, and for two main groups of PAs, mountainous and transitional waters. In the surveys the importance of various biotic, abiotic, and socio-economic variables for the ecosystem services and pressures in different PAs were assessed.

A mismatch between academic and management perceptions of ecosystem services and management priorities may well result in important shortcomings for the application of research outputs in adaptive PA management. To tackle this issue, here we will assess the similarities and differences in the vision of environmental scientists versus PA managers on which ecosystems services and pressures are most important in their PA. We also assess whether these variables identified by scientists and managers are of biotic, abiotic or socio-economic/anthropogenic nature.
As the respondents' perception of these variables was the central topic of the assessment, the definition of importance was left open to their interpretation. In general, we hypothesised that there would be differences in perceptions between scientists and managers due to their daily work routine, and between mountainous PAs and transitional water PAs.

Material and Methods

The importance of various variables underlying the ecosystem services and threats in transitional waters (marine coastal waters, deltas, lagoons) and mountainous PAs were assessed in two surveys; one survey distributed among environmental scientists (hereafter called 'scientists') and the other distributed among the managers of the studied PAs. The link with the ecosystem structures and functions of these areas was only assessed in the survey distributed among the scientists. The surveys were sent by email to 15 scientists working in the EcoPotential project, and 11 managers of protected areas were interviewed face to face by scientists working in the EcoPotential project.

To be able to obtain a proper overview of the major variables important for environmental scientists and PA managers in Europe, a broad range of PAs with different biogeographic settings and environmental conditions were included in the analyses (Fig 3.1). The analyses included transitional waters, such as the Wadden Sea in the Netherlands, the Curonian Lagoon in Lithuania, the Danube Delta in Romania, and the Camargue in France, as well mountainous areas, such as the Gran Paradiso in Italy, the Nördliche Kalkalpen in Austria, the Sierra Nevada in Spain, and Peneda-Gerês in Portugal (Table 2.1). All of these areas are recognised PAs having one or more of the following designations: National Park status, Natura 2000, UNESCO World Heritage area, or UNESCO Biosphere Reserve (Table 2.1).
Fig 3.1: Overview of PAs surveyed in Europe. Mountain symbol = mountainous PA, wave symbol = transitional waters PA (figure is for illustrative purposes only).

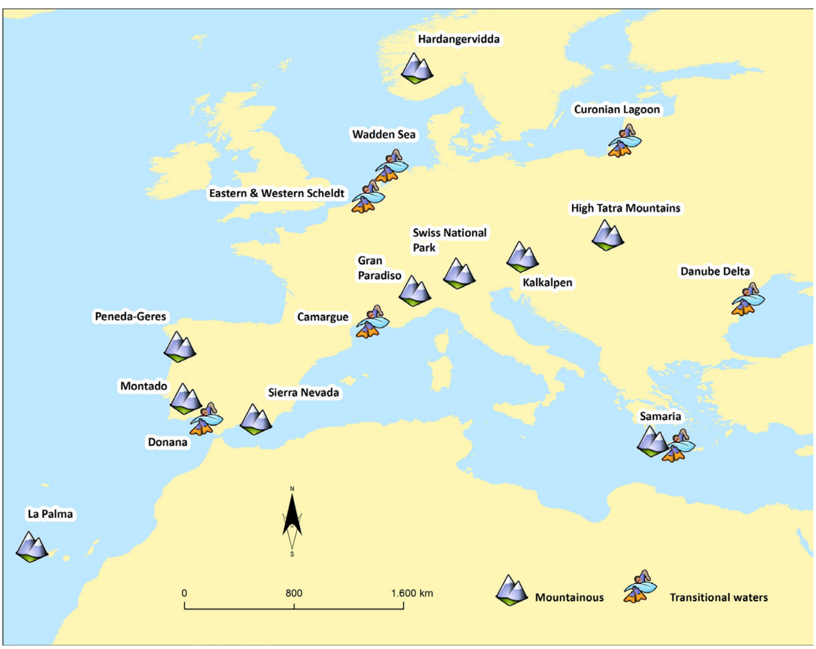

Table 3.1: Protected areas surveyed in the study including country and Protection status

		Transitional Waters		Mountains		
	Country	Scientists	Managers	Scientists	Managers	Protection status
Camargue	F	+	+			UBR, N2
Curonian Lagoon	LT	+	+			NP, N2,U-WH
Danube Delta	RO	+				N2, UBR, UWH
Doñana	E	+	+			NP, N2, UBR, UWH
Eastern Scheldt	NL	+				NP, N2
Wadden Sea	NL	+	+			NP, N2, UBR, UWH
Western Scheldt and Saeftinghe	NL	+				N2
Samaria	GR	+	+	+	+	NP, N2, UBR
Gran Paradiso	I			+	+	NP, N2,
Hardangervidda	N			+	+	NP
High Tatra Mountains	SK			+	+	NP, N2, UBR
La Palma	E				+	NP, N2, UBR
Kalkalpen National Park	A			+	+	NP,N2
Oros Idi	GR			+		NP, N2
Peneda-Gerês	P			+		NP, N2, UBR
Sierra Nevada	E			+		NP, N2, UBR
Swiss National Park	CH				+	NP, UBR

NP: National Park, UBR: Unesco Biosphere Reserve, N2: Natura 2000 site,
UWH: Unesco World Heritage

In the survey for scientists they were asked to identify the major ecosystem types for the PA and the most important ecosystem services in these ecosystems (for all ecosystem types encountered see S4 table, for an example of the survey see S1 table).
Subsequently the major ecosystem functions and structures underlying the most important services had to be indicated, and lastly the major threats to these ecosystem services, functions and structures.

The relative number of times a variable was mentioned in a category (ecosystem services or threats) per PA, across all ecosystem types, was adopted as the degree of importance of that variable in a given PA. The importance of each variable was then averaged over all surveyed PAs, and the standard error was calculated. Mean importance values of less than 2% were not included in further analyses.

To overcome the critical issue that often similar variables were assigned by scientists with several different names, the variables were harmonised to a standard set of variables. An overview of this harmonisation of variables is given in S2 table.

After harmonisation, all variables were categorised in variables of biotic, abiotic and socio economic nature for ES, and of biotic, abiotic and anthropogenic nature for threats (details can be found in S2 table). The categorisation of the variables is dependent on the origin of the variable, to prevent loss of causality. For example: the ES aquaculture is categorised as biotic since the object in aquaculture is of biotic origin, and the ES materials of economic use as abiotic since the materials are of abiotic origin, though both could be considered to be socio-economic, because both are an economic activity. If both would have been categorised as socio-economic, the origin of the variable (abiotic or biotic) would be lost, and with this the possible connections and implications for the supporting (functions in the) (eco)system.

To remain as close as possible to the original answers given by managers and scientists we have chosen for the analyses not to use the existing ES classification schemes of the Millennium Ecosystem Assessment (MEA, 2005) TEEB (TEEB, 2008) and CICES (Haines-Young & Potschin, 2012), also because they lack an integrated approach for classifying the EF and threats, making it hard to harmonise all variables in the same way.
Moreover, using the original variables as given by managers and scientists as much as possible makes it easier to distinguish between the different answers and different views of scientists and managers.

3

Some variables were miscategorised by the scientists. For example “water supply” was indicated as an ecosystem function whereas it is an ecosystem service. For further analysis, and to overcome this type of flaw, the variables were matched with the contextually most similar variable within a category.
In this specific case “water supply” was matched with the variable “hydrodynamics” in the category of Ecosystem functions and structures (all incorrectly categorised variables are summarised in S5 table; the “corrected” variables are included in S2 table).
During the survey, PA managers were asked to indicate the major ecosystem services and threats in their protected area (for an example of the survey see S3 table). Next, they were asked to indicate what the relative importance of each service and threat was. For services we have used the standard 5 point Likert scale (Likert, 1932) (0 = not present, 1= very low importance, 2 = low importance, 3 = moderate importance, 4 = high importance, 5 = very high importance).
For threats we have adopted the 3 point IPCC scaling for Risks (Gattuso et al., 2015) (0= no threat, 1 = low to moderate threat, 2 = strong threat, 3 = very strong threat). The counts of importance for each variable were averaged over all surveyed PAs, indexed (max score is 100 %), and the standard error was calculated.

In each survey the total importance of all variables mentioned by a scientist or a manager for each category (i.e. the ES and threats) in each PA always summed up to 100 %.
The (average) relative importance of the specific variables, as viewed by all scientists and PA managers, both within and between the two different types of PAs, i.e. Transitional Waters and Mountains, were compared after examining for normality using a Kolmogorov-Smirnov test, and statistically analysed for significant differences by means of a Mann Whitney U Test (IBM SPSS, 2016).

All underlying data and analyses will be made available at publication through open access at https://doi.org/10.6084/m9.figshare.5513530.v1

Results

Ecosystem Services
The 5 most important ES for scientists were: leisure activities, habitat for feeding and breeding, animals of economic use, climate regulation, and waste and toxicant mediation (Fig 3.2a).
The scientists of transitional waters and those of mountainous PAs often had a strongly, sometimes significantly, different view on the level of importance of these ES (table 3.2).
For example, scientists of transitional waters indicated habitat for feeding and breeding as very important, whereas for scientists of mountainous areas the habitat was hardly important but climate regulation was much more important (Fig 3.2a).

PA managers also considered leisure activities and habitat for feeding and breeding to be important ES (Fig 3.2b), although the importance of habitat was lower than with scientists (in mountainous areas even significantly less important; table 3.2).

Among the 5 most important ES identified by managers were education and research, sedimentological regulation, and aesthetic qualities, which were all judged by scientists to be of significantly less importance (Fig 3.2b; table 2.2).
Moreover, among PA managers, the difference in importance of most ES between transitional water and mountainous PAs was much smaller than among scientists (Fig 3.2; see also table 2 second versus third column).

It became clear that scientists put more emphasis on the biotic and abiotic (system related) ES, whereas PA managers put more emphasis on the socio-economic and cultural ES (Fig 3.2).

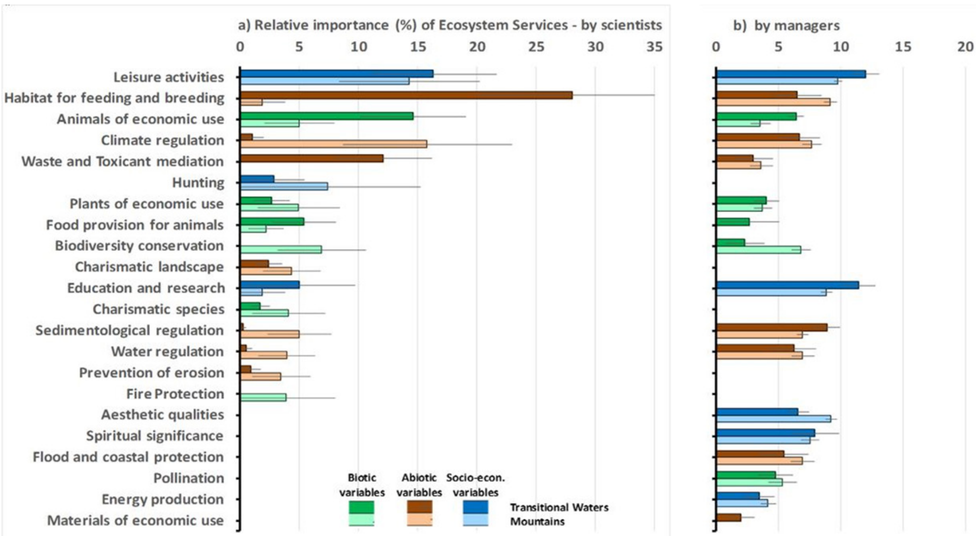

Fig 3.2. Relative importance (in %) of ecosystem services by scientists and PA managers in Transitional Waters and Mountains. (a) indicates scientists (b) indicates PA managers. Upper row (darker colours) indicates Transitional Waters, lower row (lighter colours) indicates Mountains, separated in ecosystem services of biotic (green), abiotic (brown) and socio-economic (blue) nature (indicated are averages and standard errors)

Pressures and Threats

The most important threat to ecosystem services and underlying functions according to both scientists and PA managers was climate change (Fig 3.3).
Furthermore, for scientists the overall top 5 also contains two abiotic and two anthropogenic threats (Fig 3.3a), overexploitation and habitat loss, which were more important for transitional waters, while fire and illegal activities were more important for mountainous areas.
For PA managers the most important threats besides climate change consisted solely of anthropogenic pressures (Fig 2.3b). PA managers hardly name any abiotic or biotic threats (see also Fig 3.4).
For threats the same holds as for ES, among PA managers the difference in importance of most threats between transitional water and mountainous PAs was much smaller than among scientists (Fig 3.3).

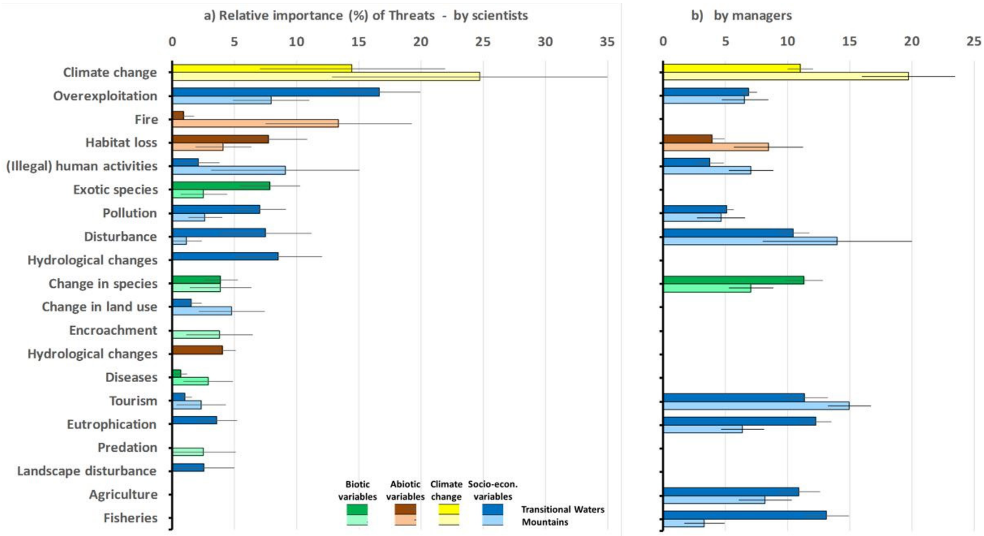

Fig 3.3. Relative importance of threats by scientists and PA managers in Transitional Waters and Mountains. (a) indicates scientists (b) indicates PA managers. Upper row (darker colours) indicates Transitional Waters, lower row (lighter colours) indicates Mountains, separated in biotic (green), abiotic (brown), climate change (yellow), and anthropogenic (blue) threats (indicated are averages and standard errors).

Biotic, Abiotic and Anthropogenic variables

Summing up the variables and distinguishing between those of biotic, abiotic and anthropogenic (or socio-economic and cultural) nature showed differences in perception by scientists and managers, and differences between mountainous areas and transitional waters.
This shows that the importance of biotic ES was considered higher among scientists of mountainous PAs than in transitional waters (Fig 3.4), whereas the abiotic ES were more important in transitional waters. PA managers indicated ES of anthropogenic nature as most important for both transitional waters and mountainous areas (Fig 3.4).
Regarding threats, PA managers indicated those of anthropogenic origin to be by far the most important, and threats of biotic and abiotic nature were least important (third row, Fig 3.4).
Scientists also indicated a high importance of anthropogenic threats, but also a considerable importance of biotic and abiotic threats. In mountainous areas climate change was considered a major threat by scientists, while it was considered less of a threat for transitional waters.

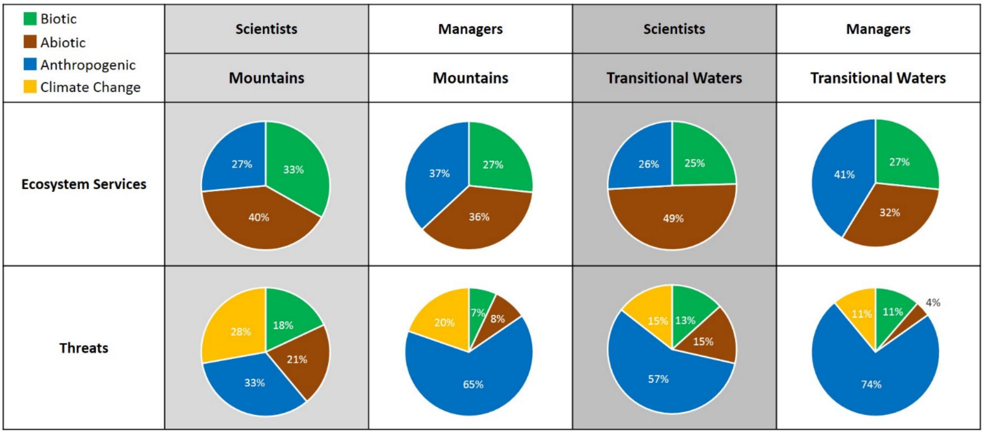

Fig 2.4. Overall importance of Ecosystem Services and Threats for both scientists and PA managers in Transitional Waters and Mountains. Importance is separated in biotic (green), abiotic (brown), climate change (yellow), and anthropogenic (blue) variables.

Variability of Perception

An analysis of variance showed a remarkable difference in the perception of the importance of variables between scientists and PA managers.
The variation in perception of important ecosystem functions, services, and threats in mountainous and transitional water PAs was threefold higher among scientists than among PA managers (table 3; also compare error bars of Fig 3.2a with 3.2b, and Fig 3.3a with 3.3b).
Irrespective of the large variability in the perception of the importance of ES and threats by the scientists, a strong significant difference occurred in the level of importance for most (two-thirds) of the ES and threats as indicated by scientists versus those indicated by managers (table 3.2).
When comparing the perception of the importance of ES and threats in mountainous PAs with those in transitional water PAs, the differences between both types of PAs were mostly non-significant in the view of scientists as well as in the view of managers (table 3.2).

Table 3.2: Statistical significance of the difference in importance to scientists (SC) and Managers (MA) of Ecosystem Services and Threats for Mountainous (MO) and Transitional Water (TW) Protected Areas (SC+MA means the data of SC and MA pooled together; MO+TW means the data of MO and TW pooled together). – indicates no significant difference, ● means significant difference at the level $p \leq 0.05$, ●● means $p \leq 0.01$, and ●●● means $p \leq 0.005$

	MO vs. TW			SC vs. MA		
	SC+MA	SC	MA	MO+TW	MO	TW
Ecosystem Services						
Leisure activities	-	-	-	-	-	-
Habitat for feeding and breeding	-	●	-	-	●	-
Animals of economic use	-	-	-	-	-	-
Climate regulation	●●	●	-	-	-	●●
Waste and Toxicant mediation	●	●	-	-	●	-
Hunting	-	-	-	-	-	-
Plants of economic use	-	-	-	●	-	-
Food provision for animals	-	-	-	-	-	-
Biodiversity conservation	●●	-	-	●	-	-
Charismatic landscape	-	-	-	●●	-	●
Education and research	-	-	-	●●●	●●	●
Charismatic species	-	-	-	●	-	-
Sedimentological regulation	-	-	-	●	-	●●●
Water regulation	-	-	-	●	-	●●
Prevention of erosion	-	-	-	-	-	-
Fire Protection	-	-	-	-	-	-
Aesthetic qualities	-	-	●	●●●	●●●	●●●
Spiritual significance	-	-	-	●●●	●●●	●●●
Flood and coastal protection	-	-	-	●	●	-
Pollination	-	-	-	●	-	●●●
Energy production	-	-	-	●●●	●	●●●
Materials of economic use	●●	-	-	-	-	-
Total number significant differences	4 / 22	3 / 22	1 / 22	12 / 22	7 / 22	9 / 22
Threats						
Climate change	-	-	-	-	-	-
Overexploitation	-	-	-	-	-	●
Fire	-	-	-	●	●	-
Habitat loss	-	-	-	-	-	-
(Illegal) human activities	-	-	-	-	-	-
Exotic species	-	-	-	●●●	-	●
Pollution	-	-	-	-	-	-
Disturbance	-	-	-	●●	●	-
Hydrological changes	-	-	-	-	-	●
Change in species	-	-	-	●	-	●

3

Change in land use	-	-	-	●	-	-
Encroachment	-	-	-	-	-	-
Hydrological changes	●●●	●●●	-	●	-	-
Diseases	-	-	-	-	-	-
Tourism	-	-	-	●●●	●●	●●●
Eutrophication	-	●	-	●●●	●●	●
Predation	-	-	-	-	-	-
Landscape disturbance	-	-	-	-	-	-
Agriculture	-	-	-	●●●	●●	●●●
Fisheries	●	-	●●	●●●	-	-
Total number significant differences	2 / 20	2 / 20	1 / 20	10 / 20	5 / 20	7 / 20

Table 3.3. Coefficient of variation (CV) in the relative importance of ecosystem s ervices (ES) and threats (Thr) indicated by scientists and PA managers, for transitional water PA (TW) and for mountainous PA (MO).

Domain	Variable	CV among Scientists	CV among PA Managers
TW	ES	1.15	0.55
TW	Thr	1.25	0.30
MO	ES	1.82	0.28
MO	Thr	1.63	0.72
Average		1.46	0.46

Discussion

The results show that common categories of ES and threats are considered to be important across transitional water as well as mountainous PAs. This would allow to make a harmonised list of most important variables of ES and threats over both geographic domains.

Such a harmonised list may in the future be helpful to overcome the difference in vocabulary between scientists and managers. This may also help include ES in PA management, since until now PA managers expressed that they did not explicitly apply the ES approach in their management, with only a few exceptions (Fisher & Brown, 2014; Nolte et al., 2016).

A noteworthy result of this study is that the variables mentioned, and the importance given to these variables by scientists and managers, are dissimilar. The overall view on important ES and threats by scientists does not match the view of PA managers. Although the set-up of the surveys (offering scientists a blank page, and managers a list that indicated potential variables) may have enhanced the differences, both groups had the liberty to identify variables of their choice which they regarded to be important. Moreover, the differentiation is also very apparent at a higher organisational level of factors.

Scientists gave more importance to variables of abiotic and biotic nature, whereas the PA manager's view was that the socio-economic, cultural and anthropogenic variables are more important. This indicates that there are fundamental differences in the perception of various categories of variables.

In relation to this with regard to threats, it has been found that managers may have a low perception of environmental risks, which may explain a lower variability in views, yet at the same time may be reason for incidental strong mismatches between managers (Petrosillo et al., 2009).

A potential reason managers emphasise anthropogenic ES and threats more than scientists may be related to the fact that managers deal with various stakeholders, like municipalities, local businesses,

farmers and fishermen, in day to day management of a PA (Agardy, 2000; Parrish et al., 2003). Thereby, they bring aspects such as disturbance, tourism and agriculture more to the foreground, since these are the elements they are faced with on a more regular basis.
Scientists on the other hand, have less interaction with stakeholders, and seemingly focus more on the functional aspects underlying the services (Pomeroy et al., 2005), and thereby regard these functional aspects to be of more or equal importance.
An important difference in the perception of the system by scientists and managers may also be caused by the spatial and temporal frame in which they observe the system. While scientists often model and observe long-term, large-scale processes and changes, managers commonly deal with decision-making on annual or sub-annual timeframes, and at local scales (for example managing tourist numbers or issuing licenses).
Because of this, scientists are likely to pay more attention to long term processes, while managers will give more weight to issues they deal with in their daily work, such as anthropogenic disturbance (Hein et al., 2006; Fisher et al., 2009; Bagstad et al., 2014).
Furthermore, the formal goals of PA management, as indicated in the legal documents, when establishing National Parks, often include cultural services, like education, protection of cultural heritage, and recreation. For example, the regulation on the protection of Hardangervidda specifies that the aim of the park is to protect both the ecosystem itself and cultural services, including hunting, recreation and education (Regulation 4839/1981).
Due to these formal aims and regular management of tourism activities in their PA, PA managers could be led to emphasise both anthropogenic threats and cultural ES (LOVDATA, 1981).

The observed differences in views may also be an effect of the more in-depth and theoretical view of scientists on ecosystems, and the more general and practical view of managers (Fisher & Brown, 2014). The scientists may have a more detailed theoretical understanding of what is underpinning the ES in a PA, whereas the managers need to keep a broad overview of all processes and deal with the practical implementation, including societal aspects.
For example, considering the ES that are provided by trees and undergrowth, the type of tree is of lesser importance as long as the ES such as carbon sequestration, flood mitigation, or erosion control themselves are sustained.
Similarly, in the debate on the role of biodiversity, some studies argue that species traits are more important to the functioning of an ecosystem than the diversity itself (Norling et al., 2007; Bremner, 2008; Tornroos et al., 2015). Whereas detailed information may be superfluous for managers, the scientists require detailed knowledge to understand and model the system (Ridder, 2008).
In addition, the higher variation in the perception of important variables among scientists than among managers (table 3.3) may be caused by the same process, since the scientists are inclined to have a more detailed theoretical understanding of the system, therefore being able to come up with a wider variety of terms than the PA managers.
Of note here is that among stakeholders interested in the ES of a PA such as farmers or fishermen, the perception of ES may even be influenced by the scale and duration (in decades) that a PA has been managed and under protection (McCanahan et al., 2005; Lamarque et al., 2011; Hauck et al., 2013).
The (duration of the) communication between PA managers and these stakeholders, and the creation of awareness and understanding, may increase the appreciation of the benefits of the management installed in a PA and the ES delivered by the PA. Similar factors may also influence the perception of ES and Threats in a PA by managers and scientists.

It has to be kept in mind that the concept of ES is highly anthropogenic (Kremen, 2005), and therefore it is easy to forget about the structures and functions that underlie these services if one is not forced to do so. Nevertheless, for a full understanding of the functioning and potentials of a PA, it is advisable to account for the entire range of ecosystem elements when considering the complete flow from ecosystem structures and functions to ecosystem services and benefits, including the threats, and not to focus solely on the outcomes of a few elements in the system.

Conclusion

Scientists and managers of PAs differ markedly in their view on the importance of various major ecosystem services and threats. Managers emphasised the anthropogenic (socio-economic and cultural) variables, and scientists underlined the importance of abiotic and biotic variables.
Obviously, the perception of problems and challenges is biased by day-to-day business and workload.
Therefore, it is advisable that in cooperation between scientists and managers, the social and economic factors, including the requirements and pressures of ecosystem services beneficiaries and practitioners, need to be linked more closely to the progress in natural sciences, including the abiotic and biotic processes underlying ecosystem functions and services and changes therein. Intensified and harmonised communication across disciplinary and professional boundaries is needed to improve ES oriented management strategies in existing PAs.
This is also crucial when networks of PAs need to be adapted or when new PAs are installed. A more overarching approach will enable a more successful and realistic assessment of management strategies and policy options for current and novel PAs.

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References

Adams JS, McShane TO. The myth of wild Africa: conservation without illusion. Univ of California Press; 1992.

Agardy T. Information needs for marine protected areas: scientific and societal. Bulletin of Marine Science. 2000 May 1;66(3):875-88.

Atkins JP, Burdon D, Elliott M, Gregory AJ. Management of the marine environment: integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine pollution bulletin. 2011 Feb 28;62(2):215-26.

Bagstad K, Villa F, Batker D, Harrison-Cox J, Voigt B, Johnson G. From theoretical to actual ecosystem services: mapping beneficiaries and spatial flows in ecosystem service assessments. Ecology and Society. 2014 Jun 18;19(2).

Bishop K. Speaking a common language: The uses and performance of the IUCN system of management categories for protected areas. IUCN; 2004.

Bonet-García FJ, Pérez-Luque AJ, Moreno-Llorca RA, Pérez-Pérez R, Puerta-Piñero C, Zamora R. Protected areas as elicitors of human well-being in a developed region: A new synthetic (socioeconomic) approach. Biological Conservation. 2015 Jul 31;187:221-9.

Bremner J. Species' traits and ecological functioning in marine conservation and management. Journal of Experimental Marine Biology and Ecology. 2008 Nov 15;366(1):37-47.

Carvalho-Santos C, Nunes JP, Monteiro AT, Hein L, Honrado JP. Assessing the effects of land cover and future climate conditions on the provision of hydrological services in a medium-sized watershed of Portugal. Hydrological Processes. 2015 Jan 1.

Coad L, Campbell A, Miles L, Humphries K. The costs and benefits of protected areas for local livelihoods: a review of the current literature. UNEP World Conservation Monitoring Centre, Cambridge, UK. 2008.

Costanza R, d'Arge R, De Groot R, Farber S, Grasso M, Hannon B, et al. The value of the world's ecosystem services and natural capital. nature. 1997 May 15;387(6630):253-60.

Daily G. Nature's services: societal dependence on natural ecosystems. Island Press; 1997 Feb 1.

Daily GC, Söderqvist T, Aniyar S, Arrow K, Dasgupta P, Ehrlich PR, et al. The value of nature and the nature of value. Science. 2000 Jul 21;289(5478):395-6.

Díaz S, Fargione J, Chapin III FS, Tilman D. Biodiversity loss threatens human well-being. PLoS Biol. 2006 Aug 15;4(8):e277.

Draper MA, Spierenburg M, Wels H. African dreams of cohesion: Elite pacting and community development in transfrontier conservation areas in Southern Africa. Culture and Organisation. 2004 Dec 1;10(4):341-53.

Fisher B, Turner RK, Morling P. Defining and classifying ecosystem services for decision making. Ecological economics. 2009 Jan 15;68(3):643-53.

Fisher JA, Brown K. Ecosystem services concepts and approaches in conservation: Just a rhetorical tool?. Ecological Economics. 2014 Dec 31;108:257-65.

Fitter A, Elmqvist T, Haines-Young R, Potschin M, Rinaldo A, Setala, et al. An assessment of ecosystem services and biodiversity in Europe. Issues in Environmental Science and Technology. 2010 Jul 1;30:1-28.

Gattuso JP, Magnan A, Billé R, Cheung WW, Howes EL, Joos F, et al. Contrasting futures for ocean and society from different anthropogenic CO2 emissions scenarios. Science. 2015 Jul 3;349(6243):aac4722.

Haines-Young R, Potschin M. The links between biodiversity, ecosystem services and human well-being. Ecosystem Ecology: a new synthesis. 2010:110-39.

Haines-Young R, Potschin M. Common international classification of ecosystem services (CICES, Version 4.1). European Environment Agency. 2012 Sep;33.

Hattam C, Atkins JP, Beaumont N, Börger T, Böhnke-Henrichs A, Burdon D, et al. Marine ecosystem services: linking indicators to their classification. Ecological Indicators. 2015 Feb 28;49:61-75.

Hauck J, Görg C, Varjopuro R, Ratamäki O, Jax K. Benefits and limitations of the ecosystem services concept in environmental policy and decision making: Some stakeholder perspectives. Environmenal Science & Policy 2013; 25: 13-21.

Hector A, Bagchi R. Biodiversity and ecosystem multifunctionality. Nature. 2007 Jul 12;448(7150):188-90.

Hein L, Van Koppen K, De Groot RS, Van Ierland EC. Spatial scales, stakeholders and the valuation of ecosystem services. Ecological economics. 2006 May 1;57(2):209-28.

Honrado JP, Vieira C, Soares C, Monteiro MB, Marcos B, Pereira HM, et al. Can we infer about ecosystem services from EIA and SEA practice? A framework for analysis and examples from Portugal. Environmental Impact Assessment Review. 2013 Apr 30;40:14-24.

IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp. 2016

ISCBD, Interim Secretariat of the Convention on Biological Diversity. Convention on Biological Diversity:Text and Annexes (UNEP/CBD/94/1). 1994. United Nations Environment Programme, Geneva.

Kremen C. Managing ecosystem services: what do we need to know about their ecology?. Ecology letters. 2005 May 1;8(5):468-79.

Lamarque P, Tappeiner U, Turner C, Steinbacher M, Bardgett RD, Szukics U, et al. Stakeholder perceptions of grassland ecosystem services in relation to knowledge on soil fertility and biodiversity. Regional Environmental Change 2011; 11: 791-804.

Likert R. A technique for the measurement of attitudes. Archives of psychology. 1932.

LOVDATA, Forskrift om vern for Hardangervidda nasjonalpark - Odda, Ullensvang og Eidfjord kommunar, Hordaland, Vinje og Tinn kommunar, Telemark, Hol, Nore og Uvdal kommunar, Buskerud, 1981 https://lovdata.no/dokument/MV/forskrift/1981-04-10-4830

Maes J, Barbosa A, Baranzelli C, Zulian G, e Silva FB, Vandecasteele I, et al. More green infrastructure is required to maintain ecosystem services under current trends in land-use change in Europe. Landscape ecology. 2015 Mar 1;30(3):517-34.

McCanahan T, Davies J, Mains J. Factors influencing resource users and managers'perceptions towards marine protected area management in Kenya. Environmental Conservation 2005;32 (1): 42-49

MEA, Millennium Ecosystem Assessment. Ecosystems and Human Well-being. Island Press, Washington, DC, 2005

Nagendra H, Mairota P, Marangi C, Lucas R, Dimopoulos P, Honrado JP, et al. Satellite Earth observation data to identify anthropogenic pressures in selected protected areas. International Journal of Applied Earth Observation and Geoinformation. 2015 May 31;37:124-32.

Nolte A, Alfthan B, Danks F, Jurek M, Andresen M, Kurvits T. Synthesis Report – Analysis of Ecosystem Services and Earth Observation Understanding and Needs by ECOPOTENTIAL Protected Areas. 2016

Norling K, Rosenberg R, Hulth S, Grémare A, Bonsdorff E. Importance of functional biodiversity and species-specific traits of benthic fauna for ecosystem functions in marine sediment. Marine Ecology Progress Series. 2007 Mar 5;332:11-23.

Pachauri RK, Allen MR, Barros VR, Broome J, Cramer W, Christ R, et al. Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. IPCC; 2014.

Palmer M, Bernhardt E, Chornesky E, Collins S, Dobson A, Duke C, et al. Ecology for a crowded planet. Science. 2004 May 28;304(5675):1251-2.

Parrish JD, Braun DP, Unnasch RS. Are we conserving what we say we are? Measuring ecological integrity within protected areas. BioScience. 2003 Sep;53(9):851-60.

Paruelo JM, Texeira M, Staiano L, Mastrángelo M, Amdan L, Gallego F. An integrative index of Ecosystem Services provision based on remotely sensed data. Ecological Indicators. 2016 Dec 31;71:145-54.

Petrosillo I, Valente D, Zaccarelli N, Zurlini G. Managing tourist harbours: Are managers aware of the real environmental risks? Marine Pollution Bulletin. 2009; 58: 1454-1461.

Phillips, 2007, A short history of the International System of Protected Areaas Management Categories, IUCN

Pomeroy RS, Watson LM, Parks JE, Cid GA. How is your MPA doing? A methodology for evaluating the management effectiveness of marine protected areas. Ocean & Coastal Management. 2005 Dec 31;48(7):485-502.

Potts T, Burdon D, Jackson E, Atkins J, Saunders J, Hastings E, et al. Do marine protected areas deliver flows of ecosystem services to support human welfare?. Marine Policy. 2014 Feb 28;44:139-48.

Ridder B. Questioning the ecosystem services argument for biodiversity conservation. Biodiversity and Conservation. 2008 Apr 1;17(4):781-90.

Sil Â, Rodrigues AP, Carvalho-Santos C, Nunes JP, Honrado J, Alonso J, et al. Trade-offs and synergies between provisioning and regulating ecosystem services in a mountain area in Portugal affected by landscape change. Mountain Research and Development. 2016 Nov;36(4):452-64.

TEEB (The Economics of Ecosystems and Biodiversity): The Economics of Ecosystems and Biodiversity: An Interim Report, European Commission; 2008. Available at: www.teebweb.org

Tittensor DP, Walpole M, Hill SL, Boyce DG, Britten GL, Burgess ND, et al. A mid-term analysis of progress toward international biodiversity targets. Science. 2014 Oct 10;346(6206):241-4.

Törnroos A, Bonsdorff E, Bremner J, Blomqvist M, Josefson AB, Garcia C, et al. Marine benthic ecological functioning over decreasing taxonomic richness. Journal of Sea Research. 2015 Apr 30;98:49-56.

UNEP. Marine and coastal ecosystems and human wellbeing: a syntheses report based on the findings of the millennium ecosystem assessment. Nairobi, Kenya: United Nations Environment Programme. 2016

Upton C, Ladle R, Hulme D, Jiang T, Brockington D, Adams WM. Are poverty and protected area establishment linked at a national scale?. Oryx. 2008;42(01):19-25.

Van der Biest K, D'Hondt R, Jacobs S, Landuyt D, Staes J, Goethals P, et al. EBI: an index for delivery of ecosystem service bundles. Ecological Indicators. 2014 Feb 28;37:252-65.

Vassallo P, Paoli C, Rovere A, Montefalcone M, Morri C, Bianchi CN. The value of the seagrass Posidonia oceanica: A natural capital assessment. Marine pollution bulletin. 2013 Oct 15;75(1):157-67.

Vermaat JE, Hellmann FA, van Teeffelen AJ, van Minnen J, Alkemade R, Billeter R, et al. Differentiating the effects of climate and land use change on European biodiversity: A scenario analysis. Ambio. 2016 Nov 1:1-4.

Vitousek PM, Mooney HA, Lubchenco J, Melillo JM. Human domination of Earth's ecosystems. Science. 1997 Jul 25;277(5325):494-9.

S1 Table.
Example of the survey sent to, and answers from, the scientists working on protected areas

Responsible scientific researcher filling in the table: S. W.

	Name of Protected Area (type of protection): Western Scheldt & Saeftinghe (Natura2000)		
Habitat / Ecosystem type	Ecosystem service	Ecosystem functions and structures	Major threat(s)
Tidal flats	Feeding grounds for birds and fish	Primary and secondary production	Increasing hydrodynamics, Increasing elevation and steepening edges (deepening for shipping); Increasing wave-action (more and larger boats); Reduction of intertidal area; Invading species
	Resting places for birds and mammals	Undisturbed habitats	Disturbance by recreants and food-collectors
	Cultural: Aesthetic values	Habitat heterogeneity	Reduction of intertidal area
	Cutting Sea-aster	Secondary production	Over-exploitation
Salt marshes	Protection of coastline	Habitat heterogeneity	Storm surges; Increasing hydrodynamics (deepening for shipping)
	Charismatic species	Breeding grounds for birds (biodiversity)	Disturbance by recreants); Reduction of area salt marshes (deepening for shipping); aging of marshes (obstruction of succession)
	Mediation of wastes	Nutrient cycling	Reduction of area, change in species composition (spatial planning)
	Tourism and wilderness experience	Habitat heterogeneity and biodiversity	Disappearance appreciated plant species (by eutrophication)
High dynamic gulleys	Fishing	Secondary production	Overfishing; Disturbance foodweb by pollutants; Disturbance foodweb by increasing sediment loads upstream (deepening for shipping)
	Waterway for supertankers	Surface, currents, hydrodynamics	Cons and impacts becoming larger than the benefits
	Cooling water intake	Buffering capacity, hydrodynamics	Invading species (fouling)
Low dynamic shallow waters (e.g. subtidal flats and small gulleys)	Nursery area for shrimps and fish	Habitat heterogeneity	Overfishing; Increasing hydrodynamics (deepening for shipping); Reduction of low dynamic shallow water areas
	Shellfish fisheries	Secondary production	Overfishing; Increasing hydrodynamics (deepening for shipping); Increasing water turbidity; Reduction of low dynamic shallow water areas; Invading species

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S2 Table.
Harmonisation tables for all variables (S2a) ecosystem services, (S2b) threats, and the classification of the variables into variables of biotic, abiotic or socio-economic (anthropogenic) nature, grey cells are variables indicated by PA managers

S2a:

Harmonised variable	Former (original) indication	Classification
Aesthetic qualities	Aesthetic qualities	Socio-economic
Aesthetic qualities	Cultural heritage	Socio-economic
Animals of economic use	Animal Production	Biotic
Animals of economic use	Aquaculture	Biotic
Animals of economic use	Bait collection	Biotic
Animals of economic use	Beekeeping	Biotic
Animals of economic use	Capture fisheries	Biotic
Animals of economic use	Cattle grazing	Biotic
Animals of economic use	Collecting of bait	Biotic
Animals of economic use	Commercial fisheries	Biotic
Animals of economic use	Fishing	Biotic
Animals of economic use	Food provision	Biotic
Animals of economic use	Honey production	Biotic
Animals of economic use	Manual cockle fisheries	Biotic
Animals of economic use	Oyster culture	Biotic
Animals of economic use	Shellfish fisheries	Biotic
Animals of economic use	Wild foods	Biotic
Animals of economic use	Agriculture, meat	Biotic
Animals of economic use	Farmed sea food	Biotic
Animals of economic use	Fisheries	Biotic
Animals of economic use	Wild land meat	Biotic
Biodiversity conservation	Biodiversity Conservation	Biotic
Biodiversity conservation	Biodiversity protection	Biotic
Biodiversity conservation	Refuge for biodiversity	Biotic
Biodiversity conservation	Genetic resources	Biotic
Charismatic landscape	Aesthetic values	Abiotic
Charismatic landscape	Charismatic habitat	Abiotic
Charismatic landscape	Charismatic habitat and species	Abiotic
Charismatic landscape	Charismatic landscapes	Abiotic
Charismatic landscape	Cultural heritage	Abiotic
Charismatic landscape	Cultural landscape	Abiotic
Charismatic landscape	Iconic landscapes	Abiotic
Charismatic species	Charismatic reindeer	Biotic
Charismatic species	Charismatic species	Biotic
Charismatic species	Existence value (of cetaceans)	Biotic
Charismatic species	Presence of flagship species	Biotic
Climate regulation	Carbon sequestration	Abiotic
Climate regulation	Carbon Uptake	Abiotic

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Climate regulation	Climate regulation	Abiotic
Climate regulation	Local Scale Climate Regulation	Abiotic
Climate regulation	Carbon sequestration and storage	Abiotic
Education and research	Education	Socio-econom-ic
Education and research	Research	Socio-econom-ic
Education and research	Scientific research	Socio-econom-ic
Education and research	Education	Socio-econom-ic
Education and research	Research	Socio-econom-ic
Energy production	Energy production (e.g. hydropower, wind farms)	Socio-econom-ic
Energy production	Geothermic water	Socio-econom-ic
Fire Protection	Wildfire regulation	Biotic
Flood and coastal protection	Buffer for coastal erosion	Abiotic
Flood and coastal protection	Buffering floods	Abiotic
Flood and coastal protection	Coastal protection	Abiotic
Flood and coastal protection	Flood and erosion protection	Abiotic
Flood and coastal protection	Flood mitigation	Abiotic
Flood and coastal protection	Flood retention	Abiotic
Flood and coastal protection	Protection of coastline	Abiotic
Flood and coastal protection	Flood prevention	Abiotic
Food provision for animals	Fodder	Biotic
Food provision for animals	Food for birds	Biotic
Food provision for animals	Food for cattle	Biotic
Food provision for animals	Food for fish	Biotic
Food provision for animals	Grazing	Biotic
Food provision for animals	Sheep fodder	Biotic
Food provision for animals	Reed as raw material or fodder	Biotic
Food provision for humans	Food collection	Biotic
Habitat for feeding and breed-ing	Breeding places and shelter for birds	Abiotic
Habitat for feeding and breed-ing	Feeding and staging grounds for birds	Abiotic
Habitat for feeding and breed-ing	Feeding grounds for birds	Abiotic
Habitat for feeding and breed-ing	Feeding grounds for fish	Abiotic
Habitat for feeding and breed-ing	Fishing ground	Abiotic
Habitat for feeding and breed-ing	Migration corridor for fish	Abiotic
Habitat for feeding and breed-ing	Nursery area	Abiotic

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Habitat for feeding and breeding	Nursery area for shrimp and fish	Abiotic
Habitat for feeding and breeding	Nutrition for cattle	Abiotic
Habitat for feeding and breeding	Rangeland for cattle	Abiotic
Habitat for feeding and breeding	Resting place for birds	Abiotic
Habitat for feeding and breeding	Resting place for mammals	Abiotic
Habitat for feeding and breeding	Resting places for birds	Abiotic
Habitat for feeding and breeding	Resting places for mammals	Abiotic
Habitat for feeding and breeding	Sanctuary for fish fry	Abiotic
Habitat for feeding and breeding	Spawning and nursery grounds for fish	Abiotic
Habitat for feeding and breeding	Water for aquaculture	Abiotic
Habitat for feeding and breeding	Lifecycle and habitat protection	Biotic
Habitat for feeding and breeding	Nursery area - supporting	Biotic
Hunting	Hunting	Socio-economic
Hunting	Selling licenses	Socio-economic
Hydrological regulation	Hydrological cycle and water flow maintenance	Abiotic
Hydrological regulation	Hydrology	Abiotic
Leisure activities	Birdwatching	Socio-economic
Leisure activities	Ecotourism	Socio-economic
Leisure activities	Recreation	Socio-economic
Leisure activities	Recreation and tourism	Socio-economic
Leisure activities	Recreational activities	Socio-economic
Leisure activities	Recreational diving	Socio-economic
Leisure activities	Recreational fishing and boating	Socio-economic
Leisure activities	Symbolic and Aesthetic values	Socio-economic
Leisure activities	Tourism	Socio-economic
Leisure activities	Recreation and tourism	Socio-economic
Materials of economic use	Amber extraction	Abiotic
Materials of economic use	Cooling water	Abiotic

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Materials of economic use	Mining	Abiotic
Materials of economic use	Salt production	Abiotic
Materials of economic use	Amber extraction	Abiotic
Materials of economic use	Gitios extraction	Abiotic
Materials of economic use	Salt production	Abiotic
Plants of economic use	Agriculture	Biotic
Plants of economic use	Biomass (wood, food)	Biotic
Plants of economic use	Biomass extraction	Biotic
Plants of economic use	Building material	Biotic
Plants of economic use	Cork Production	Biotic
Plants of economic use	Fruit crops	Biotic
Plants of economic use	Fuel pellets	Biotic
Plants of economic use	Pine seed extraction	Biotic
Plants of economic use	Plant collection	Biotic
Plants of economic use	Thatching materials	Biotic
Plants of economic use	Timber	Biotic
Plants of economic use	Wild plants and their outputs	Biotic
Plants of economic use	Agriculture , grain	Biotic
Plants of economic use	Timber	Biotic
Plants of economic use	Wild non meat food products	Biotic
Pollination	Pollination	Biotic
Pollination	Pollination and seed dispersal	Biotic
Pollination	Pollination	Biotic
Prevention of erosion	Control of erosion	Abiotic
Prevention of erosion	Erosion regulation	Abiotic
Raw materials	Sand, gravel, shell extraction	Abiotic
Resilience	Resilience	Biotic
Sedimentological regulation	Land incrementation	Abiotic
Sedimentological regulation	Mainenance of soil	Abiotic
Sedimentological regulation	Maintenance of soil fertility	Abiotic
Sedimentological regulation	Soil formation	Abiotic
Sedimentological regulation	Soil protection	Abiotic
Sedimentological regulation	Erosion prevention (coastal or inland)	Abiotic
Spiritual significance	Spiritual significance	Socio-econom-ic
Transport facilitation	Shipping lanes	Socio-econom-ic
Transport facilitation	Waterway for shipping	Socio-econom-ic
Waste and Toxicant mediation	Denitrification	Abiotic
Waste and Toxicant mediation	Dewatering of wastewater treatment sludge	Abiotic
Waste and Toxicant mediation	Mediation of wastes	Abiotic
Waste and Toxicant mediation	Nutrient Regulation	Abiotic
Waste and Toxicant mediation	Pollution trapping	Abiotic
Waste and Toxicant mediation	Toxicity regulation	Abiotic
Waste and Toxicant mediation	Water filtration	Abiotic
Waste and Toxicant mediation	Water purification	Abiotic
Waste and toxicant mediation	Nutrient retention	Abiotic

Waste and toxicant mediation	Pest and disease control	Abiotic
Water regulation	Fresh water	Abiotic
Water regulation	Water storage	Abiotic
Water regulation	Water supply	Abiotic
Water regulation	Fresh water	Abiotic
Water regulation	Water treatment	Abiotic

S2b:

Harmonised variable	Former (original) indication	Classification
Biodiversity	Biodiversity	Biotic
Biodiversity	Bird biodiversity	Biotic
Biodiversity	Invertebrate biodiversity	Biotic
Biodiversity	Responce of biodiversity to climate change	Biotic
Biodiversity	Vegetation biodiversity	Biotic
Carbon cycle	Carbon Sequestration	Abiotic
Carbon cycle	Carbon storage	Abiotic
Climate dynamics	Climate change attenuation	Abiotic
Climate dynamics	Climate regulation	Abiotic
Climate dynamics	Change of microclimate	Abiotic
Element cycling	Biogeochemical cycling and storage	Abiotic
Element cycling	Element cycling	Abiotic
Element cycling	Hydro-geo-eco processes	Abiotic
Element cycling	Water purification	Abiotic
Flood protection	Flood control	Abiotic
Food chain energy transfer	Energy flow	Biotic
Food chain energy transfer	Functional connectivity	Biotic
Gene pool	Genetic resources	Biotic
Habitat suitability	Breeding grounds for birds	Abiotic
Habitat suitability	Disturbance regime management	Biotic
Habitat suitability	Dominance of palatable grasses	Biotic
Habitat suitability	Feeding area for birds	Abiotic
Habitat suitability	Habitat	Abiotic
Habitat suitability	Habitat availability	Abiotic
Habitat suitability	Habitat heterogeneity	Abiotic
Habitat suitability	Habitat suitability	Abiotic
Habitat suitability	Habitat suitability for birds	Abiotic
Habitat suitability	Maintenance of habitat: landscape structure	Abiotic
Habitat suitability	Nursery grounds	Abiotic
Habitat suitability	Provision of shade and shelter	Abiotic
Habitat suitability	Salt water	Abiotic
Habitat suitability	Supporting habitats	Abiotic
Habitat suitability	Tree Encroachment	Biotic
Habitat suitability	Undisturbed habitats	Abiotic
Hydrodynamics	Buffer against floods	Abiotic
Hydrodynamics	Buffering capacity	Abiotic
Hydrodynamics	Currents	Abiotic
Hydrodynamics	Hydrodynamics	Abiotic

Hydrodynamics	Hydrologic flux and storage	Abiotic
Hydrodynamics	Water cycle regulation	Abiotic
Hydrodynamics	Water Flow	Abiotic
Hydrodynamics	Water regulation	Abiotic
Hydrodynamics	Water retention	Abiotic
Hydrodynamics	Water supply	Abiotic
Hydrodynamics	Water treatment	Abiotic
Landscape	Charismatic landscapes	Abiotic
Landscape	Dunes landscape	Abiotic
Landscape	Landscape formation	Abiotic
Landscape	Landscape opportunity	Abiotic
Landscape	Seascape formation	Abiotic
Nutrient regulation	Nutrient regulation	Abiotic
Nutrient regulation	Nutrients regulation	Abiotic
Population dynamics	Dense canopy over-shading understory	Biotic
Population dynamics	Distribution and densities of pine trees	Biotic
Population dynamics	Distribution of pine trees	Biotic
Population dynamics	Dominance of meso-hygrophytic plants	Biotic
Population dynamics	Flowering	Biotic
Population dynamics	Grass quality	Biotic
Population dynamics	Ibex and Chamois population dynamics	Biotic
Population dynamics	Insect demographics	Biotic
Population dynamics	Invertebrate population dynamics	Biotic
Population dynamics	Key stone species reproduction	Biotic
Population dynamics	Phenology	Biotic
Population dynamics	Plant phenology	Biotic
Population dynamics	Pollination	Biotic
Population dynamics	Population dynamics	Biotic
Population dynamics	Recruitment	Biotic
Population dynamics	Seed dispersal	Biotic
Population dynamics	Sheep presence	Biotic
Population dynamics	Species turnover	Biotic
Population dynamics	Vegetation structure	Biotic
Population dynamics	Zooplankton population dynamics	Biotic
Primary production	Olive oil production	Biotic
Primary production	Pharmacological resources	Biotic
Primary production	Primary Production	Biotic
Primary production	Primary production of lichens	Biotic
Primary production	Vegetation productivity	Biotic
Raw materials	Raw materials	Abiotic
Secondary production	Productivity of fish	Biotic
Secondary production	Secondary Production	Biotic
Sediment characteristics	Regulation of soil carbon storage	Abiotic
Sediment characteristics	Regulation of soil fertility	Abiotic
Sediment characteristics	Regulation of soil structure	Abiotic
Sediment characteristics	Retention of soil	Abiotic
Sediment characteristics	Retention of soil nutrients	Abiotic

Sediment characteristics	Sediment retention	Abiotic
Sediment characteristics	Sediment transport	Abiotic
Sediment characteristics	Soil formation	Abiotic
Sediment characteristics	Soil moisture	Abiotic
Sediment characteristics	Soil retention	Abiotic
Sediment characteristics	Soil structure	Abiotic

Water dynamics	Evaporation	Abiotic
Water surface characteristics	Albedo	Abiotic
Water surface characteristics	Surface	Abiotic

S2c:

Harmonised variable	Former (original) indication	Classification
(Illegal) human activities	Conflicting activities	Anthropogenic
(Illegal) human activities	Illegal catches	Anthropogenic
(Illegal) human activities	illegal logging	Anthropogenic
(Illegal) human activities	Picking of plants	Anthropogenic
(Illegal) human activities	Poaching	Anthropogenic
(Illegal) human activities	Gas extraction	Anthropogenic
(Illegal) human activities	Hunting	Anthropogenic
Agriculture	Agriculture	Anthropogenic
Agriculture	Agriculture	Anthropogenic
Bad management	Inappropriate water management	Anthropogenic
Bad management	Negligent management	Anthropogenic
Change in land use	Abandonment	Anthropogenic
Change in land use	Abandonment of farming	Anthropogenic
Change in land use	Changes in land use	Anthropogenic
Change in land use	Decrease of crops	Anthropogenic
Change in land use	Depopulation	Anthropogenic
Change in land use	Development of tourist facilities	Anthropogenic
Change in land use	Extension port areas	Anthropogenic
Change in land use	Forest management around the park	Anthropogenic
Change in land use	Harbour Extension	Anthropogenic
Change in land use	Settlements	Anthropogenic
Change in land use	Soil tillage	Anthropogenic
Change in land use	Spatial planning	Anthropogenic
Change in land use	Urbanisation	Anthropogenic
Change in species	Aging of the wild stocks	Biotic
Change in species	Bush encroachment	Biotic
Change in species	Change of plant species composition	Biotic
Change in species	Changes in bird dispersal	Biotic
Change in species	Disappearing charismatic species	Biotic
Change in species	Extinction of species	Biotic
Change in species	Food competition with cultured species	Biotic
Change in species	Impact of bird colonies	Biotic
Change in species	Plant species composition	Biotic

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Change in species	Prey decline	Biotic
Change in species	Species composition	Biotic
Change in species	Species loss	Biotic
Change in species	Species reduction	Biotic
Change in species	Storms	Biotic
Change in species	Succession	Biotic
Change in species	Successional stagnation	Biotic
Change in species	Sudden oak death	Biotic
Change in species	Invasive species	Biotic
Civil engineering	Increased number of dams	Anthropogenic
Climate change	Change in precipitation	Climate change
Climate change	Change in snow cover	Climate change
Climate change	Changes in snow cover	Climate change
Climate change	Climate change	Climate change
Climate change	Droughts	Climate change
Climate change	Less precipitation	Climate change
Climate change	Sea Level Rise	Climate change
Climate change	Severe drought	Climate change
Climate change	Temperature changes	Climate change
Climate change	Climate change	Anthropogenic
Diseases	Diseases	Biotic
Diseases	Forest pests	Biotic
Diseases	Forests pests	Biotic
Diseases	Pests	Biotic
Diseases	Pests and diseases	Biotic
Disturbance	Anthropogenic disturbance	Anthropogenic
Disturbance	Disturbance	Anthropogenic
Disturbance	Disturbance by humans	Anthropogenic
Disturbance	Human actions	Anthropogenic
Disturbance	Human disturbance	Anthropogenic
Disturbance	Off-road Vehicles	Anthropogenic
Disturbance	Transport	Anthropogenic
Encroachment	Heath and scrub encroachment	Biotic
Encroachment	Tree Encroachment	Biotic
Eutrophication	Eutrophication	Anthropogenic
Eutrophication	Hypertrophic conditions	Anthropogenic
Eutrophication	Nitrification	Abiotic
Eutrophication	Eutrophication	Anthropogenic
Exotic species	Alien species	Biotic
Exotic species	Exotic Species	Biotic
Exotic species	Invading species	Biotic
Exotic species	Invasive Species	Biotic
Fire	Forest fire	Abiotic
Fire	Forest fires	Abiotic
Fire	Uncontrolled burning	Abiotic
Fire	Wildfires	Abiotic
Fisheries	Bycatch in gill nets	Anthropogenic

Fisheries	Fisheries	Anthropogenic
Fisheries	Shellfish fisheries	Anthropogenic
Fisheries	Fishing	Anthropogenic
Habitat loss	Aging of marshes	Abiotic
Habitat loss	Forest decay	Biotic
Habitat loss	Fragmentation	Anthropogenic
Habitat loss	Habitat change	Abiotic
Habitat loss	Habitat loss	Abiotic
Habitat loss	Habitat reduction	Abiotic
Habitat loss	Reduction of area	Abiotic
Habitat loss	Reduction of intertidal area	Abiotic
Habitat loss	Reduction of salt marshes	Abiotic
Habitat loss	Urban development	Anthropogenic
Habitat loss	Isolation	Abiotic
Habitat loss	Landscape fragmentation	Abiotic
Harmfull Algae	Algal blooms	Biotic
Harmfull Algae	Toxic algae	Biotic
Hydrological changes	Decrease of sediment transport	Abiotic
Hydrological changes	Deepening shipping lanes	Anthropogenic
Hydrological changes	Dredging	Anthropogenic
Hydrological changes	Hydraulic	Anthropogenic
Hydrological changes	Hydraulic modification	Anthropogenic
Hydrological changes	Hydroperiod reduction	Anthropogenic
Hydrological changes	Increased turbidity	Abiotic
Hydrological changes	Increasing hydrodynamics	Anthropogenic
Hydrological changes	Increasing sediment loads	Abiotic
Hydrological changes	Increasing turbidity	Abiotic
Hydrological changes	Increasing wave action	Anthropogenic
Hydrological changes	Reduced tidal energy	Anthropogenic
Hydrological changes	Storm surges	Abiotic
Hydrological changes	Underground water extraction	Anthropogenic
Hydrological changes	Water management	Anthropogenic
Hydrological changes	Water quantity	Abiotic
Increased salinisation	Groundwater salinisation	Abiotic
Increased salinisation	Hypersaline conditions	Anthropogenic
Landscape disturbance	Gas exploitation	Anthropogenic
Landscape disturbance	Visual ruining of landscape	Anthropogenic
Overexploitation	Harvesting	Anthropogenic
Overexploitation	Intensive agriculture	Anthropogenic
Overexploitation	Intensive Grazing	Anthropogenic
Overexploitation	Negative impact becoming larger than profits	Anthropogenic
Overexploitation	Overexploitation	Anthropogenic
Overexploitation	Overfishing	Anthropogenic
Overexploitation	Overgrazing	Anthropogenic

Overexploitation	Over-tourism	Anthropogenic
Overexploitation	Too high boat density	Anthropogenic
Overexploitation	Forestry	Anthropogenic
Overexploitation	Other biological resource extraction	Anthropogenic
Pollution	Air pollution	Anthropogenic
Pollution	Atmospheric Pollution	Anthropogenic
Pollution	Increased pollution	Anthropogenic
Pollution	Pesticides	Anthropogenic
Pollution	Pollution	Anthropogenic
Pollution	Water pollution	Anthropogenic
Pollution	Pollution	Anthropogenic
Pollution	Sonar and sound pollution	Anthropogenic
Predation	Predation	Biotic
Sediment dynamics changes	Avalanches	Abiotic
Sediment dynamics changes	Embankments within wetlands	Anthropogenic
Sediment dynamics changes	Erosion	Abiotic
Sediment dynamics changes	Port dredging	Anthropogenic
Sediment dynamics changes	Sediment disturbance	Anthropogenic
Sediment dynamics changes	Siltation	Abiotic
Sediment dynamics changes	Soil loss	Abiotic
Tourism	Hiking impact	Anthropogenic
Tourism	Mountaineering, rock climbing, speleology	Anthropogenic
Tourism	Recreation	Anthropogenic
Tourism	Recreational activities	Anthropogenic
Tourism	Tourism	Anthropogenic
Tourism	Tourism	Anthropogenic

S3 Table. Example of the survey sent to PA managers

Filled in by PA managers of the Curonian lagoon and Nenumas Delta

	How important are the following ecosystem services to the beneficiaries of the PA? (relative to the other ecosystem services, on a scale from 1 (least important) to 5 (most important) 0 = not important or unknown)						
	Ecosystem service	0	1	2	3	4	5
Provisioning services	Agriculture, meat	X	☐	☐	☐	☐	☐
	Agriculture , grain	X	☐	☐	☐	☐	☐
	Fisheries	☐	☐	☐	☐	☐	X
	Farmed sea food	X	☐	☐	☐	☐	☐
	Genetic resources	X	☐	☐	☐	☐	☐
	Timber	☐	☐	☐	☐	X	☐
	Wild land meat	X	☐	☐	☐	☐	☐
	Wild non meat food products (e.g. berries, mushrooms, kelp)	☐	X	☐	☐	☐	☐
	Fresh water	X	☐	☐	☐	☐	☐
	Energy production (e.g. hydropower, wind farms)	X	☐	☐	☐	☐	☐
	Please fill in if others:						
	Amber extraction	☐	☐	☐	☐	☐	X
	Geothermic water	☐	☐	☐	☐	☐	X
		☐	☐	☐	☐	☐	☐
Regulating services	Carbon sequestration and storage	☐	☐	☐	X	☐	☐
	Erosion prevention (coastal or inland)	☐	X	☐	☐	☐	☐
	Lifecycle and habitat protection	☐	☐	☐	☐	X	☐
	Pollination	☐	☐	☐	☐	☐	X
	Pest and disease control	☐	☐	☐	☐	☐	X
	Water treatment	X	☐	☐	☐	☐	☐
	Flood prevention	X	☐	☐	☐	☐	☐
	Please fill in if others:						
		☐	☐	☐	☐	☐	☐
Cultural services	Spiritual significance	☐	☐	☐	☐	X	☐
	Recreation	☐	X	☐	☐	☐	☐
	Education	☐	☐	X	☐	☐	☐
	Aesthetic qualities	☐	X	☐	☐	☐	☐
	Research	☐	☐	X	☐	☐	☐
	Please fill in if others:						
		☐	☐	☐	☐	☐	☐
Other	Please fill in if others:						
		☐	☐	☐	☐	☐	☐
		☐	☐	☐	☐	☐	☐

What are the most damaging environmental pressures or threats to your PA?				
Environmental pressures	High pressure	Medium pressure	Low pressure	No pressure
Agriculture	☐	☐	X	☐
Forestry	☐	X	☐	☐
Climate change	☐	☐	X	☐
Invasive species	☐	X	☐	☐
Eutrophication	X	☐	☐	☐
Tourism	X	☐	☐	☐
Pollution	☐	☐	X	☐
Hunting	☐	☐	☐	X
Fishing	☐	X	☐	☐
Other biological resource extraction (e.g. shells, berries)	☐	☐	X	☐
Transport	X	☐	☐	☐
Landscape fragmentation	☐	X	☐	☐
Please fill in if others:				
Sonar and sound pollution	☐	☐	☐	X
	☐	☐	☐	☐

S4 Table. List of Ecosystem Types. Indicated for the transitional waters (TW) and the mountainous (MO) protected areas.

Ecosystem Type	Transitional Waters / Mountainous
Aeolic sands with juniper forest and playa lakes	TW
Alpine and subalpine meadows	MO
Alpine Prairies	MO
Altitudinal transects from the Montane to the Alpine belt	MO
Coastal and marine ecosystems	TW
Coastal dunes and sea shore	TW
Coniferous and mixed mountain forests	MO
Cupressus Forests	MO
Freshwater and brackish marshes with emergent vegetation	TW
Freshwater ecosystems	TW
Fruit tree crops	MO
Grass lands	MO
Heath and Scrub	MO
High altitude Alpine Lakes	MO
High dynamic gulleys	TW
High mountain grasslands and shrub lands	MO
Lagoon fringe reed beds	TW
Lagoons	TW
Lichen fields	MO
Low dynamic shallow waters	TW
Mediterranean annual rich dry grassland	TW

Mediterranean shrub land with cork oak forest	TW
Mid mountain shrub lands	MO
Montado	MO
Montane Spruce-Fir-Beech forest	MO
Mountain lakes and surrounding meadows	MO
Native Deciduous Forest	MO
Natural forests	MO
Olea and Ceratonia forests	MO
Open Lagoon	TW
Permanent Grassland	MO
Pine forests	MO
Pine plantations	MO
Quercus forests	MO
River	TW
Rocks and screes	MO
Rocky Watersheds	MO
Salt marshes	TW
Seagrass Meadows	TW
Seasonal freshwater marshland	TW
Shrub lands	MO
Tidal Flats	TW
Wetlands	TW

S5 Table. List of mistakes made in the surveys and the ways used to correct them. Categories are Ecosystem Services (ES), Threats (Thr), and Ecosystem Types (ETy). The variable which was originally indicated (“between quotation marks”) is followed by our Remark on it (unless it may have been renamed). For the Actions taken: Split means that the term is split into two or three new terms, Rename means that the original term was renamed (and with its new name entered into the harmonisation tables of S2 Table), Omitted means the term was not used in the analysis (and in case of duplications one of the two terms was omitted). In the column ‘Renamed in’, the new name for the variable used in the analysis is given.

Area	Category	“Original variable” and Remark	Action	Renamed in
Camargue	ES	“Flood retention” is no service, but a function (buffering is the service)	Rename	Buffering floods
Camargue	ES	“Waterfowl hunting, fishing, cattle” are separate services	Split	
Camargue	EF	“Climate change attenuation, Sea level rise attenuation” have (as EF) no clear relation with the ES “sunbathing and swimming” nor with the Thr “destruction due to massive touristic frequentation”	Rename	Climate regulation
Camargue	EF	“Water epuration” (F: Epurification) is a service and not a function (nutrient cycling would have been better)	Rename	Element cycling
Curonian lagoon	ES	“Nutrient and toxic substance removal” are not the same. Therefore, split into nutrient control and toxicity control	Split	
Curonian lagoon	ES	Denitrification is not a service but a function	Rename	Waste and Toxicant mediation
Danube	EF	“Biological productivity” is not specific enough	Rename	Primary production
Danube	EF	“Landscape opportunity” is not a clear function nor structure	Rename	Charismatic landscapes
Doñana	Thr	“Phytophtora infestation” is too specific	Rename	Diseases
Doñana	Thr	“None” is not a useful term in the threats section	Omitted	
Eastern Scheldt	EF	“Breeding grounds for birds” is a service not a function	Rename	Habitat suitability
Eastern Scheldt	EF	“Salt water” is not a function, nor a service	Rename	Habitat suitability
Gran Paradiso	ES	“Cultural ecosystem services” is an indistinct, too much overarching, term	Omitted	
Gran Paradiso	EF / Thr	“Tree encroachment” is duplicated as function and threat; it is a threat	Omitted as EF	
Hardangervidda	ETy	“Reindeer Lichens Interaction”; an interaction is not an Ecosystem Type	Rename	Lichen fields
Hardangervidda	ETy	“Sheep and Browsing-grassing resources interaction”; an interaction is not an Ecosystem Type	Rename	Grass lands
Hardangervidda	ETy	“Grouse and shrub structure interaction”; an interaction is not an Ecosystem Type	Rename	Shrub lands

High Tatra	EF	"Water supply" is a service and not a function	Rename	Water regulation
High Tatra	ES / EF	"Climate regulation" is indicated as both service and function; function is renamed	Rename	Change of Microclimate
High Tatra	Thr	"B02.06" is a specification of B02	Omitted	
High Tatra	EF	"Genetic resources" and "Pharmacological resources" are not functions but services	Rename	"Gene pool" and "Primary production"
High Tatra	ES / EF	"2.3.1.1 - Pollination" is indicated as service and function; as function renamed	Rename	Population dynamics
High Tatra	ES	"3.2.2.1 Other cultural outputs – Existence" is an indistinct term	Rename	Charismatic habitat and species
High Tatra	EF	"Landscape opportunity" is a service not a function	Rename	Landscape
High Tatra	Thr	"Dispersed habitation" and "Urbanisation", are merely duplications	Omitted	
High Tatra	ES	"3.1.1.1 Physical and intellectual interactions with biota, ecosystems, and landscapes" is too indistinct	Rename	Tourism
High Tatra	ES	"3.2.2.1 Other cultural outputs – Existence" is too indistinct	Rename	Tourism
High Tatra	ES / EF	"2.3.3.1 - Soil formation" is indicated as a function as well as a service; as service renamed	Rename	Sedimentological regulation
Oros Idi	EF	"Olive oil production" is a service, not a function	Rename	Primary production
Samaria	EF	"Biodiversity" and "Sea scape formation" are different functions	Split	
Samaria/Oros Idi	EF	"Habitat provision" is not a function nor structure	Rename	Habitat
Samaria/Oros Idi	EF	"Pollination" is not a function for beekeeping but a result of beekeeping	Rename	Population dynamics
Samaria/Oros Idi	EF	Water treatment is not a function but a service	Rename	Hydrodynamics
Sierra Nevada	ES / EF	"Hydrological cycle" and "Water supply" are switched as service and function	Rename	"Hydrological regulation" and "Hydrodynamics", resp.
Sierra Nevada	ES / EF	"Pollination" is indicated as service and function; renamed for EF	Rename	Population dynamics
Sierra Nevada	EF	"Evapotranspiration" is merely a duplication of "Evaporation"	Omitted	
Sierra Nevada	EF	"Water supply" is not a function and merely a duplication of "Water regulation"	Omitted	
Western Scheldt	EF	"Secondary production" to obtain plants as Sea-aster should have been primary production	Rename	Primary production
Western Scheldt	EF	"Raw materials" is not a function to obtain sand and gravel (but the service itself)	Rename	Habitat suitability

3

Chapter 4 - The use of Fuzzy Cognitive Models to strengthen stakeholder participation in the management of Protected Areas: the Dutch Wadden Sea

4

Chapter 4 - The use of Fuzzy Cognitive Models to strengthen stakeholder participation in the management of Protected Areas:

the Dutch Wadden Sea

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Ready to submit

Abstract

By means of Fuzzy Cognitive Modelling the stakeholder's perceptions of the most important ecological, socio-economic and cultural processes, functions and threats in the Wadden Sea were inventoried and quantified to obtain aspects that may contribute to stronger support of the management in this World Heritage protected area. The stakeholders belonged to industry, recreation, academic education and research, policy and governance, and NGO's, who's institutions could have a local, regional or national orientation. The FCM networks on most important elements and relations are in general similar for the various types of stakeholders. Though nationally orientated stakeholders indicated lower connection densities, i.e. lower number of interrelationships per element, than those with a regional or local orientation, and stakeholders with a recreational vocation marked a higher centrality and higher connection densities than other stakeholder groups, there is overall strong agreement among all stakeholders on the factual content about what are the most important elements and their level of importance in the structure and functioning of the Wadden Sea system. The prime issues at stake to guarantee a stakeholder supported management and decision making in the Wadden Sea are Nature, Regulations, Management, Wadden experience and Recreation. The FCM modelling technique has shown to be a proper practical tool to highlight the prime ecological, socio-economic and cultural issues at stake to strengthen the management as perceived by all stakeholders in a protected area.

1. Introduction

Protected Areas (PA) are an important tool in conservation science (Chape et al., 2005), and are founded to maintain species and habitat diversity, as well was to protect specific landscapes or sacred areas (Brooks et al., 2004; Rodrigues et al., 2004; Coad et al., 2008; Wild and McLeod, 2008; Butchart et al., 2010).
Traditionally, PA are managed to protect biodiversity, because biodiversity is considered to have a functional as well as an inherent and aesthetic value (Wilson, 1988). Nowadays, PA are set up for a multitude of other functions, such as to maintain healthy functioning ecosystems (Dudley, 2008), to act as a sanctuary (Liu et al., 2001), or to save specific habitats or ecological processes that would be unable to survive in intensely managed land- and seascapes (Parrish et al, 2003; Chape et al., 2005).

More recently also Ecosystem Services (ES) and human wellbeing are considered in PA management (Doak et al, 2015) together with ecological functions and threats (Ostrom, 2009). Although there are multiple definitions of ES, they all have in common that ES are usable products and other benefits delivered by ecosystems that satisfy the needs of society (Hummel et al., 2019). The beneficiaries of ES can be referred to as stakeholders (Glicken, 2000).

PA can often be more effective in supplying ES than exploited areas, because proper delivery of ES is dependent on a healthy and resilient ecosystem (Stolton et al., 2008; Dudley et al., 2010). The spill-over effect of a PA may positively reflect on the bordering area (Di Lorenzo et al., 2016). Properly protected and managed PA can make society benefit from a vast array of ES, including basic life-support goods, such as drinking water, or processes that regulate water and air quality, prevention from natural hazards such as flooding or erosion, or mitigation of climate change by storing carbon (Costanza et al., 1997; Daily, 1997; Dudley & Stolton, 2003; Sohngen & Brown, 2006; Campbell et al., 2008).
Moreover, PA can provide cultural ES such as recreation, tourism, research opportunities and maintain cultural identity (Butcher, 2005; Eagles & Hillel, 2008). The ES concept is therefore a good method to visualise the delivery of goods and benefits from ecosystems (natural, semi-natural, and human-dominated) to human society. This may help to emphasise the value of nature to different stakeholders, and in this way assist the management of a PA (Hummel et al., 2019).

It is important to involve as many stakeholders as possible, including scientists, policy makers, managers, and practitioners in visualising and understanding the major elements and influencing factors in the ES delivery of a PA (Wildenberg et al., 2014).
Stakeholder involvement will help in the PA managing process, elucidating a joint rationale for protection of areas, solving potential conflicts between stakeholders that may stand in the way of proper management of a PA, and identify areas where future activities and research could be focused (Jetter and Kok, 2014).
Yet, the informal and formal knowledge on a PA, and how a PA is perceived should be captured from a variety of different stakeholders in a standardised way if it is to be helpful in optimising the management of a PA. Both this informal and formal knowledge are important to incorporate into PA management, enhancing the support of the wider community for the PA and thereby also optimising the PA's protection level (White and Vogt, 2000; Young et al., 2013).

For elucidating the stakeholders' perception of a PA in a standardize way, we will use Fuzzy Cognitive Models (FCM) (Kosko, 1986, 1988, 1993) to map and analyse their viewpoints on the major elements and influencing factors in a system. Drawing FCMs results in a conceptual model that is not limited by exact values or measurements. FCMs can be used to represent relatively unstructured qualitative and semi-quantitative knowledge (Isak, 2008). FCM's are suitable for including and integrating knowledge from different, even opposite, viewpoints as well as from various disciplines such as for example ecology, physics, economics or sociology (Groumpos, 2010).

In this study, we will present a FCM analysis of the stakeholder's perception of one of the major and most well-known PA in the Netherlands, the Wadden Sea, a UNESCO World Heritage site,. We will elicit on the important Ecosystem Functions, Ecosystem Services, and pressures acting upon them, using a bottom-up participatory approach.
This FCM analysis acts as an exemplary case-study to assess the relations between the various ecological, socio-economic and cultural aspects in and around a PA that may form the building blocks for a

stakeholder oriented and societal supported PA management.

2. Materials and methods

2.1. Study Area

The Dutch Wadden Sea, with a size of 2500 km^2, is an internationally well recognised Protected Area (PA) protected by various designations, such as Natura 2000, the Ramsar convention, the UNESCO World Heritage programme, the UNESCO Man and Biosphere programme, and by the Dutch "planologische kernbeslissing Waddenzee" (Key planning decision Wadden Sea).

It is a highly dynamic, shallow coastal area characterised by large tidal flats and wetlands. It is protected by a 150 km long chain of barrier islands (Wolff, 1983; De Jonge et al., 1993). These islands have dunes and sandy beaches towards the North Sea and a low, tidal coast towards the mainland. The Wadden Sea mainly consists of large intertidal areas, the tidal flats, of which two third are emergent at low tide. Most tidal flats are bare, and consist mainly of sand, whereas along the mainland and in estuaries also mudflats and salt marshes occur (Dijkema et al., 1990).

The tidal flats in the Wadden Sea have a very high benthic biomass and productivity, dominated by molluscs and polychaetes (Dankers et al., 1978), and provide an important nursery and feeding area for shrimps and many fish of commercial importance (Dankers et al., 1978; Lozan, 1994) and for birds (Van der Jeugd et al., 2014). The Wadden Sea is well known for its rich bird life, such as gulls and terns, as well as waders, ducks and geese, which use the area as a migration stopover or wintering site (Von Nordheim et al., 1996). There is also a large population of harbour seals Phoca vitulina in the Wadden Sea (Drescher, 1979; Brasseur et al., 2018).

Mussels and cockles were harvested massively for human consumption until 10 to 15 years ago, when the cockle fisheries were banned and mussel culture had to be reduced (Sieben et al., 2013; Floor et al., 2019). Now small areas may only be used for hand-raking of cockles and mussel-seed fisheries.

The Dutch Wadden Sea attracts approximately 1.2 million tourists each year that deliver a strong impulse to the local economy (CBS, 2017). The Wadden Sea is thereby ecologically, sociologically as well as economically of major importance for a range of stakeholders in a much wider area than just the territory of the specific PA.

2.2. Stakeholder interviews and the use of Fuzzy Cognitive Models

During interviews with important stakeholders of the Wadden Sea PA firstly the factors, actors, or processes, further to be called the elements. that were perceived by the stakeholders to be important for the functioning, environmental quality, management and protection of the Wadden Sea were inventoried. Secondly, the strength and direction of the dependencies and influences between the elements were mapped. In total 23 interviews with stakeholders were held.

Following the FCM technique (Kosko, 1986, 1988, 1993) the elements (originally called concepts by Kosko (1986)), are depicted in diagrams as nodes that are connected with arrows showing the direction and strength of influence between the elements as perceived by the interviewed stakeholderrs (see example in Fig. 4.1). An arrow with a positive value pointing from element A to element B indicates that element A increases or stimulates element B, and a negative arrow from element B to element C indicates that element B decreases element C. The values (ranging from -10 to +10) indicate the strength of this relation.

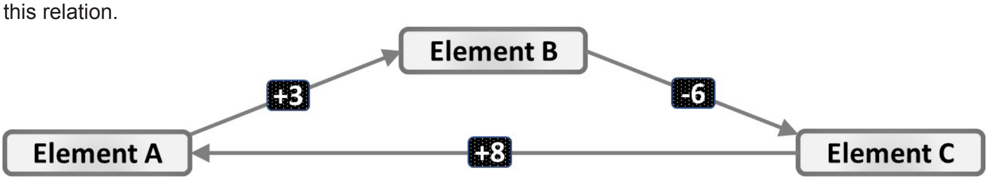

Figure 4.1: An example of the Fuzzy Cognitive Model as used in the Wadden Sea surveys.

System elements such as factors (e.g. fish), actors (e.g. policies) or processes (e.g. eutrophication) form nodes in the diagram. Related Elements are connected with arrows (vectors) showing the direction and strength of influence between these Elements. Feedback mechanisms in the system are possible as indicated between Elements C and A.

All interviewed stakeholders are living and/or working in and around the Wadden Sea. For sake of convenience, the interviews with stakeholders were each time carried out at the premises of the stakeholder. During the interviews and the creation of the FCM, all participants were allowed to speak freely. To facilitate easy communication with the participants, the native language, in this case Dutch, was used throughout the entire interview. For further analyses, all terms were translated to English (see Appendix A).

Every stakeholder interview was started by explaining why the research was conducted. The location of the interview, date, time and duration, and the names of the participants and their professional occupation were noted. Then a presentation was shown on ES, and on request an introduction to FCM was given with an unrelated example to eliminate bias in drawing up the FCM for the Wadden Sea (Taber, 1991).

Next, the central question, on which the FCM would be based, was introduced, being: “According to your point of view what elements (factors, actors, and processes) are important for the environmental quality, ecosystem services, and protection of the Wadden Sea, and how are these elements related with each other?”

Subsequently, together with the participant, the FCM was drawn up, in two steps:

Firstly, the stakeholders were requested to mention the elements (factors, actors, processes) that according to them are important for the environmental quality, ecosystem services, and protection of the Dutch Wadden Sea PA.
Because during the interviews with stakeholders the important elements in the Wadden Sea are verbally described, these may contain hard to quantify concepts, such as “cultural identity”, or “nice view” (Jetter and Kok, 2014), or semi-quantifiable concepts such as “fish”, “clean water”, or “tourism”. Such faint or abstract concepts can all be used in the FCM, resulting in an all-encompassing view of the system.
If difficulties were encountered in completely capturing the participants’ meaning, paraphrasing in a supporting way was used (Isak et al., 2009: “Do I understand correctly that you mean “…….” by this?”.
Some elements could be expressed by stakeholders as dis-concepts. A dis-concept is the contrary of a concept, for example mistrust instead of trust. Such dis-concepts were translated to concepts, because using dis-concepts may result in a false positive effect. If a certain element (i.e. concept) has a positive-arrow towards the element “mistrust” (i.e. increases mistrust) this is in fact a negative arrow towards the element “trust” (Kosko, 1986). In this case “trust” should be used. At the end of the first round of the interview such translations were applied in consultation with the stakeholders.

Secondly, the actual drawing of the FCM took place by placing the previously noted elements one-by-one on a post-it paper, and subsequently connecting them by drawing arrows, and noting the connection strength between the elements (see example in Figure 4.2). The strength was indicated with a value between +1 and +10 in case of a positive relation, or between -1 and -10 in case there was a negative impact; (+ or -) 10 being a very strong connection, and (+ or -) 1 a very weak connection.

If the participant had difficulty in assigning a strength to a certain connection between elements, linguistic terms were used to describe the strength, and these were translated to numbers as is shown in table 4.1 (Glykas et al., 2010).

Table 4.1: Translation of connection strength between elements from linguistic terms to numbers.

Linguistic term	Connection strength
Very weak	0.2
Weak	0.4
Medium	0.6
Strong	0.8
Very strong	1.0

Figure 4.2. Example of the end-result of a stakeholder interview showing the FCM network

2.3. Stakeholder characterisation

The interviewed stakeholders represent various socio-economic groups that are important to form a complete picture on the elements determining and influencing (the management of) the Wadden Sea. The selected stakeholders came from tourism and transport sectors, fisheries, industry, SME's, local, provincial and state authorities, NGO's and research institutes. For the details on al interviewed stakeholders see table 4.2.

For a comparison of the various FCMs composed by the stakeholders an analysis was made of the differences related to the type of institution the stakeholders were associated to (table 4.2). To this end, we have divided stakeholders into different categories. Firstly, the area coverage of the activities of the stakeholder's institution was determined, being either national, regional or local. Secondly, the disciplinary orientation of the stakeholder was determined, a stakeholder could belong to industry, academic education and research, recreation, policy and governance, or NGO's. Thirdly, the stakeholder's institution were classified according to their main orientation being economic or ecological, or a mix of both.

Table 4.2: Stakeholders interviewed for drawing up FCMs and the typology of the stakeholder's institution (for Area Coverage: N = National, R = Regional (District), L = Local; for Discipline: ER = academic Education and/or Research, I = Industry, N = NGO, P= Policy and Governance, R = Recreation / Tourism; for ecological or economic (Ecol/Econ) orientation: Ecol = Ecological, Econ = Economic, Mix = Mix of Ecological and Economic orientation)

Date of interview (all in 2019)	Location (all in the Netherlands)	Type of institution		
		Area Coverage	Discipline	Ecol/Econ
25 April	West Terschelling	L	R	Econ
25 April	West Terschelling	R	R	Mix

25 April	West Terschelling	L	R	Mix
26 April	Urk	R	I	Econ
9 May	Harlingen	L	P	Econ
9 May	West Terschelling	L	P	Econ
9 May	Hoorn (Terschelling)	L	R	Econ
13May	Surhuisterveen	R	R	Mix
13 May	Leeuwarden	R	R	Mix
29 May	Harlingen	R	NGO	Ecol
4 June	Harlingen	L	P	Econ
4 June	Harlingen	L	I	Econ
25 July	Leeuwarden	N	ER	Mix
25 July	Leeuwarden	R	P	Mix
13 August	Leeuwarden	N	NGO	Ecol
20 August	Roden	N	P	Mix
21 August	Olterterp	R	NGO	Ecol
2 September	Yerseke	N	I	Econ
5 September	Holwerd	R	I	Econ
12 September	Leeuwarden	N	P	Mix
17 September	Yerseke	N	ER	Ecol
15 October	Den Haag	N	P	Econ
18 October	Den Helder	N	ER	Mix

2.4. Analysis and comparison of FCM

2.4.1. Accumulation curves
To determine whether enough interviews had been performed to capture most essential elements accumulation curves were composed at regular intervals (after about each 5 interviews) on basis of the harmonised terms (Appendix A), following Ozesmi and Ozesmi (2003). To compose the accumulation curves the FCMs were randomly selected and compared among each other 1000 times and the average number of elements versus the number of interviews was plotted.
We aimed to stop with interviews once there would be a too small increase in number of elements with a too great effort (following Ozesmi and Ozesmi, 2004), which in our case was set at less than 5% new elements to be expected within the coming 5 interviews. For practical reasons, i.e. making appointments for interviews far on beforehand, and because of hindsight, a small overshoot of the number of interviews was taken into account.

2.4.2. Comparison of FCM through indices
For comparing the FCM of different stakeholders, all FCM were turned into diagrams that indicate the strength of connections between different elements, so called adjacency matrices (Kosko, 1986). Since different stakeholders could use various synonyms for some elements in their FCM diagrams, these elements were harmonised. For example, biodiversity, species diversity, and species, were together called biodiversity. This harmonisation resulted in 133 different elements (Appendix A), which were used to analyse the main characteristics of these FCM diagrams.
A set of indices was calculated to characterise, and to indicate similarities or differences within and between individual stakeholder's FCM networks (Ozesmi & Ozesmi, 2003) (table 4.3).

Table 4.3: Indices to characterise stakeholder FCMs.

Index name	Abbreviation	Calculated as:	Determined in order to indicate:
Number of elements	NE	Number of nodes in network	Diversity of viewpoints on essential elements in the Wadden Sea
Number of connections	NC	Number of arrows in networks	Diversity of interactions between elements in the Wadden Sea
Connection Density	CD	Ratio of realised versus theoretic maximum number of connections between all nodes in the FCM	The higher the density, the more arrows connect the elements among each other in a network, and thereby more potential management options exist according to the stakeholder.
Number of transmitter elements	NTE	Number of elements with connections pointing away from them	Elements that have a forcing function in the FCM, influence several other elements, but are not influenced by any other elements. Can be the starting points of PA management.
Number of receiver elements	NRE	Number of elements with connections pointing towards them	Elements that are influenced by other elements in the FCM, but do not influence other variables themselves. These elements can be easily influenced (by other elements and/or management)
Number of ordinary elements	NOE	Number of elements with connections pointing away from them, and pointing towards them	Elements that have an influence on (several) other elements, that are also influenced by other elements themselves.
Complexity	COMP	Ratio between the number of receiver and the number of transmitter elements (=NRE/NTE)	A higher complexity index indicates more receiver elements per transmitting element, making more outcomes possible in response to a few forcing elements (i.e. more solutions to a possible issue). At the other hand, a system with many transmitters and less receiver elements, thus a low complexity index, is perceived to be top-down (i.e. several issues point to the same solution).
Hierarchy	HIER	The Standard Error around the mean Outdegree (the Outdegree is the sum of the absolute values of all connections exciting, i.e. pointing away from, an element)	A high hierarchy index, i.e. equal to 1, means the outdegree of the various elements varies strongly, with some outdegrees very high and some very low. Thereby the FCM is called fully hierarchical, or “linearly directed”. When the index is close to 0, the outdegrees of the various elements in the network are almost equivalent, resulting in a web-like design of the network, which is called democratic. Stakeholder groups with networks, that represent a more democratic system, are more likely to perceive that the system can be changed in various ways, and can be a starting point for management objectives.

Centrality	CENT	Sum of the absolute values for the Indegree and Outdegree of a network (the Indegree is the sum of the absolute values of all connections entering, i.e. pointing towards, an element; for Outdegree see above cell)	A network with high Centrality indicates that there is a central steering element in the system, influencing, and influenced by, many other elements.

2.4.3. Differences and similarities between stakeholders
In order to be able to analyse similarities or differentiation between (groups of) stakeholders (table 4.2) the 133 elements were further harmonised to a set of 34 elements (Appendix A).
Subsequently, the most important elements mentioned by stakeholders, and groups of stakeholders, were calculated (table 4.4) in order to indicate which elements could be highlighted to achieve a stakeholder supported management of the Wadden Sea.

Table 4.4: Most important elements mentioned by stakeholders

Index name	Calculated as:	Determined in order to indicate:
Most important elements	Elements that are the most connected in an FCM (with the most arrows connected to them, irrespective direction)	Elements that can have an influence on (several) other elements, yet that can also be influenced by other elements themselves. Can be intermediary variables in PA management, because they are central, altering one of these elements may have an effect on the entire FCM.
Most important transmitter elements	Elements with the most connections pointing away from them	Elements that have a forcing function in the FCM, influence several other elements, but are not influenced by any other elements. Can be the starting points of PA management.
Most important receiver elements	Elements with the most connections pointing towards them	Elements that are influenced by other elements in the FCM, but do not influence other variables themselves. These elements can be easily influenced (by other elements and/or management). Can be seen as possible outcomes of PA management.

2.5. Mathematical analyses

2.5.1. Analysis and comparison of the individual FCM networks.
A cluster analysis using Principal Component Analysis (Metsalu & Vilo, 2015) was performed to identify any pattern in the similarities or differences between the harmonised elements indicated by the stakeholders.

2.5.2 Mathematical analyses of stakeholder group indices
A cluster analysis using Principal Component Analysis and Heatmaps (Metsalu & Vilo, 2015) was performed to identify the similarities or differences between groups of stakeholders on basis of Centrality (CENT), the Connection Density (CD), the Number of Connections per Number of Elements (NC/NE), and Hierarchy (HIER)(abbreviations. see table 4.3).
The stakeholder groups were categorised according the type of institution they were associated to, following 3 criteria, i.e. 1) the area coverage of the activities at their institution being national, regional (district) or locally oriented, 2) the disciplinary orientation of the institution classified into industry, academic education and research, recreation, policy and governance, and non-governmental organisations, and 3) their main orientation being economic or ecological, or a mix of both (table 4.2).

3. Results

3.1. Accumulation curves

In hindsight, the last accumulation curve drawn after 23 interviews indicated that, with the criteria set, i.e. less than 5% increase in number of elements to be expected with 5 more interviews, the threshold level was reached already with 20 interviews to obtain a proper overview of the stakeholder's opinions on the Wadden Sea (Figure 4.2). With 23 interviews thus an almost complete coverage of the amount of elements potentially to be mentioned by stakeholders has been reached.

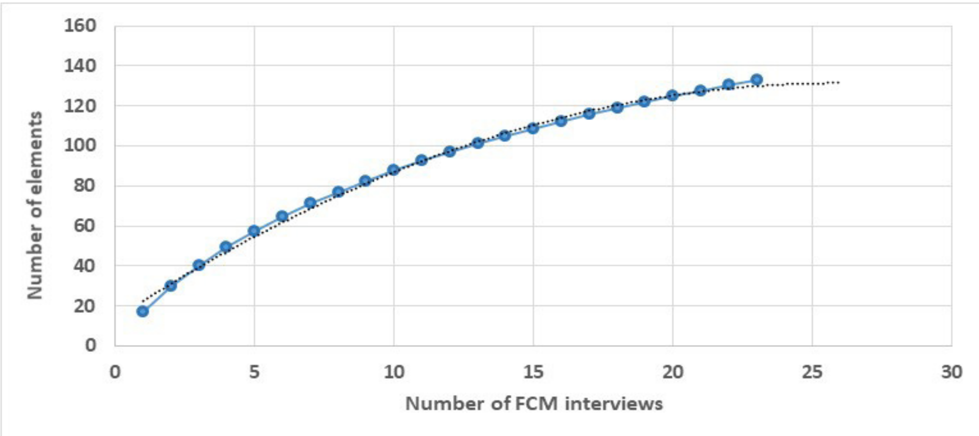

Figure 4.2. Accumulation curve of the total number of elements in the Wadden Sea FCMs versus the number of FCM interviews (dotted line is the 2nd order polynomial fitted to the data: y = -0,1755x2 + 9,0942x + 13,603; R^2 = 0,996).

3.2 Comparing FCM indices

A comparison of the indices of the FCMs for the different stakeholders makes clear there is a strong variation between stakeholders, and thereby a high diversity in the forms of FCMs composed with those stakeholders (table 4.5).

Table 4.5: Indices of the FCMs of different stakeholders in the Wadden Sea (for abbreviations of indices see table 4.3)

Index	1	2	3	4	5	6	7	8	9	10	11	12
NE	14	9	13	15	21	15	13	13	14	20	25	17
NC	33	12	19	15	40	38	24	37	34	73	67	35
CD	0,17	0,15	0,11	0,07	0,09	0,17	0,14	0,22	0,17	0,18	0,11	0,12
NTE	4	3	4	5	4	1	3	1	2	3	3	2
NRE	11	3	4	1	0	1	4	0	0	0	2	3
NOE	9	3	5	7	17	13	6	12	12	17	20	12
COMP	0,25	1	1	0,2	0	1	1,33	0	0	0	0,67	1,5
HIER	0,01	0,01	0,01	0,001	0,001	0,006	0,02	0,01	0,015	0,002	0,002	0,005
CENT	50	12,4	23	14,2	10,98	36,87	24,6	25,91	47	31,33	33,72	17,2
Index	13	14	15	16	17	18	19	20	21	22	23	
NE	15	19	24	21	18	16	15	23	11	19	17	
NC	13	54	62	40	33	21	24	56	15	19	30	
CD	0,06	0,15	0,11	0,09	0,1	0,08	0,11	0,11	0,12	0,05	0,1	
NTE	2	2	6	2	3	8	0	3	4	8	5	

NRE	2	4	1	1	2	1	2	2	2	3	1	
NOE	7	13	17	18	13	7	12	16	5	0	11	
COMP	1	2	0,17	0,5	0,67	0,13	High	0,67	0,5	0,38	0,2	
HIER	0,003	0,001	0,002	0,001	0,003	0,002	0,002	0,003	0,003	0,001	0,001	
CENT	21,6	35,53	22,7	21,28	34,6	29,87	16,55	30,08	5,36	10,98	14,16	

The largest FCM contains 25 elements (NE), and the smallest contains 9 elements. The ordinary elements (NOE; up to 20) were in most cases outnumbering the elements that are only receiver (NRE; upto 11)) or only transmitter (NTE; upto 8)(table 4.5).
The variation in the number of connections (NC) was high, ranging from 12 to 67. Nevertheless, the values of the connection density (CD) were more alike, indicating that different stakeholders see roughly the same amount of management options for each element mentioned.
The complexity (COMP=NRE/NTE) of the FCMs differs quite a lot among the stakeholders, the lowest score is 0, and the highest score is high (>>2, in fact infinitive). This indicates a difference in viewpoint of the stakeholders, some perceive lots of different receiver variables, whereas others perceive little to no receiver variables.
The hierarchy (HIER) scores of the different FCM are overall very low (0.001 to 0.02), indicating a dominance of democratic FCMs, meaning that all stakeholders perceive that the system can be changed in different ways, giving an open starting point for management objectives.
The centrality of the FCMs differs a lot between stakeholders, indicating a difference in viewpoint regarding the importance of one or more variables.

3.3 Comparing important FCM elements
The important elements mentioned by the stakeholders in their FCM, show despite some differences, also quite some similarities (table 6 for the most important elements, i.e. the elements with the strongest average strength of the connections irrespective whether it are ordinary, transmitter or receiver elements, table 4.7 for the most important transmitting elements, and table 8 for the most important receiver elements).

Table 4.6: Top three most important elements per stakeholder (in colour are the elements most often mentioned in the top three)

Stakeholder	1	2	3
1	SocioEconomics	Nature	Regulations
2	WaddenExperience	Regulations	Recreation
3	Nature	WaddenExperience	NatureConservation
4	Policy	Research	NGOs
5	WaddenExperience	Regulations	SocioEconomics
6	Nature	Management	Regulations
7	Nature	Education	Regulations
8	Fisheries	NatureConservation	AnthropogenousDisruption
9	Nature	WaddenAuthority	SustainableUse
10	Fisheries	Nature	SustainableUse
11	Nature	Durability	NatureConservation
12	Minerals	Infrastructure	SocioEconomics
13	Knowledge	Research	Policy
14	Policy	Management	Regulations
15	GeophysicalNature	SustainableUse	Management

16	Governance	Management	Arrangements
17	Management	Nature	SharedUSe
18	EconomicBiota	Regulations	SharedUse
19	Recreation	Nature	WaddenExperience
20	Management	Knowledge	Policy
21	Recreation	WaddenExperience	Education
22	GeophysicalNature	SharedUse	Nature
23	DecentralisedManagement	NatureConservation	Management

The most important elements according to the Wadden Sea stakeholders are Nature (10 times in the top three), Management (7), Regulations (7), Wadden Experience (5).
Table 4.7: Top three most important transmitting elements per stakeholder (in colour are the elements most often mentioned in the top three)

Stakeholder	1	2	3
1	NGOs	Nature	Infrastructure
2	Regulations	GeophysicalNature	Recreation
3	Nature	NatureConservation	Durability
4	Research	Policy	NGOs
5	Regulations	SocioEconomics	WaddenExperience
6	Nature	Management	NatureConservation
7	Nature	WaddenAuthority	Regulations
8	Regulations	AnthropogenousDisruption	NatureConservation
9	WaddenAuthority	Nature	Arrangements
10	Fisheries	Nature	GeophysicalNature
11	Nature	NatureConservation	NGOs
12	Minerals	Industry	Infrastructure
13	Education	ClimateChange	Policy
14	Education	DecentralisedManagement	Transition
15	SustainableUse	GeophysicalNature	Zoning
16	Governance	Management	Socioeconomics
17	Management	SharedUSe	Governance
18	SharedUse	Regulations	Policy
19	GeophysicalNature	Nature	Recreation
20	Knowledge	Management	Policy
21	WaddenExperience	GeophysicalNature	Regulations
22	Knowledge	SharedUse	ClimateChange
23	DecentralisedManagement	Arrangements	Management

The most important transmitting elements in the Wadden Sea according to stakeholders are Nature (8 times in the top 3), Regulations (6), Geophysical Nature (5), Management (5)
Table 4.8: Top three most important receiver elements per stakeholder (in colour are the elements most

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often mentioned in the top three)

Stakeholder	1	2	3
1	SocioEconomics	Recreation	Fisheries
2	WaddenExperience	Fisheries	Recreation
3	Nature	WaddenExperience	Recreation
4	Policy	EconomicBiota	SustainableUse
5	WaddenExperience	Recreation	Infrastructure
6	Nature	Regulations	Fisheries
7	Durability	Nature	Education
8	Fisheries	EconomicBiota	Nature
9	Nature	SustainableUse	WaddenExperience
10	SustainableUse	EconomicBiota	Aquaculture
11	Durability	Nature	Regulations
12	Minerals	SocioEconomics	Regulations
13	Knowledge	Research	Waddenauthority
14	Management	Policy	Regulations
15	Management	GeophysicalNature	NatureConservation
16	AnthropogenousDisruption	SharedUse	Arrangements
17	Nature	Management	GeophysicalNature
18	EconomicBiota	Aquaculture	Fisheries
19	Recreation	WaddenExperience	Nature
20	Management	GeophysicalNature	Nature
21	Recreation	WaddenExperience	Education
22	GeophysicalNature	Nature	SharedUse
23	NatureConservation	DecentralisedManagement	Regulations

The most important receiver elements in the Wadden Sea according to the different stakeholders are Nature (10 times in the top three), Recreation (6), Wadden Experience (6), Fisheries (5), Regulations (5).

The importance of a couple of elements is illustrated also when compiling the above top three lists (table 4.9). Nature is most often an important element, followed by Regulations and Management. Next important are Wadden Experience and Recreation, followed by Geophysical Nature and Fisheries.
Table 4.9. Overview of elements occurring in the top three lists of importance mentioned by stakeholders (only those elements that have a score of at least 5 times in the top three in one of the lists)

Element	Score top three positions among most important elements (table 4.6)	Score top three positions among most important transmitting elements (table 4.7)	Score top three positions among most important receiving elements (table 4.8)
Nature	10	8	10
Regulations	7	6	5
Management	7	5	4

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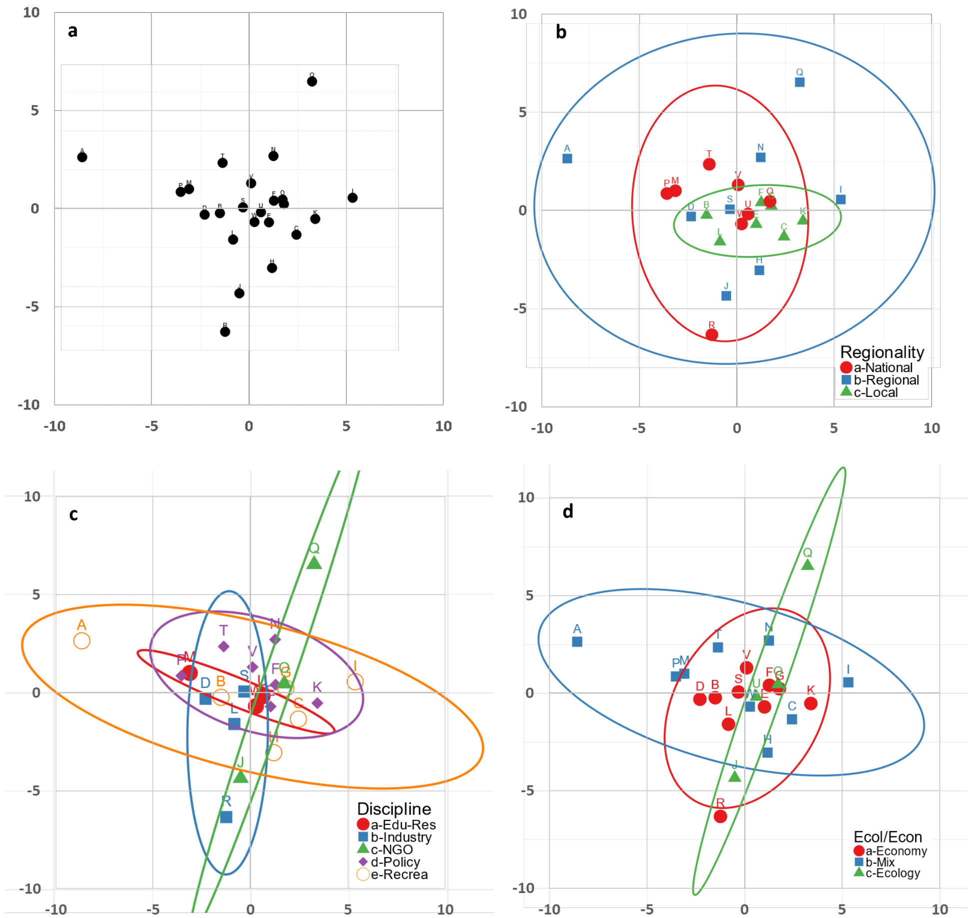
Wadden Experience	5	2	6
Recreation	3	2	6
Geophysical Nature	2	5	4
Fisheries	2	1	5

3.4 Cluster analysis of stakeholder's views on most important elements

No clear differentiation in the clustering of most important harmonised elements between any of the interviewed stakeholders could be found (Fig. 4.3a). Also, the very low level of variance explained by the first two axis (21.8 %) indicates that the variation in the type and level of importance of elements can't be assigned to any of the variables. Moreover, not any clear difference could be found when the institutions of the stakeholders were clustered according their affiliation, or classified according various disciplines, or being more or less economic or ecological orientated (fig. 4.3b,c,d). All scores of the various stakeholder groups were orientated around the origin (in the centre of both axes) and thereby overlapped strongly.



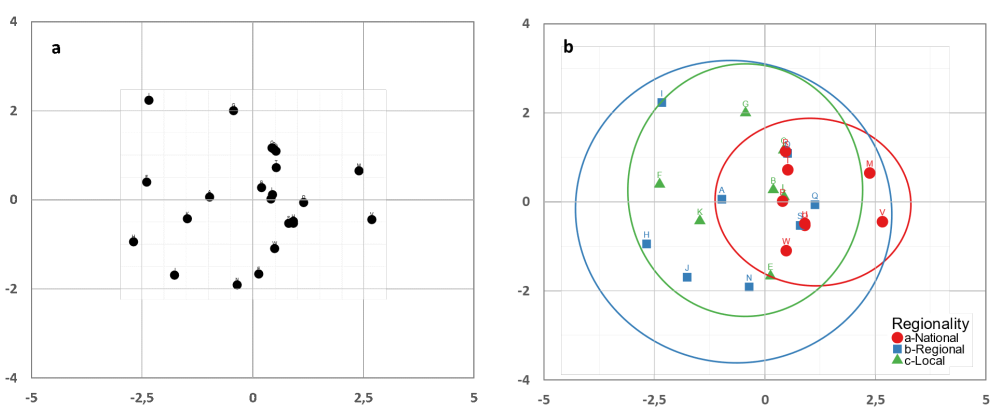
This indicates that the priority listings of important elements on the structure and functioning of the Wadden Sea system mentioned in the previous chapters are in general similar for all (groups of) stakeholders. Figure 4.3. Cluster analysis of the important elements (n=34) mentioned by stakeholders (n= 23) of the Wadden Sea, without group-indications of the stakeholders (a), and distinguishing various types of stakeholder's institutions following area coverage (b), disciplinarity (c), and economic or ecological orientation (d). Unit variance scaling is applied to the elements; Nipals PCA is used to calculate principal components. X and Y axis show principal component 1 and principal component 2 that explain 12.1% and 9.7% of the total variance, respectively. Prediction ellipses are such that with probability 0.95, a new observation from the same group will fall inside the ellipse.

3.5 Cluster analysis stakeholder group indices

The cluster analysis of key indices, i.e. Centrality, Connection Density, the Number of Connections per Number of Elements, and Hierarchy, showed in general overlapping confidence interval ellipses (Fig. 4.4). Nevertheless, a few skewed distributions (outside the origin of the graph) could be found for the stakeholders from nationally orientated institutions (Fig 4.4.b) and the stakeholders with a recreational vocation (Fig 4.4.c). A more directional distribution is corroborated by the high level of variance explained along the first two axis (79 %).

To clarify the tendency of the skewed distributions of indices among groups of stakeholders a heatmap was composed (fig. 4.5).
In the heatmap a distinction could be made between two cluster groups regarding the stakeholder's institutions (Fig. 4.5). The first group consists of the nationally orientated stakeholder's institutions (in Fig.5 under Regionality in the right cluster), characterised by lower connection densities, lower connections per element, and lower hierarchy (table 4.10). The second group is the cluster that regarding discipline encompasses all the stakeholders with a recreational vocation (in Fig. 4.5 under Discipline in the left cluster), marked by a higher centrality, higher connection densities and higher hierarchy (table 10). These results corroborate the results seen in Fig. 4.4b and Fig. 4.4c, respectively.

This means that stakeholders from institutions with a national orientation do observe a lower diversity of elements and connections in the Wadden Sea system than stakeholders with a regional and local orientation. Moreover, they observe the various elements in the system as of almost equivalent importance, tending towards a weblike design of the Wadden Sea system.
At the other hand, the stakeholders with a recreational vocation tend to indicate a few dominant steering elements influencing, and influenced by, a large range of other (less important) elements. This view would offer more clear options for management. Though their view is less web-like, and more hierarchical, than among national orientated stakeholders, their view on hierarchy is still sufficient near to zero (still largely "democratic"), indicating that the system can still be managed in sufficient various ways.



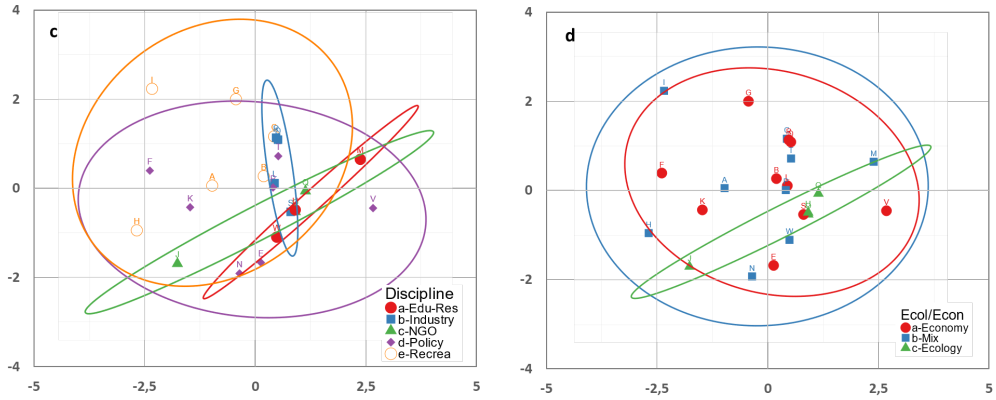


Figure 4.4. Cluster analysis of key indices (n=4) based on the most important elements (n=34) mentioned by stakeholders (n= 23) of the Wadden Sea, without group-indications of the stakeholders (a), and distinguishing various types of stakeholder's institutions following area coverage (b), disciplinarity (c), and economic or ecological orientation (d). Unit variance scaling is applied to the centrality, connection and hierarchy indices; Nipals PCA is used to calculate principal components. X and Y axis show principal component 1 and principal component 2 that explain 48.7% and 30.2% of the total variance, respectively. Prediction ellipses are such that with probability 0.95, a new observation from the same group will fall inside the ellipse.

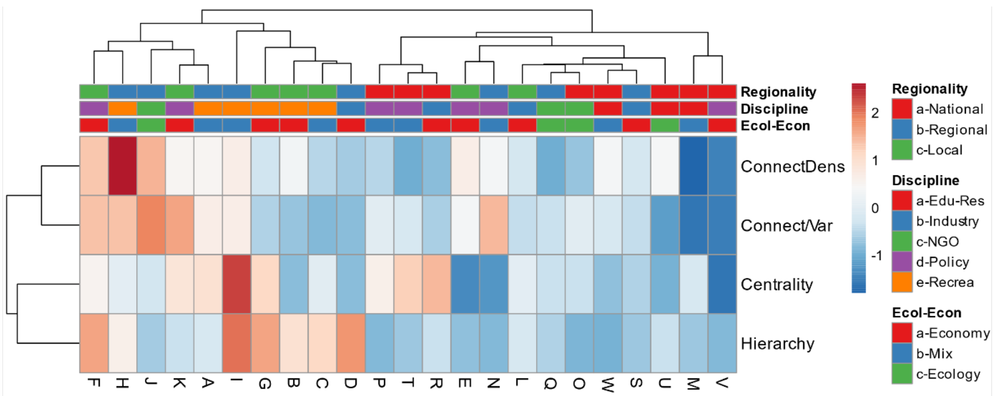


Figure 4.5. Heatmap of cluster analyses on the centrality, connection and hierarchy indices based on the most important elements mentioned by stakeholders of the Wadden Sea versus the types of the institutions of the stakeholders.

Table 4.10. Averages (and standard errors) for the indices (Connection Densities, Connections per Variable, Centrality) showing differentiation between clusters of stakeholder institutional types (Student t-test * p<0.01, ** p<0,001; all others not shown are not significant p>0.05).

Institutional type: Distinctive cluster (versus the other clusters)	Index	Avg (SE) <u>Distinctive Cluster</u>	Avg (SE) Other clusters
Regionality: <u>National</u> (other: Regional, Local)	Connect Dens	0,128** ((0,018)	0,192 (0,015)
	Connect/Var	1,543** (0,184)	2,271 (0,191)
	Hierarchy	0,0019** (0,0005)	0,0084 (0,0017)
Discipline: <u>Recreational</u> (other: Edu-Res, Industry, NGO, Policy)	Centrality	9,081** (2,060)	5,616 (0,939)
	Connect Dens	0,203* (0,030)	0,158 (0,014)
	Hierarchy	0,0124** (0,0021)	0,0040 (0,0012)

4. <u>Discussion</u>

Policy makers and Protected Area managers could encounter serious difficulties when trying to approach a dynamic system. This is caused by the fact that modelling a dynamic system needs intricate mathematical models that may be difficult and costly to construct and need lots of numerical data to calibrate (Aguilar, 2005). Fuzzy cognitive models were proposed by Bart Kosko to overcome this problem (Kosko, 1986; Kosko, 1988; Kosko 1993). In this study, we have made an extensive survey of the opinion of stakeholders in the management of the Dutch Wadden Sea using Fuzzy Cognitive Modelling (FCM).

The technique of FCMs is often used for the understanding of the opinions of groups (Rouse and Morris, 1985). For such group understanding mostly aggregated FCMs are used (Mazzuto et al., 2018), though interviews with groups are also frequently used. In our analyses we have chosen not to make use of aggregated FCMs of stakeholders, because in this way the unique opinions of different stakeholders are added up mathematically, leading to a non-existing artificial opinion. In our results we therefore could indicate differences in the form of the FCM networks between stakeholders with a Recreational vocation and those from institutions with a national orientation (versus those with a more local orientation). This thus urges for an individual approach of stakeholders as we have followed.

During the creation of the FCMs, we have let the participants speak as freely as possible. We have not used any lists with predefined terms, because although this may lead to better standardisation of the FCMs, the reliability of the FCM structure and function may be biased since predefined concepts shape individuals' cognitive abstractions (Rouse and Morris, 1985; Pohl, 2004). Such an absence of predefined concepts may also be a reason that we were able to indicate the above mentioned differentiation between the FCM networks of stakeholder groups.

We have drawn up FCMs of 23 stakeholders of the Dutch part of the Wadden Sea. These stakeholders all have different backgrounds and have different opinions on the management of the Wadden Sea. According to Clarkson (2016) there is always the risk that some stakeholders are left out accidently, and as a consequence not all relevant stakeholders are included in an analysis. However, on the other hand it is often not possible to include all stakeholders, and somewhere a line should be drawn.
This line must be based on well-founded criteria (Clarke and Clegg, 1998). We have chosen to use an accumulation curve based on rarefaction techniques that are common in ecological research (Simberloff, 1978). On basis of the outcome of the accumulation curve we may assume to have interviewed a large enough number of relevant stakeholders, even a higher number (23) than the minimally (20) needed, to be able to draw sufficiently accurate conclusions for the Dutch Wadden Sea.

On an average the connection density of the FCM networks is low (about 12 %), and far from the theoretical number of connection possible. This indicates that according the stakeholders there are not too many important elements that are potentially suitable to be managed because of a low number of causal interrelations (Hage and Harary, 1983). Moreover, because the values of the connection density were

alike, the various stakeholders see roughly the same amount of management options for each element mentioned.
The very low hierarchy (on an average 0.05), indicates that the system is a so-called "democratic network" (Ozesmi and Ozesmi, 2004), meaning that all stakeholders perceive the system can be changed in different ways, and is not just overruled nor linearly directed by one dominant element.
However, the rather high centrality (on an average 25) indicates that there is a difference in viewpoint regarding the importance of, and outcomes of interactions between, one or more variables (Eden et al., 1992). As such, some small differences in perception could be found between groups of stakeholders. Those with a recreational vocation mentioned a higher connection density, as also as higher centrality, indicating that in their view there are more potential options for management through a smaller number of central steering elements.
On the other hand, the stakeholders at institutes with a national orientation (versus a local orientation) mentioned a lower connection density and lower hierarchy, indicating that to their opinion there are less potential management options going together with a higher number of influencing factors.

Irrespective of these small difference between groups of stakeholders, we observed the few same elements, suitable for management, re-occurring among all different types of elements, i.e. central, as well transmitting, as receiver, elements.
The most often mentioned most central terms are Nature, Regulations, Management, Wadden experience and Recreation.
This seems logical, in an area like the Wadden Sea, where nature is protected by several different frameworks, such as Natura 2000, Ramsar convention, the UNESCO World Heritage programme and the UNESCO Man and Biosphere programme, and thus a proper management and regulations has been installed to safeguard the Wadden Sea nature. In addition, a strong Wadden experience and Recreation may also be quite obvious elements in the Wadden Sea known for the special experience it delivers among the millions of tourists each year.

Most of these elements are also indicated as important transmitting elements (being nature, regulations, management, now also including geophysical nature), which could serve as good starting points for management since these elements influence through many outgoing connections several other elements (Ozesmi and Ozesmi 2004).
Likewise, these elements were also often mentioned to be important receiver elements (again nature, regulations, Wadden experience, recreation, now also including fisheries), being because of the many incoming connections easily influenced by planning and management.
This is corroborated by earlier studies in the Wadden Sea on nature (Enemark, 1993), recreation and Wadden experience (Versluis, 2012), and fisheries (Sieben et al., 2013), whereby all authors indicated that these elements are highly regulated within the Wadden Sea, meaning that they are outcomes of, or at least strongly influenced by, management.

From the various FCMs in this study it becomes clear that mainly the five elements Nature, Regulations, Management, Wadden experience and Recreation, should be focused on, and extensively communicated with the stakeholders, to reach a bottom-up citizen and practitioner supported spatial planning and decision making in the Wadden Sea.

5. Conclusion

Our final conclusion is that though differences may exist in the way the most important elements of the Wadden Sea system are expressed by various stakeholders and how they are connected within the system-network, there is an overall strong agreement among all stakeholders on the factual content about what are the most important ecological, socio-economic and cultural elements and their level of importance in the structure and functioning of the Wadden Sea system.
It is more about semantic differences than it is about fundamental substantive contrasts.
The elements to focus on for further bottom-up stakeholder supported planning and decision making in the Wadden Sea are the aspects regarding Nature, Regulations, Management, Wadden experience and Recreation.

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References

Aguilar, J. (2005). A survey about fuzzy cognitive maps papers. International journal of computational cognition, 3(2), 27-33.

Brasseur, S. M. J. M., P. J. H. Reijnders, J. Cremer, E. Meesters, R. Kirkwood, L. F. Jensen, A. Jeβ, A. Galatius, J. Teilmann and G. Aarts. (2018). Echoes from the past: Regional variations in recovery within a harbour seal population. PLoS ONE 13:e0189674.

Brooks, T. M., Da Fonseca, G. A., & Rodrigues, A. S. (2004). Protected areas and species. Conservation Biology, 616-618.

Butcher, J. (2005). The moralisation of tourism: sun, sand... and saving the world?. Routledge.

Butchart, S. H., Baillie, J. E., Chenery, A. M., Collen, B., Gregory, R. D., Revenga, C., & Walpole, M. (2010). National Indicators Show Biodiversity Progress—Response. Science, 329(5994), 900-901.

Campbell, A., Clark, S., Coad, L., Miles, L., Bolt, K., & Roe, D. (2008). Protecting the future: Carbon, forests, protected areas and local livelihoods. Biodiversity, 9(3-4), 117-121.

CBS (2017), Centraal Bureau voor de Statistiek, Den Haag/Heerlen, http://statline.cbs.nl/Statweb/publication/?VW=T&DM=SLN-L&PA=70232NED&D1=6-7&D2=a&HD=190415-1413&HDR=T&STB=G1

Chape, S., Harrison, J., Spalding, M., & Lysenko, I. (2005). Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1454), 443-455.

Clarke, T., & Clegg, S. (1998). Changing paradigms: The transformation of management knowledge for the 21st century. HarperCollins Business.

Clarkson, M. B. (2016). A stakeholder framework for analysing and evaluating corporate social performance (pp. 243-274). University of Toronto Press.

Coad, L., Campbell, A., Miles, L., & Humphries, K. (2008). The costs and benefits of protected areas for local livelihoods: a review of the current literature. UNEP World Conservation Monitoring Centre, Cambridge, UK.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., ... & Raskin, R. G. (1997). The value of the world's ecosystem services and natural capital. Nature, 387(6630), 253-260.

Daily, G. (Ed.). (1997). Nature's services: societal dependence on natural ecosystems. Island Press.

Dankers N, Wolff WJ, Zijlstra JJ (1978) Fishes and fisheries of the Wadden Sea. Report 5 of the Wadden Sea Working Group, Stichting Veth tot Steun aan Waddenonderzoek, Leiden, The Netherlands

De Jonge, V. N., Essink, K., & Boddeke, R. (1993). The Dutch Wadden Sea: a changed ecosystem. Hydrobiologia, 265(1-3), 45-71.

Di Lorenzo, M., Claudet, J., & Guidetti, P. (2016). Spillover from marine protected areas to adjacent fisheries has an ecological and a fishery component. Journal for Nature Conservation, 32, 62-66.

Dijkema, K.S., J.H. Bossinade, P. Bouwsema & R.J. de Glopper (1990). Salt marshes in the Nether-lands Wadden Sea: rising high-tide levels and accretion enhancement. In J.J. Beukema, W.J. Wolff & J.J.W.M. Brouns (eds), Expected effects of climatic change on marine coastal ecosystems. Kluwer Publishers, Dordrecht; pp 173-188

Doak, D. F., Bakker, V. J., Goldstein, B. E., & Hale, B. (2015). What is the future of conservation?. In Protecting the Wild (pp. 27-35). Island Press/Center for Resource Economics.

Drescher, H.E. (1979). Spatial distribution of the harbour seal in the Wadden Sea during the breeding season.ICES,C.M.1979/N:6.

Dudley, N. (Ed.). (2008). Guidelines for applying protected area management categories. Iucn.

Dudley, N. & Stolton, S., eds. (2003). Running pure: the importance of forest protected areas to drinking water. Gland, Switzerland, WWF/World Bank Alliance for Forest Conservation and Sustainable Use.

Dudley, N., Stolton, S., Belokurov, A., Krueger, L., Lopoukhine, N., MacKinnon, K., ... & Sekhran, N. (2010). Natural solutions: Protected areas helping people cope with climate change. Natural solutions: protected areas helping people cope with climate change.

Eagles, P., & Hillel, O. (2008). Improving protected area finance through tourism. In Second meeting of the Ad Hoc Open-ended Working Group on Protected Areas (WGPA-2), Rome, Italy

Eden, C., Ackermann, F., & Cropper, S. (1992). The analysis of cause maps. Journal of management Studies, 29(3), 309-324.

Enemark, J. A. (1993). The Protection of the Wadden Sea in an International Perspective: Planning, Protection, and Management of the Wadden Sea. In Coastlines of the Southern North Sea (pp. 202-213). ASCE.

Floor, J.R., C.S.A. van Koppen & J.P.M. van Tatenhove (2019). Knowledge uncertainties in environmental conflicts: how the mussel fishery controversy in the Dutch Wadden Sea became depoliticised, Environmental Politics, 28:7, 1236-1258, DOI: 10.1080/09644016.2018.1546561

Glicken, J. (2000). Getting stakeholder participation "right": a discussion of participatory processes and pitfall. Environmental science and policy 3, 305-10

Glykas, M. (Ed.). (2010). Fuzzy cognitive maps: Advances in theory, methodologies, tools and applications (Vol. 247). Springer Science & Business Media.

Groumpos, P. P. (2010). Fuzzy cognitive maps: Basic theories and their application to complex systems. In Fuzzy cognitive maps (pp. 1-22). Springer, Berlin, Heidelberg.

Hage, P., & Harary, F. (1983). Arapesh sexual symbolism, primitive thought and Boolean groups. L'Homme, 57-77.

Hummel, C., Poursanidis, D., Orenstein, D., Elliott, M., Adamescu, M. C., Cazacu, C., Ziv, G., Chrysoulakis, N,, Van der Meer, J., Hummel, H. (2019). Protected Area management: Fusion and confusion with the ecosystem services approach. Science of The Total Environment, 651, 2432-2443. https://doi.org/10.1016/j.scitotenv.2018.10.033.

Isak, K. G., Wildenberg, M., Adamescu, M., Skov, F., De Blust, G., & Varjopuro, R. (2009) A Long-Term Biodiversity, Ecosystem and Awareness Research Network.

Isak, K. G. Q. (2008). Investigating fuzzy cognitive mapping as a participatory tool for conceptual landscape modelling (Doctoral dissertation, Københavns Universitet, Det Biovidenskabelige Fakultet for Fødevarer, Veterinærmedicin og Naturresourcer, Skov & Landskab).

Jetter, A. J., & Kok, K. (2014). Fuzzy Cognitive Maps for futures studies—A methodological assessment of concepts and methods. Futures, 61, 45-57.

Kosko, B. (1986). Fuzzy cognitive maps. International journal of man-machine studies, 24(1), 65-75.

Kosko, B. (1988). Hidden patterns in combined and adaptive knowledge networks. International Journal of Approximate Reasoning, 2(4), 377-393.

Kosko, B. (1993). Adaptive inference in fuzzy knowledge networks. In Readings in Fuzzy Sets for Intelligent Systems (pp. 888-891). Morgan Kaufmann.

Liu, J., Linderman, M., Ouyang, Z., An, L., Yang, J., & Zhang, H. (2001). Ecological degradation in protected areas: the case of Wolong Nature Reserve for giant pandas. Science, 292(5514), 98-101.

Lozan JL (1994) Zur Geschichte der Fischerei im Wattenmeer und in Kuestennaehe. In: Lozan JL, Rachor E, Reise K, von Westernhagen H, Lenz W (eds) Warnsignale aus dem Wattenmeer. Blackwell, Berlin, pp 215–226

Mazzuto, G., Bevilacqua, M., Stylios, C., & Georgopoulos, V. C. (2018, July). Aggregate experts knowledge in fuzzy cognitive maps. In 2018 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE) (pp. 1-6). IEEE.

Metsalu, T. & Vilo, J. (2015). Clustvis: A web tool for visualizing clustering of multivariate data using Principal Component Analysis and heatmap. Nucleic Acids Research, 43(W1): 566–570, 2015. doi: 10.1093/nar/gkv468.

Morris, N. M., & Rouse, W. B. (1985). Review and evaluation of empirical research in troubleshooting. Human factors, 27(5), 503-530.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. Science, 325(5939), 419-422.

Özesmi, U., & Özesmi, S. (2003). A participatory approach to ecosystem conservation: fuzzy cognitive maps and stakeholder group analysis in Uluabat Lake, Turkey. Environmental management, 31(4), 0518-0531.

Özesmi, U., & Özesmi, S. L. (2004). Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. Ecological modelling, 176(1-2), 43-64.

Parrish, J. D., Braun, D. P., & Unnasch, R. S. (2003). Are we conserving what we say we are? Measuring ecological integrity within protected areas. BioScience, 53(9), 851-860.

Pohl, R.F. (ed.) (2004). Cognitive Illusions: A Handbook on Fallacies and Biases in Thinking, Judgment and Memory. Psychology Press, Hove

Rodrigues, A. S., Andelman, S. J., Bakarr, M. I., Boitani, L., Brooks, T. M., Cowling, R. M., Fishpool, L. D. C., Da Fonseca, G. A. B., Gaston, K. J., Hoffmann, M., Long, J.S., Marquet, P. A., Pilgrim, J. D., Pressey, R. L., Schipper, J., Sechrest, W., Stuart, S. N., Underhill, L. G., Waller, R. W., Watts, M. E. J., Yan X. (2004). Effectiveness of the global protected area network in representing species diversity. Nature 428 (6983), 640–643.

Sieben, C., J, Gascoigne, G. Nehls, P. Ramirez-Monsalve, J. Raakjaer (2013). Sustainable fisheries in the Trilateral Wadden Sea. Final Report. MEP Report Ref. 2471R02D, MacAlister Elliott and Partners Ltd, Lymington, United Kingdom 212 pp.

Simberloff, D. (1978). Use of rarefaction and related methods in ecology. In: Biological data in water pollution assessment: quantitative and statistical analyses. ASTM International.

Sohngen, B., & Brown, S. (2006). The influence of conversion of forest types on carbon sequestration and other ecosystem services in the South Central United States. Ecological Economics, 57(4), 698-708.

Stolton, S., Dudley, N., Randall, J. (2008) Natural security protected areas and hazard mitigation (WWF.).

Taber, R. (1991). Knowledge processing with fuzzy cognitive maps. Expert systems with applications, 2(1), 83-87.

Versluis, J. P. (2012). The options of economic interference in Natura 2000 areas: Recreation in the Wadden Sea (Master's thesis).

Van der Jeugd HP, Ens BJ, Versluijs M, Schekkerman H (2014). Geïntegreerde monitoring van vogels van de Nederlandse Waddenzee. Vogeltrekstation rapport 2014-01. Vogeltrekstation, Wageningen, Sovon-rapport 2014/18, Sovon Vogelonderzoek Nederland, Nijmegen, 261 pp.

von Nordheim H, Andersen ON, Thissen J (1996) Red lists of biotopes, flora and fauna of the Trilateral Wadden Sea Area, 1995. Helgol Meeresunters 50(Suppl):1–136

White, A. T., & Vogt, H. P. (2000). Philippine coral reefs under threat: lessons learned after 25 years of community-based reef conservation. Marine Pollution Bulletin, 40(6), 537-550.

Wild R., McLeod C. (2008). Sacred natural sites: Guidelines for protected area managers. IUCN, Gland, Switzerland, pg. 106

Wildenberg, M., Bachhofer, M., Isak, K. G., & Skov, F. (2014). Use and evaluation of FCM as a tool for long term socio ecological research. In Fuzzy cognitive maps for applied sciences and engineering (pp. 221-236). Springer, Berlin, Heidelberg.

Wilson, E. O. (ed.) (1988), Biodiversity, National Academies Press, Washington D.C.

Wolff W.J., Ecology of the Wadden Sea. Rotterdam: Balkema (1983). DOI: 10.4319/lo.1984.29.6.1348

Young, J. C., Jordan, A., Searle, K. R., Butler, A., Chapman, D. S., Simmons, P., & Watt, A. D. (2013). Does stakeholder involvement really benefit biodiversity conservation?. Biological Conservation, 158, 359-370.

Appendix A: Harmonisation of the FCM elements.

Original Term (Dutch)	Original Term (English)	Harmonised Term (Dutch)	Harmonised Term (English)	Abbreviation
Aas	Bait	Economischebiota	Economic biota	EconBio
Achterland	Hinterland	Infrastructuur	Infrastructure	Infra
Afspraken	Agreements	Afspraken	Arrangements	Arrang
Artisanaleproducten	ArtisanalProducts	Economischebiota	Economic biota	EconBio
Baggeren	Dredging	Anthropogeneverstoring	Anthropogenous dis-ruption	AnthDis
Beheer	Management	Beheer	Management	Manage
Belangen	Interests	Afspraken	Arrangements	Arrang
Beleid	Policy	Beleid	Policy	Policy
Bereikbaarheid	Accessibility	Infrastructuur	Infrastructure	Infra
Besluitvorming	DecisionMaking	Bestuur	Governance	Govern
Bestuur	Governance	Bestuur	Governance	Govern
Bijzonderesoorten	SpecialSpecies	Waddenbeleving	Wadden experience	WadExp
Biodiversiteit	Biodiversity	Natuur	Nature	Nature
BiogeneStructuren	BiogenicStructures	Geofysischenatuur	Geophysical nature	Geofys
Bodemdaling	Subsidence	Anthropogeneverstoring	Anthropogenous dis-ruption	AnthDis
Bruinevloot	TraditionalSailingVessels	Waddenbeleving	Wadden experience	WadExp
Compartimentalisering	Compartimentalisation	Zonering	Zoning	Zoning
Conditiedeelnemers	ConditionParticipants	Waddenbeleving	Wadden experience	WadExp
Connectiviteit	Connectivity	Natuur	Nature	Nature
Conservatisme	Conservatism	Afspraken	Arrangements	Arrang
Controle	Control	Beheer	Management	Manage
Cruiseschepen	CruiseShips	Recreatie	Recreation	Recreat
Cultuurhistorischerfgoed	CulturalHistoricalHeritage	Waddenbeleving	Wadden experience	WadExp
Dataschaarste	DataScarcity	Kennis	Knowledge	Know
Decentraalbeheer	DecentralisedManage-ment	Decentraalbeheer	Decentralised manage-ment	DecMan
Dijken	Dikes	Veiligheid	Safety	Safety
Duisternis	Darkness	Waddenbeleving	Wadden experience	WadExp
Duurzaamgebruik	SustainableUse	Duurzaamgebruik	Sustainable use	SustUse
Duurzaamheid	Sustainability	Duurzaamheid	Durability	Durabil
Dynamiek	Dynamics	Geofysischenatuur	Geophysical nature	Geofys
Ecologischeprocessen	EcologicalProcesses	Natuur	Nature	Nature
Ecotoerisme	EcoTourism	Recreatie	Recreation	Recreat
Educatie	Education	Educatie	Education	Educa
Energie	Energy	Infrastructuur	Infrastructure	Infra
Energiebehoefte	EnergyNeeds	Socioeconomie	Socioeconomics	SocEcon
Erosie	Erosion	Geofysischenatuur	Geophysical nature	Geofys
Evaluatie	Evaluation	Afspraken	Arrangements	Arrang
Fourageergebiedvogels	ForagingAreaBirds	Geofysischenatuur	Geophysical nature	Geofys
Garnalenbestand	ShrimpStocks	Economischebiota	Economic biota	EconBio
Garnalenvisserij	ShrimpFisheries	Visserij	Fisheries	Fish
Gebruikstransitie	UsageTransition	Transitie	Transition	Trans
Geomorfologie	Geomorphology	Geofysischenatuur	Geophysical nature	Geofys
Geslotengebieden	ClosedAreas	Geofysischenatuur	Geophysical nature	Geofys
Habitat	Habitat	Geofysischenatuur	Geophysical nature	Geofys

Handhaving	Enforcement	Beheer	Management	Manage
Haven	Harbour	Infrastructuur	Infrastructure	Infra
Industrie	Industry	Industrie	Industry	Indust
Initiatieven	Initiatives	Afspraken	Arrangements	Arrang
Inkomen	Income	Socioeconomie	Socioeconomics	SocEcon
Inspiratie	Inspiration	Waddenbeleving	Wadden experience	WadExp
Internationalisering	Internationalisation	Internationalisering	Internationalisation	Internat
Investeerders	Investors	Socioeconomie	Socioeconomics	SocEcon
Kaderrichtlijnen	FrameworkDirectives	Regelgeving	Regulations	Regulat
Kennis	Knowledge	Kennis	Knowledge	Know
Klimaatverandering	ClimateChange	Klimaatverandering	Climate change	ClimCha
Koelwater	CollingWater	Infrastructuur	Infrastructure	Infra
Kostenmosselzaadkweek	CostsMusselCulture	Socioeconomie	Socioeconomics	SocEcon
Leefomgeving	LivingEnvironment	SocialeLeefomgeving	Social Living Environment	SocEnv
Luchtkwaliteit	AirQuality	Geofysischenatuur	Geophysical nature	Geofys
Maatregelen	Measures	Regelgeving	Regulations	Regulat
Maatschappelijkewaard-ering	SocietalAppreciation	SocialeLeefomgeving	Social Living Environment	SocEnv
Medegebruik	SharedUse	Medegebruik	Shared use	ShareUse
Menselijkeinvloed	HumanInfluence	Anthropogeneverstoring	Anthropogenous dis-ruption	AnthDis
Mobiliteit	Mobility	Infrastructuur	Infrastructure	Infra
Monitoring	Monitoring	Onderzoek	Research	Research
Mosselkweek	MusselCulture	Economischebiota	Economic biota	EconBio
Mosselzaadkweek	MusselSpatCulture	Aquacultuur	Aquaculture	Aquacul
Mosselzaadvisserij	MusselSpatFisheries	Visserij	Fisheries	Fish
Natura2000	Natura2000	Natuurbescherming	Nature conservation	NatCons
Natuurbeleving	NatureExperience	Waddenbeleving	Wadden experience	WadExp
Natuurbescherming	NatureProtection	Natuurbescherming	Nature conservation	NatCons
Natuurbesef	NatureAwareness	Waddenbeleving	Wadden experience	WadExp
Natuurherstel	NatureRestoration	Natuurbescherming	Nature conservation	NatCons
Rampen	Disasters	Anthropogeneverstoring	Anthropogenous dis-ruption	AnthDis
NGOs	NGOs	NGOs	NGOs	NGOs
OnderWaterNatuur	UnderWaterNature	Natuur	Nature	Nature
Onderzoek	Research	Onderzoek	Research	Research
Overexploitatie	Overexploitation	Anthropogeneverstoring	Anthropogenous dis-ruption	AnthDis
Overleg	Consultation	Afspraken	Arrangements	Arrang
Politiek	Politics	Bestuur	Governance	Govern
Primaireproductie	PrimaryProduction	Natuur	Nature	Nature
Recreatie	Recreation	Recreatie	Recreation	Recreat
Regelgeving	Regulations	Regelgeving	Regulations	Regulat
Regiobenadering	RegionalApproach	Zonering	Zoning	Zoning
Reststoffencentrale	EnergyPlant	Industrie	Industry	Indust
Ruimte	Space	Waddenbeleving	Wadden experience	WadExp
Ruimtegebrek	LackOfSpace	Ruimtegebrek	Lack of space	LackSpa
Ruimtelijkeordening	SpatialPlanning	Regelgeving	Regulations	Regulat
Scheepsbouw	Shipbuilding	Industrie	Industry	Indust
Scheepvaart	ShipTraffic	Infrastructuur	Infrastructure	Infra
Schelpenwinning	ShellExtraction	Delfstoffen	Minerals	Mineral

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Sedimentatie	Sedimentation	Geofysischenatuur	Geophysical nature	Geofys
SocioEconomie	SocioEconomy	SocioEconomie	Socioeconomics	SocEcon
Soorten	Species	Natuur	Nature	Nature
Sporten	Sports	Recreatie	Recreation	Recreat
Stilte	Tranquility	Waddenbeleving	Wadden experience	WadExp
ToegankelijkheidHaven	AccesibilityPort	Infrastructuur	Infrastructure	Infra
ToegankelijkheidWad	AccessibilityWad	Infrastructuur	Infrastructure	Infra
Uitgestrektheid	Vastness	Waddenbeleving	Wadden experience	WadExp
UnescoWorldHeritage	UnescoWorldHeritage	Natuurbescherming	Nature conservation	NatCons
UniekeNatuur	UniqueNature	Natuur	Nature	Nature
Urbanisatie	Urbanisation	SocioEconomie	Socioeconomics	SocEcon
Vaargeulen	NavigationChannels	Infrastructuur	Infrastructure	Infra
Vastelandverbinding	MainlandConnection	Infrastructuur	Infrastructure	Infra
Veiligheid	Safety	Veiligheid	Safety	Safety
Verduurzaming	EnhanceSustainability	Duurzaamheid	Durability	Durabil
Vergunningen	Permits	Regelgeving	Regulations	Regulat
Vernieuwingbeheer	RenewalManagement	Transitie	Transition	Trans
Verstoring	Disturbance	Anthropogeneverstoring	Anthropogenous dis-ruption	AnthDis
Vervuiling	Pollution	Anthropogeneverstoring	Anthropogenous dis-ruption	AnthDis
Verzilting	Salinisation	Anthropogeneverstoring	Anthropogenous dis-ruption	AnthDis
Visbestand	FishStocks	Economischebiota	Economic biota	EconBio
Visserij	Fisheries	Visserij	Fisheries	Fish
Voedselvoorvis	FoodForFish	Natuur	Nature	Nature
Voedselweb	Foodweb	Natuur	Nature	Nature
Waddenautoriteit	WaddenAuthority	Waddenautoriteit	Wadden Authority	WadAuth
Waddennatuur	WaddenNature	Natuur	Nature	Nature
Wadlopen	WadWalking	Recreatie	Recreation	Recreat
Wadplaten	WadFlats	Geofysischenatuur	Geophysical nature	Geofys
Waterinfrastructuur	WaterInfrastructure	Infrastructuur	Infrastructure	Infra
Waterkwaliteit	Waterquality	Anthropogeneverstoring	Anthropogenous dis-ruption	AnthDis
Weer	Weather	Geofysischenatuur	Geophysical nature	Geofys
Wetenschappelijkemod-ellen	ScientificModels	Onderzoek	Research	Research
Wijdsheid	Grandness	Waddenbeleving	Wadden experience	WadExp
Windmolens	Windmills	Infrastructuur	Infrastructure	Infra
Zandsuppletie	Sandsuppletion	Anthropogeneverstoring	Anthropogenous dis-ruption	AnthDis
Zeehonden	Seals	Waddenbeleving	Wadden experience	WadExp
Zeespiegelstijging	SeaLevelRise	Klimaatverandering	Climate change	ClimCha
Zeezicht	Seaview	Waddenbeleving	Wadden experience	WadExp
Zilteteelt	SaltyProduce	Aquacultuur	Aquaculture	Aquacul
Zonering	Zonation	Zonering	Zoning	Zoning
Zoutwaterafvoer	SaltWaterDiscard	Infrastructuur	Infrastructure	Infra
Zoutwinning	SaltMining	Delfstoffen	Minerals	Mineral

Chapter 5 - A practical novel assessment tool for the socio-ecological condition of Protected Areas: the Protection Level Index (PLI)

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Chapter 5 - A practical novel assessment tool for the socio-ecological condition of Protected Areas:

the Protection Level Index (PLI)

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Abstract

Protected Area (PA) managers and policy makers need to determine and demonstrate the effectiveness of PA management and keep track of the conservation status in ways that are practical, scientifically sound and comparable among PAs in various terrestrial and aquatic environments. As most existing methods for measuring the managerial efficiency of PAs are restricted to specific elements of the management or a limited number of detailed environmental aspects, often without the participation of practitioners, we aim for a generally applicable method developed in close cooperation with PA managers; the Protection Level Index (PLI). PLI includes ecological, socio-economic, as well as managerial factors, and consists of twelve variables that together describe the state of a PA. Seven of those are derived from interviews with PA managers, and five of them are derived from GIS analyses. Data were obtained during face-to-face interviews with PA managers using a fixed protocol, thereby introducing a new way of incorporating the perception of the PA managers. PLI was tested in seven different PAs across Europe. The lowest final PLI score was for the Island Network of Protected Areas in La Palma and the highest final PLI score was for the Kalkalpen National Park. PLI is wider applicable than other related methods and more cost-effective. Therefore PLI can be used on a yearly basis to keep track of the progress of management activities and conservation status within and among (networks of) PAs.

Highlights

- Protected Areas (PA) are important in conservation strategies
- PA are important for maintaining diversity, landscapes and Ecosystem Services
- There is a need to determine effectiveness of PA management
- PA managers need to keep track of the conservation status of their PA
- PLI can determine PA management effectiveness in a quick and simple way

1. Introduction

Protected Areas (PAs) play a key role in the conservation of natural structures, functions and processes, maintaining species and habitat diversity, delivering a variety of Ecosystem Services or protecting areas of specific interest (Liu et al., 2001; Parrish et al., 2003; Brooks et al., 2004; Rodrigues et al., 2004; Chape et al., 2005; Campos & Nepstad, 2006; Coad et al., 2008; Dudley, 2008; Wild & McLeod, 2008; Butchart et al., 2010; Cardelús et al., 2013; Scull et al., 2017).
PAs have even been considered as the only hope we have of stopping many threatened or endemic species from becoming extinct (Dudley et al., 2013).

Protecting places for means of conservation has already been a tradition for many centuries. From 322 BC to 187 BC, the Mauryas protected tigers and elephants (Rangajaran, 2005), and in 118 AD the Roman Emperor Hadrian established rules to protect the mountains of Lebanon for the cedar trees used for ship building (McNeill, 2007; Rich, 2013).
The first 'modern' PAs were Yosemite National Park, founded in 1864, and Yellowstone National Park, founded in 1872 as "a public park or pleasuring ground for the benefit and enjoyment of the people" (Bishop, 2004).

Different types of PAs were set up worldwide during the past 150 years (Bishop, 2004) although for different reasons. In North America, PAs were set up to protect dramatic and sublime scenery, in Africa to maintain elite hunting traditions, and in Europe to protect the land- and seascape (Adams and McShane, 1996; Draper et al., 2004; Phillips, 2007; Hummel et al., 2019).
However, with time the focus shifted towards preventing loss of natural habitats and species due to human activities.
Still, a large range of conservation goals exist and for every PA there are unique motives for designation. This unique character makes it difficult to unequivocally define a PA.

A rather general definition of a PA, to include as many types of PAs as possible, used by the Convention on Biodiversity (CBD. 1992) is: A geographically defined area which is designated or regulated and managed to achieve specific conservation objectives. As such, in 2017, PAs covered in total about 15% of the land surface of the planet and about 7% of the marine environment (ProtectedPlanet, 2017).

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As more and more PAs were established around the world with different management and protection objectives, for means of clarification and standardisation, the International Union for the Conservation of Nature (IUCN) developed a categorising system for PAs in 1933 (Holdgate, 2014).
In 1994 IUCN defined six categories for classifying PAs according to their management objectives: Ia – Strict nature reserve, Ib – Wilderness area, II – National park, III – Natural Monument or feature, IV – Habitat/species management area, V – Protected landscape or seascape, and VI – Protected areas with sustainable use of natural resources (Dudley et al., 2013).
The designation of a certain IUCN category to a PA however does not guarantee an effective insight in the actual (environmental or socio-economic) status of a PA. The reason for this is that IUCN categories are mainly based on the PA management strategy, on paper, and not on the actual effects of that strategy in the field. Consequently, so called "paper parks" can occur, PAs that despite a good management plan on paper have little or no actual effective protection in the field, due to absent or ineffective management (Brandon et al., 1998; Blom et al., 2004, Bonham et al., 2008).

In the last decades, many efforts have been made to develop PA management effectiveness methodologies (Blanco and Gabaldon, 1992; Courrau, 1999; Dudley et al., 1999; Hockings et al., 2000; Cifuentes et al., 2000; Ervin, 2003a; Stolton et al., 2003; Blom et al., 2004; BirdLife International, 2006; Leroux et al., 2010; Mc Arthur et al., 2010). These methodologies mainly focus on managerial issues and only a few contextual environmental and socio-economic issues. By not paying enough attention to the effects in the field, they may cause a threat to the management. Moreover, the majority of these methods are often not generally applicable (Hockings & Phillips, 1999; Pomeroy, 2004), and may require quite some financial or personnel effort (Stoll-Kleeman, 2010).
The more recent publications show an even stronger restriction to a limited number of detailed variables, mostly abstracted from databases, with a managerial focus (Eklund et al., 2019; Armitage et al., 2020), or environmental focus (Hofmann et al., 2017; Mikoláš et al., 2017; Friedrichs et al., 2018; Brown

et al., 2019; Riggio et al., 2019; Cazalis et al., 2020; Negret et al., 2020; Terraube et al., 2020; Wolf et al., 2021); or socio-economic emphasis (Bennett et al., 2019; Cazalis & Prévot, 2019; Jones et al., 2020).

As PA managers and policy makers are under increasing pressure to determine the effectiveness of their PA in ways that are practical, scientifically sound and comparable among different PAs (Parrish et al., 2003), we aimed to develop a new index to overcome the before mentioned obstacles, the Protection Level Index (PLI).
As such, PLI allows for a cost effective, multidisciplinary, and practical assessment of the degree of protection in any type of PA worldwide from a managerial as well as an environmental and socio-economic point of view.

PLI assesses the level of protection in a PA by measuring managerial, socio-economic as well as environmental factors.
It consists of a set of twelve sub-indices. Next to the inclusion of the major disciplinary approaches, one of the innovative elements of PLI is that it includes the perception of the PA manager to put numerical quantifications of some parameters into context.

2. Materials and Methods

2.1 PLI sub-indices

All twelve sub-indices that together form the final PLI score have been selected in such a way that they allow for a quick and easy assessment of the degree of protection in a PA.
PLI sub-indices were designed and calculated so that a maximum score of 1 is obtained in the case of a desirable situation (high level of protection) and a minimum score of 0 in case of an undesirable situation (low level of protection).

The twelve socio-economic and environmental sub-indices (table 5.1) are derived from the variables that have been previously identified in the EcoPotential project in which more than 120 PA managers, rangers and scientists, of 26 PAs in and around Europe, have been interviewed (Hummel et al., 2018).

Table 5.1: List of the 12 sub-indices used in PLI, along with abbreviations used in formulas and graphs, and whether they are derived from the PLI interview or GIS analyses.

Index (sub-indices of PLI)	Abbreviation in formulas	Abbreviation in graphs	Derived from
Illegal Activities	Ii	IlAR	Interview
Enforcement Employees	Ie	Enfo	Interview
Controlled Visitor Access	Icva	CoVA	Interview
Funding	If	Fund	Interview
Corruption Regulations	Icr	CoRe	Interview
Biodiversity	Ib	Biod	Interview
Management Objectives	Imo	ManO	Interview
Edge Effects	Iee	EdgE	GIS
Naturalness	In	Natu	GIS
Light Pollution	Ilp	LiPo	GIS
Fragmentation	Ifrag	Frag	GIS
Expandability	Iexp	Expa	GIS

2.1.1 Illegal Activities

Monitoring threats to PAs is important for effective biodiversity conservation (Schulze et al. 2018). As Geldmann et al. (2019) indicated, establishing PAs without ensuring an appropriate mechanism and resources to reduce human pressures can lead to negative effects. One of the strongest human pressures, i.e. illegal activities, should therefore be inventoried.
The Illegal Activities sub-index is the average extent to which a set of illegal activities take place in a PA (table 5.2).
Table 5.2: List of possible illegal activities in a PA used in PLI.

1.	Agriculture/Aquaculture
2.	Commercial extraction of wild biological resources
3.	Non-commercial extraction of biological resources
4.	Building infrastructure
5.	Recreation
6.	Poaching
7.	Extraction of non-renewable natural resources
8.	Drone flights
9.	Motorised access
10.	Littering
11.	Vandalism

The extent to which an illegal activity takes place as indicated by the PA management, is divided into 6 categories (table 5.3). In case an activity from the list is not regarded as illegal by the PA management, it is disregarded from the analysis (i.e. no value, and excluded in the calculation of the average for that specific PA). The Illegal Activities sub-index, I_i, reflects the score (sum of the individual scores, A_k) as a fraction of the maximum score:

$$I_i = \frac{1}{n} \sum_{k=1}^{n} A_k$$

where n represents the number of activities regarded as illegal (i.e. the maximum possible score), and A_k is the individual score of k^{th} illegal activity (table 5.3).

Table 5.3: Categories and scoring of the different illegal activities (Ak) as indicated by the PA manment.

Extent to which an illegal activity takes place	Score (Ak)
Does not take place	1.00
Takes place to a negligible extent	0.80
Takes place to a small extent	0.60
Takes place to a moderate extent	0.40
Takes place to a large extend	0.20
Takes place to a very large extent	0.00

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2.1.2 Enforcement Employees
The score for the Enforcement Employees sub-index is based on the average amount of square kilometres to be patrolled by one enforcement employee (table 5.4), and the PA-managers perception of the number of enforcement employees (table 5.5). The index is the sum of both scores.

An enforcement employee is considered to be one full time equivalent (FTE). The optimum number of enforcement employees is based on studies of African PAs, where a ranger density of one ranger per 26-50 km2 appears to be adequate to control poaching activities (Vreugdenhil, 2003; Lindsey et al., 2011; Henson et al., 2016). This ranger density was set as the optimum and a deviation from this density lowers the score. A too high ranger density is not ideal as this means that financial resources are spent on enforcement employees that do not enhance PA protection.

Table 5.4: Scoring of the enforcement density based on the average amount of square kilometres to be patrolled by 1 employee (E1).

Enforcement density	Score (E1)
1 – 12.5 km2	0.2
12.5 – 25 km2	0.3
26 – 50 km2	0.4
51 – 100 km2	0.2
≥ 101 km2	0.0

The Enforcement Employees sub-index, I_e, is calculated as follows:

$$I_e = E_1 + E_2$$

Where E_1 represents the average amount of square kilometres to be patrolled by one enforcement employee, and E_2 represents the PA-managers' perception of the number of employees. See table 4 and 5 for E_1 and E_2 respectively.

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Table 5.5: Scoring of the perception of PA-managers of the number of enforcement employees needed to ensure the proper functioning of a PA (E2).

Perception of number of enforcement employees	Score
The number of enforcement employees is way too low	0.0
The number of enforcement employees is slightly too low	0.3
The number of enforcement employees is adequate	0.6
The number of enforcement employees is slightly too high	0.5
The number of enforcement employees is way more than needed	0.4

2.1.3 Controlled Visitor Access
Human presence is not by default detrimental for PAs. When managers can control visitor's behaviour, an effective balance between nature and humans can exists from which PAs can benefit (Marion & Reid, 2007; Parolo et al., 2009). The Controlled Visitor Access sub-index consists of three aspects: entrance and exit of the PA (table 5.6), presence of pathways and/or shipping lanes (table 5.7), and percentage of clearly indicated pathways or shipping lanes (table 5.8). The score for this sub-index is the sum of these three aspects.
A PA that is fully fenced with only a limited number of entrances provides a high degree of control over visitors, but such a hard boundary significantly lowers connectivity between natural areas. Therefore, the highest score of 0.50 is assigned to a PA that is not fully enclosed with a fence, but where visitors are concentrated by using designated entrances to the PA (table 5.6).

Table 5.6: Scores of the different ways to access a PA (V_1).

Access to the PA	Score (V_1)
The PA is fully fenced (or de facto protected due to geographical circumstances) and can only be accessed via a limited number of entrances	0.25
The PA has no fence and can be accessed anywhere along the border	0.00
The PA has no fence, but concentrates visitors by using designated entrances (e.g. parking lots, public transport connections, visitor centres, harbours)	0.50

The presence of pathways and/or shipping lanes increases the control of visitors and results in a score of 0.25, no pathways/shipping lanes results in a score of 0.00 (table 5.7).

Table 5.7: Scores of presence of pathways/shipping lanes (V_2)

Presence of pathways/shipping lanes	Score (V_2)
Pathways/shipping lanes are not present	0.00
Pathways/shipping lanes are present	0.25

When pathways are present visitors are more likely to use them when they are part of a well-managed route that is clearly indicated with directional signs to preferred destinations (Manning, 2014; Svobodova et al., 2019). Therefore, the higher the percentage of pathways that are part of a route, the more likely that visitors will use them. This leads to higher control of visitors potentially lowering their impact. More indicated routes lead to a higher score (table 5.8).
Table 5.8: Scores of indicated signposted pathways/shipping lanes as percentage of total length of paths/lanes in PA (V_3)

Percentage of indicated or signposted pathways/shipping lanes	Score (V_3)
0%	0.00
1% - 20%	0.05
21% - 40%	0.10
41% - 60%	0.15
61% - 80%	0.20
81% - 100%	0.25

$$I_{cva} = V_1 + V_2 + V_3$$

The Controlled Visitor Access sub-index, I_{cva}, is a sum of the individual scores of the three abovementioned aspects:

2.1.4 Funding
Funding has a major influence on the management of a PA, and thus the degree of nature protection. The funding sub-index consists of two parts, one part is based on the actual amount of funding the PA receives, the second part is based on the perception of the manager regarding this funding.

The score assigned to the first part, F_1, is based on the amount of funding the PA receives. Hereby we correct for both the total surface area of the PA and the Gross National Product of the country in which the PA is located. The value of the following ratio determines the score for this first part:

$$F_1 = \frac{\left(\frac{F_{PA}}{A_{PA}}\right)}{GNI}$$

Where F_{PA} is the average funding the PA receives on a yearly basis, A_{PA} is the total surface area of the PA (in km2) and GNI is the Gross National Income per capita of the country in which the PA is located.

A maximum score for F_1 is obtained when this ratio equals 0.50, because we assumed that a funding per 1 km2 that equals half of the average income of a person in the country is sufficient to sustain effective management of a PA. This assumption is based on data from Bovarnick et al. (2010) for the financial sustainability of American PAs.

As all sub-indices have a range from 0-1, an upper limit is created by assuming that a F_1 value of 0.50 is sufficiently high (if F_1 > 0.50, then = 0.50). Using the data from Bovarnick et al. (2010) on the financial sustainability of American PAs the average Funding index would be 0.044 with a maximum of 0.16, yet they state that double the amount would be more optimal. Therefore, we assumed a Funding index of 0.3 to be optimal, whereas 0.5 (or higher) would be more than sufficient for an effective management of a PA.

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The score assigned to the second part of the Funding index, F_2, is determined by the perception of the PA management of funding (Table 5.9).

Table 5.9: Scores of the perception of funding by the PA manager (F2)

Perception of manager on amount of funding	Score(F2)
Absolutely insufficient, critical lack of funding	0.1
Partly insufficient, the PA management can go on but there is still a big lack of funding	0.2
Sufficient, all (required) management actions can be executed	0.3
More than sufficient, enough funding for proper management and some additional actions	0.4
Superfluous, more than enough funding for management and many additional actions	0.5

The Funding sub-index,, I_f, is then the sum of the two parts:

$$I_f = F_1 + F_2$$

2.1.5 Corruption Regulations
The Corruption Regulations sub-index is made up by the Corruption Perception Index of the country in which the PA is located as calculated by Transparency International on a yearly basis, divided into 10 score-classes (table 5.10).

Table 5.10: The Corruption Perception Index (CPI) divided into 10 score-classes

CPI	Score
1 – 10	0.1
11 – 20	0.2
21 – 30	0.3
31 – 40	0.4
41 – 50	0.5
51 – 60	0.6
61 – 70	0.7
71 – 80	0.8
81 – 90	0.9
91 – 100	1.0

The perception of the manager whether corruption is actually higher or lower in the PA then for the country, can change the final score. If the corruption is perceived to be much higher than, slightly higher than, equal, slightly lower than or much lower than for the country, the score-class changes by –0.2, –0.1, 0, +0.1 or +0.2 respectively (table 5.11). In case the score becomes lower than 0 or higher than 1, the values 0 and 1 are used, respectively.

Table 5.11: Scores of the perception on corruption by the PA manager

Perception of PA management on corruption in their PA	Score change
Corruption in the PA is much higher than in the country	-0.2
Corruption in the PA is slightly higher than in the country	-0.1
Corruption in the PA is equal to that in the country	0.0
Corruption in the PA is slightly lower than in the country	+0.1
Corruption in the PA is much lower than in the country	+0.2

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2.1.6 Biodiversity

Biodiversity strongly depends on the type of ecosystem, e.g. tropical rainforests have much higher species densities than deserts. Therefore, the Biodiversity sub-index is not designed to quantify and evaluate only species diversity, but rather to assess the effort put in by the PA management to monitor and safeguard the (natural or original) biodiversity in their PA. The Biodiversity index Ib is calculated as follows:

$$I_b = \frac{B_1 + (B_2 * k) + B_3 + B_4}{4}$$

where B_x depends on the answers to the following questions:

B_1 Is the biodiversity measured in one way or another? (1 if yes, 0 if no)

B_2 Are historical reference data available? (1 if yes, 0 if no)

B_3 Are there non-native species present? (1 if yes, 0 if no)

B_4 What is the impact of non-native species? (1 if positive, 0 if negative, 0.5 if neutral)

The B_2 term is multiplied by k (0 to 1), which is the average fraction of how many species are present today compared to about 50 years ago (in case the current species diversity is higher than 50 years ago, then k equals 1).

2.1.7 Management Objectives

A list of twelve management objectives (table 5.12) is used to derive the score for the Management Objectives sub-index. For every management objective present in the management plan 1 point can be scored. If there is no management plan, but the day-to-day management of the PA does incorporate one of the management objectives, 0.5 points can be scored for each objective. The final score is the addition of all scores divided by twelve.

Table 5.12: List of management objectives

Management objective
Protection of endangered species
Protection of a nationally significant landscape
Protection of ecosystem services
Protection of cultural sites
Protection of natural resources for sustainable use
Providing food or other products for the markets/Provide benefits to the local and national economy
Maintaining natural processes
Preserve significant natural features
Safeguard the genetic diversity
Provide recreation and tourism services
Provide education, research and environmental monitoring
Provide homes to human communities with traditional cultures and knowledge of nature

5

2.1.8 Edge effect
The boundary of a PA forms the contact zone between protected and unprotected area. The longer the contact zone, the higher the chance that the PA is negatively influenced by the adjacent unprotected area (Woodroffe & Ginsberg, 1998; Ries & Sisk, 2004, Balme et al., 2010). Moreover, the longer the PA border, the more effort must be put in controlling (illegal) in- and outflows. Therefore, the desirable situation is a PA with a PA border length as short as possible. The score of the Edge Effect sub-index is the ratio between the actual PA perimeter and the ideal perimeter (as if the PA had a circular shape):

$$I_{ee} = \frac{P_{ideal}}{P_{PA}} = \frac{2\pi\sqrt{\frac{A_{PA}}{\pi}}}{P_{PA}}$$

Where A_{PA} is the total surface area of the PA (in m2) and PPA is the perimeter of the PA (in m).

2.1.9 Naturalness
Most commonly the rationale behind a PA is to maximise natural aspects and to minimise human impact and anthropogenic structures. Therefore, the Naturalness sub-index of a PA is the fraction of the PA surface area that is occupied with natural structures. This natural area occupation is calculated by subtracting the surface area of all anthropogenic structures, e.g. settlements, agricultural land or aquaculture and traffic roads, from the total PA surface area.

The Naturalness sub-index, I_n , represents the surface area of non-anthropogenic structures as a fraction of the total PA area:

$$I_n = \frac{A_{PA} - A_{antrop}}{A_{PA}}$$

Where A_{PA} is the total surface area of the PA (in m2) and A_{antrop} is the total surface area of the anthropogenic structures inside the border of the PA (in m2).

When considering roads in a PA, not only the road surface itself is considered to be man-made, but also the shoulders. Dirt roads are excluded from the calculation of anthropogenic structures, as being difficult to recognise with GIS in forested areas and considered to be much less disturbing to nature than paved roads.

The surface area of an anthropogenic structure was calculated in ArcMAP version 10.8 (ESRI, 2020) using shapefiles supplied by the PA managers or by manually drawing polygons based on satellite images of the PA. A buffer zone is added on both sides of roads, to account for the shoulders (maintenance of vegetation, signs or milestones, streetlights, etc.). The width of this buffer zone depends on the type of road. Table 5.13 shows the three types of roads distinguished by PLI.

Table 5.13. Division of paved roads into three categories

Road type	Total road width	Number of lanes	Degree of through traffic	Width buffer zone
Primary roads	> 20 m	> 2 lanes	High (high ways)	15 m
Secondary roads	10 - 20 m	2 lanes	Medium	10 m
Tertiary roads	< 10 m	1 lane	Low (local roads)	5 m

For the calculation of the anthropogenic surface area related to roads, all primary roads are regarded as 4 lane roads, assuming a lane width of 4 meters, the anthropogenic surface area covered by primary roads equals the total length of the primary roads (in m) multiplied by 46 m. Same for secondary roads, from which the length is multiplied with 28 m and for tertiary roads the length is multiplied by 14 m (figure 1).

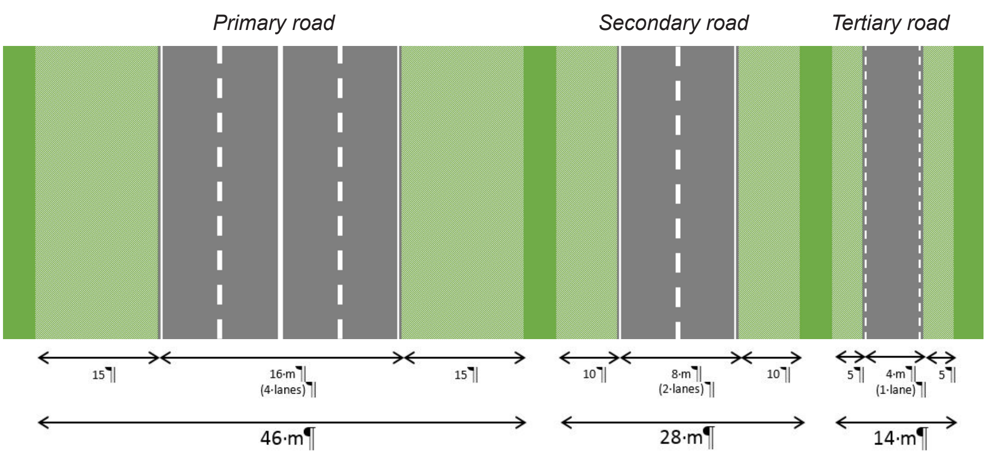

Figure 1. Widths of primary, secondary and tertiary roads together with the widths of their corresponding buffer zones.

2.1.10 Light Pollution
Artificial lights in the night originating from human settlements, can disrupt the natural behaviour of plants and animals and is therefore regarded as a negative impact on the degree of protection in a PA (Aschoff, 1960; Longcore & Rich, 2004, Chepesiuk, 2009, Sanders et al., 2020, Ditmer et al., 2020). The Light Pollution sub-index assesses the artificial light intensities that occur in a PA, using the Zenith sky brightness scale. The online light pollution map as produced by Falchi et al. (2016) has been used. For ease of calculation their scale has been divided into three categories (table 5.14). For the PA the fraction of the total surface area falling into each category is derived from GIS, by manually drawing polygons based on the light pollution map of the PA in ArcMAP, multiplied with the associated score for each category. The Light Pollution sub-index equals the sum of aforementioned three products of surface fraction and scores.

Table 5.14: The three categories of light pollution

Category	Zenith sky brightness scale (magnitude/arcsecond2)	Score
Low	22.0 to 21.7	1.0
Medium	21.7 to 20.6	0.5
High	20.6 to 17.5	0

The Light Pollution sub-index is calculated as follows:

$$I_{lp} = \left(\frac{A_1}{A_{PA}} * 1.0\right) + \left(\frac{A_2}{A_{PA}} * 0.5\right) + \left(\frac{A_3}{A_{PA}} * 0\right)$$

Where A_{PA} is the total surface area of the PA (in m2) and A_1 , A_2 and A_3 are respectively the total surface areas of the PA (in m2) that fall in the low, medium and high light categories (Table 5.14).

2.1.11 Fragmentation
Fragmentation lowers the connectivity in a PA (Bruschi et al., 2015), and has a negative impact on gene flow between populations (Corlatti et al., 2009). The Fragmentation index assesses the degree of fragmentation (i.e. number of fragments) caused by primary and secondary roads (for definitions see table 5.13). Tertiary roads are not considered, because those are narrow enough and with a sufficiently low enough intensity, that they can safely be crossed by animals.
The Fragmentation sub-index is based on (1) the number of fragments, since a highly fragmented PA is more difficult to manage than one with less fragments, and (2) the surface area of the fragments. A PA with one large fragment and a few smaller fragments provides a larger surface area of undisturbed habitat compared to a PA with the same number of fragments, but with equally sized, smaller fragments.

The Fragmentation sub-index is calculated as follows:

$$I_{frag} = \frac{0.5}{f} + 0.5 * \frac{A_{largest\ frag}}{A_{PA}}$$

Where f is the number of fragments, $A_{largest\ frag}$ is the surface area of the largest fragment in the PA (in m^2) and is the total surface area of the PA (in m^2).

2.1.12 Expandability
Generally, the degree of protection increases towards the centre of a PA, because the outer zone of a PA is closer to unprotected areas and subsequently experiences higher distortion from humans (Woodroffe & Ginsberg, 1998; Ries & Sisk, 2004; Balme et al., 2010). Accordingly, a PA manager may always

explore possibilities to expand the PA.
The Expandability sub-index is the potential of a PA to expand its borders. To standardise the possibility of expansion we measure the possibility of expansion by creating an expansion band, which is 20 % of the radius of a circle that has the same surface area as the PA. Parts of the expansion band that are covered by anthropogenic structures are summed and subtracted from the total surface area of the expansion band. This was done in ArcMAP (ESRI, 2020).
The area of this expansion band that falls under different management authorities or are beyond national jurisdiction (for example neighbouring countries) are subtracted from the total area of the expansion band, because they are often included in neighbouring PAs.
The Expandability Index is the ratio of the surface area that remains for expansion relative to the total surface of the expansion band. The desirable situation (giving a maximum score of 1) is a band that is entirely free for PA expansion. The Expandability sub-index, , is calculated as follows:

$$I_{exp} = \frac{A_{exp\,band} - A_{antropogenic\,in\,exp}}{A_{exp\,band}}$$

Where $A_{exp\,band}$ is the total surface area of the expansion band (in m2) and $A_{antropogenic\,in\,exp}$ is the total surface area of the anthropogenic structures that fall within the expansion band (in m^2).

2.2 Calculation of the total Protection Level Index
For calculating the total Protection Level Index all sub – indices area summed and divided by twelve:

$$PLI = \frac{I_i + I_e + I_{cva} + I_f + I_{cr} + I_b + I_{mo} + I_{ee} + I_n + I_{lp} + I_{frag} + I_{exp}}{12}$$

For explanation of the abbreviations, see table 5.1.

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2.3 Graphical representation

To be able to easily compare PLI scores of different PA, or for the same PA in different years, a graphical representation similar to an AMOEBA diagram is used. The colours in the diagram represent the score of the PA for a certain index. Red is a score between 0 and 0.2, orange is a score between 0.2 and 0.4, yellow is a score between 0.4 and 0.6, green is a score between 0.6 and 0.8, and blue is a score between 0.8 and 1.0. Graphs have been plotted in R (2019), using the tidyverse library (Wickham et al., 2019). The R script used can be found in appendix 2.

2.4. Data collection at case-study areas

To test the applicability and practicality of measuring PLI factors in PAs, the PA managers of a number of case-study areas were visited and interviewed (table 5.15, Fig. 5.2).

Table 5.15: Protected Areas that participated in the development of PLI.

Official name	Country	Year of foundation	IUCN Category	Realm
Lake Prespa Monument of Nature	North-Macedonia	1995	III	Lake
Pieniny National Park	Slovak Republic	1967	II	Mountainous/forest

Danube Delta Biosphere Reserve	Romania	1991	II	River delta
Island Network of Protected Areas – La Palma	Spain	1994	I-VI	Island
Curonian Spit National Park	Lithuania	1991	II	Beach/dunes/forest
Bavarian Forest National Park	Germany	1970	II	Mountainous/forest
Kalkalpen National Park	Austria	1997	II	Mountainous/forest

At least 2 interviewers were present during the face-to-face interviews with PA managers, and they raised and explained the questions following a standard interview-protocol (appendix 1). One interviewer was leading the discussion and the second interviewer noted the answers. The answers were used for the above-mentioned calculations in order to compose the PLI.

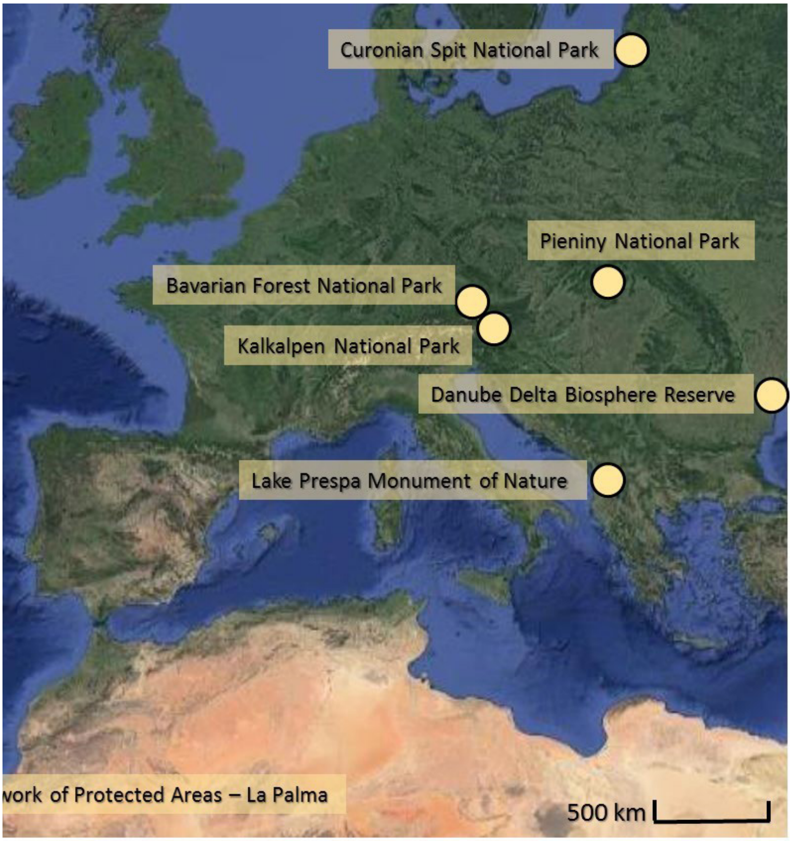
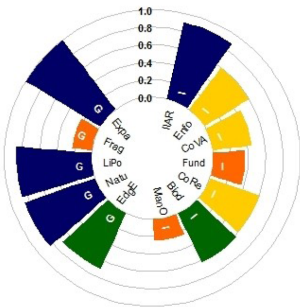


Figure 5.2: Map of the Protected Areas that participated in the development of PLI (based on Google Maps).

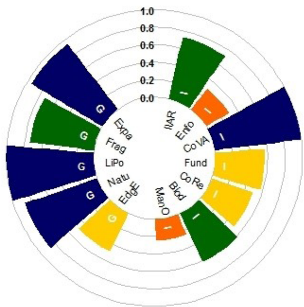
3. Results: case studies

A total of 7 European PAs (Table 5.15 and Figure 5.2) participated in the development of the PLI methodology. The wide range of terrestrial and aquatic environments and different designations that are covered by these 7 PAs enabled the development of the universal character of PLI. A detailed description of the PAs, and GIS maps can be found in appendix 3. Scores of the different indices and final PLI scores are provided in figure 5.3 and table 5.16.

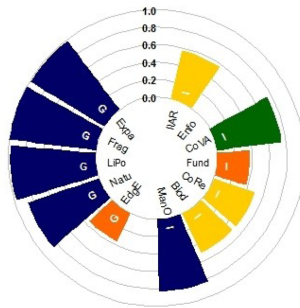
a. Lake Prespa Monument of Nature



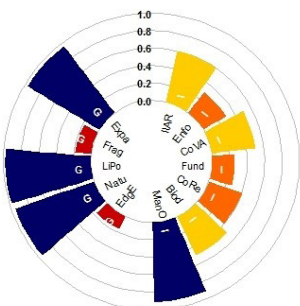
b. Pieniny National Park



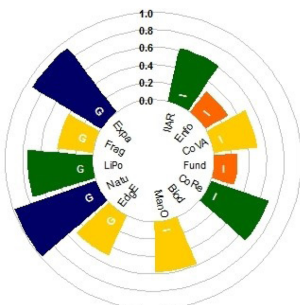
c. Danube Delta Biosphere Reserve



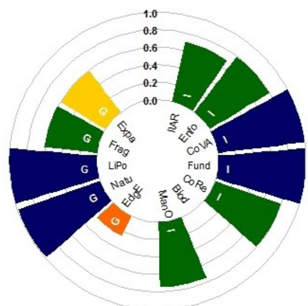
d. La Palma



e. Curonian Spit National Park



f. Bavarian Forest



g. Kalkalpen National Park

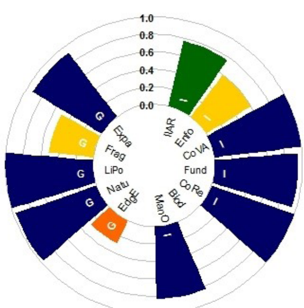


Figure 5.3. PLI scores for the 7 PAs. A score of 0 reflects a poor situation, 1 a desirable situation; “I” indicates a variable derived from the PLI Interview, “G” indicates a GIS derived variable. A red bar corresponds to a value between 0.0 and 0.2, orange between 0.2 and 0.4, yellow between 0.4 and 0.6, green between 0.6 and 0.98, and blue between 0.8 and 1.0. For abbreviations of the PAs see Table 1.

Table 5.16: PLI scores of the different PAs, above the dotted line are the interview derived variables, underneath are the GIS derived variables

	Lake Prespa	Pieniny	Danube Delta	La Palma	Curonian Spit	Bavarian Forest	Kalkal-pen
Illegal Activities	0,90	0,73	0,57	0,60	0,62	0,70	0,76
Enforcement Employees	0,60	0,30	0,00	0,30	0,30	0,80	0,60
Controlled Visitor Access	0,45	1,00	0,75	0,50	0,50	1,00	1,00
Funding	0,37	0,57	0,37	0,26	0,27	1,00	0,95
Corruption Regulations	0,60	0,50	0,50	0,40	0,70	0,80	1,00
Biodiversity	0,63	0,62	0,50	0,49	-	-	-
Management Objectives	0,25	0,25	0,83	0,92	0,58	0,75	0,83
Edge Effects	0,70	0,49	0,36	0,16	0,51	0,26	0,28
Naturalness	0,85	0,88	0,86	0,96	0,98	0,99	0,97
Light Pollution	0,86	1,00	0,98	0,98	0,74	1,00	1,00
Fragmentation	0,23	0,74	1,00	0,18	0,41	0,61	0,51
Expandability	1,00	0,95	0,99	0,96	0,92	0,59	0,92
Average PLI score	0,62	0,67	0,64	0,56	0,59	0,77	0,80

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For some of the PLI sub-indices, such as the Illegal Activities index, the Biodiversity index, the Naturalness index, the Light Pollution index and the Expandability index the PAs show very similar scores (table 16). Whereas the scores for the other PLI sub-indices show a great variability between the 7 PAs. For example, the scores for the Enforcement Employees index range from 0.00 for the Danube Delta to 0.80 for the Bavarian Forest and for the Fragmentation index, scores range from 0.18 for La Palma to 1.00 for the Danube Delta.
Also the data sources give additional variation to the results. The highest sub-indices derived from interviews derived were for Bavarian Forest and Kalkalpen National Park, and the lowest scores were for Lake Prespa Monument of Nature and Pieniny National Park. Whereas the highest sub-indices derived with GIS were obtained for Pieniny National Park and Danube Delta Biosphere Reserve. (Table 16).
Despite the strong variation in the scores of the sub-indices, all 7 PAs have a more moderately differentiating final PLI score. The lowest final PLI score is 0.56 for the Island Network of Protected Areas in La Palma and the highest final PLI score is 0.80 for the Kalkalpen National Park.

A potential relationship between all the sub-indices was determined and tested for significance. Statistical tests were performed on all possible relationships and the significance of the correlation coefficient was calculated adopting the Dunn–Šidák correction for multiple comparisons. Given 12 indices a total of 66 linear relationships were tested with a ‘population-wise’ alpha level of 0.10, whereby each individual null hypothesis is rejected that has a p-value higher than 0.002.
Given 7 PAs, thus with five (5) degrees of freedom, the corresponding correlation coefficient needed to be higher than 0.93 (in a few cases with less pairs of Biodiversity indices the degrees of freedom were two (2) and the correlation coefficient had to be higher than 0.998). Even when tested under a significance level of only $\alpha=0.10$, yet with a Dunn–Šidák correction to counteract problems with multiple comparisons, there were among the 66 comparisons, not any significant (positive or negative) relations to be found.

4. Discussion

Significant efforts have been made by different countries to develop and apply methodologies to assess the PA management effectiveness (Blanco and Gabaldon, 1992; Courrau, 1999; Dudley et al., 1999; Hockings et al., 2000; Cifuentes et al., 2000; Ervin, 2003a; Stolton et al., 2003; Blom et al., 2004; BirdLife International, 2006; Leroux et al., 2010; Mc Arthur et al., 2010). Most of these papers present outlines and reviews on the development and implementation of methods and metrics to be used, often together with a few case-studies.
The methods and metrics concern mainly managerial related factors, in several cases with contextual environmental or socio-economic factors that may pose a threat on the management of the areas. However, the majority of methods are not globally applicable, often do not focus on the effects of protection regulations in the field, and comparisons between PAs may be complicated because of different methodological approaches (Hockings & Phillips, 1999; Pomeroy, 2004; Stoll-Kleemann, 2010).

An overview of the basic methods and metrics used in many of the PA management effectiveness approaches can be found in the reviews by Pomeroy et al (2004) and Leverington et al. (2008, 2010). Though focussing on marine PAs, Pomeroy et al. (2004) present in their guidebook an extensive overview of possible environmental, socio-economic, and managerial metrics to evaluate PA management effectiveness. F
or a pity, they do not present a concise index, and so leave the end-user still to make own choices, whereby consequently not any PA will be comparable to another because of those individual choices.

In contrast to the multidisciplinary approach of Pomeroy et al (2004), most recent manuscripts on PA protection and management effectiveness focus on a restricted disciplinary approach, and refrain from using a combination of environmental, socio-economic as well as managerial aspects.
Such restricted sets of metrics focus often on environmental or ecological aspects, such as, for example, the protection of selected species, specific habitats, or ecosystems (Mikoláš et al., 2017; Brown et al., 2019; Riggio et al., 2019; Cazalis et al., 2020; Terraube et al., 2020), trends and spatial patterns of biodiversity (Hofmann et al., 2017; Brown et al., 2019; Riggio et al., 2019), or habitat status (Friedrichs et al., 2018).
Other metrics relate more to socio-economic aspects such as the scale and extent of threats as e.g. deforestation (Eklund et al., 2019; Negret et al., 2020; Wolf et al., 2021), obtaining positive social impact or local support (Bennett et al., 2019; Jones et al., 2020), and behavioural changes of people (Cazalis & Prévot, 2019). Or key parameters are managerial issues such as management inputs or good governance and their impact on a PA (Eklund et al., 2019; Armitage et al., 2020).
Moreover, these recent focused studies lean in most cases strongly on the analysis of existing databases and do not include on-site field research nor involve the view of PA practitioners. An exception being the studies focussing on socio-economic aspects by Bennett et al (2019) and Jones et al (2020), who include the views of fishermen and inhabitants, respectively, in and around the PAs.

At present, several dozen methodologies (over ninety according Stoll-Kleemann, 2010) are used at the national or global level to evaluate the effectiveness of management, of which the two most widely used management effectiveness methodologies are RAPPAM and METT (Stoll-Kleemann, 2010; Worboys et al., 2015; Coad et al 2015). Both these methods are mainly based on the assessment of management performance, for which the basic information is usually assembled through scorecards and workshops in one to three days, though a follow-up by assessment-agency workers may be needed in case outcomes of factors have to be evaluated (Hockings et al 2000; Coad et al. 2015).
Assessments including also environmental and socio-economic information, such as the Enhancing Our Heritage (EoH) methodology of UNESCO, require considerably more resources and may take up to a few months (Stoll-Kleemann, 2010; Coad et al 2015).

The Rapid Assessment and Prioritisation of Protected Area Management methodology (RAPPAM) is by far the most commonly applied PA management effectiveness methodology (Ervin, 2003a; Stoll-Kleemann, 2010; Worboys et al., 2015; Coad et al 2015). Like PLI, the collection of data occurs via a questionnaire.
The RAPPAM questionnaire is filled out during one or more participatory workshops with PA managers, administrators and stakeholders (Ervin, 2003b). RAPPAM encourages the incorporation of preliminary

assessments and existing data such as aerial photos, satellite imagery, biodiversity reviews, anthropological and sociological studies, threat analyses and/or legal and policy reviews (Ervin, 2003b). However, this is a rather time-consuming effort, and moreover, the assessment of PAs using RAPPAM may likely be biased due to differences in the availability of such preliminary data.
PLI does not require lengthy workshops and is not discriminatory towards the presence or absence of preliminary assessments and/or existing datasets. The PLI questionnaire takes up a maximum of 2 hours and the spatial analysis in GIS takes about 4 to 6 hours depending on the quality and resolution of the shapefiles.
This makes PLI a relatively fast and cost-efficient method that does not require lots of time and resources from PA management, and can thus be easily repeated every year to assess whether their management (eventually focused on specific sub-indices) has been efficient and subsequently the protection level of the PA has been enhanced.

The Management Effectiveness Tracking Tool (METT) developed by the World Bank/WWF Alliance is the second most used PA effectiveness measure at present. The METT questionnaire consists of multiple-choice questions for which the answers correspond to scores ranging from 0 to 3. Like PLI, the METT questionnaire contains questions regarding the perception of the PA managers on aspects such as the adequacy of the number of staff and the amount of funding.
In the METT methodology all questions are equally weighted and managers are allowed to exclude questions of which they believe are irrelevant for their PA. The final METT score is calculated as a percentage of the scores from those questions that were relevant to a particular PA. The developers of METT noted that this approach leads to limitations in terms of allowing comparisons between different PAs (Stolton et al., 2003).
While PLI mimics the METT-approach of using equal weights for different factors, PLI does not allow for the exclusion of any of the given factors by the PA management. In this way, each PA is assessed on the exact same set of sub-indices, making PLI more globally applicable and comparable between various PAs than METT.

Therefore, in this study we have developed a new index, the Protection Level Index (PLI), which evaluates the actual level of protection in the PA by assessing managerial, socio-economic as well as environmental factors, allows for an easy comparison between PAs, and the assessment can be carried out together with the PA management within 1 day.

One of the innovative aspects of PLI is that it has a different way of dealing with the issue of defining standard optimal conditions. In PLI the acceptable range of variation for some of the indices are not predefined but instead determined by the perception of the PA manager. In this way, the PA manager can place the conditions in context and has the possibility to assess if these conditions are optimal. The reason for this approach is that each PA is different and the optimal conditions may vary from PA to PA. Due to its nature, PLI can be used to estimate the level of protection, and keep track of temporal changes in protection level.

The lack of any relation between the sub-indices emphasises that none of the PLI sub-indices can be explained by the scores of other sub-indices. This indicates that each individual sub-index forms an equal-weighted part of PLI without being influenced by any other sub-index.
This underlines the need that the final PLI score should always be accompanied by the individual scores for the sub-indices to aid the PA management in deciding on the most efficient procedures to increase the quality and protection of their PA.

Finally, the sub-indices of PLI were developed in such a way that they are applicable to terrestrial and aquatic PAs. To this end, we have identified aquatic equivalents of terrestrial components in PLI, e.g. aquaculture for agriculture and shipping lanes for traffic roads. Our analyses show that PLI turns out to be a rather neutral unbiased measure with regard to the evaluation of PAs from various terrestrial and aquatic realms. Nevertheless, we also recognise that some PLI sub-indices may not be as suitable for especially full marine PAs as they are for other aquatic (e.g. coastal) and for terrestrial PAs, and future efforts are recommended in order to improve the applicability of PLI to such very specific PAs.

Nevertheless, in comparison to most other above mentioned PA management effectiveness methods, PLI combines a multi-disciplinary character of its indicators, with a relatively fast, and thereby cost-effective, procedure, established in cooperation with the PA management that can indicate the present and in-situ condition of the PA.

5. Conclusion

The Protection Level Index (PLI) is a new Protected Area (PA) effectiveness measure that allows for a relatively simple assessment of the degree of protection in any type of PA in the world. It could complement the IUCN categorising system, in that the IUCN Category assesses the management strategy (on paper) and PLI assesses the actual effects of this management strategy in the field. This makes PLI capable of exposing so called "paper parks". The final PLI score of a PA ranges from 0 (undesirable) to 1 (desirable) and is the average score of 12 equally weighted indices. These indices are a selection of globally recognised indicators of PA management effectiveness.
PLI is faster than RAPPAM (WWF) and more widely applicable than METT (World Bank/WWF Alliance). It also introduces a new way of incorporating the perception of the PA managers in the scoring and thereby delivers a work around for the issue of pre-defining universal optimal conditions, which is not always possible, or for which costly research is needed to construct baselines. Concluding, PLI is a useful tool for PA managers as it offers a practical, and cost-effective assessment of the effects of the current management strategy for any type of PA worldwide. Due to its uncomplicated, non-time-consuming nature, PLI could be carried out on a yearly basis to assess the status of a PA.

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References

5

Adams, J. S., McShane, T. O. (1996). The Myth of Wild Africa: Conservation Without Illusion, University of California Press, Berkeley, CA, USA.

Armitage, D., Mbatha, P., Muhl, E.-K., Rice, W., Sowman, M. 2020. Governance principles for community-centered conservation in the post-2020 global biodiversity framework. Conservation Science and Practice, 2:e160. https://doi.org/10.1111/csp2.160.

Aschoff, J. (1960). Exogenous and endogenous components in circadian rhythms. In Cold Spring Harbor symposia on quantitative biology (Vol. 25, pp. 11-28).

Balme, G. A., Slotow, R. O. B., Hunter, L. T. (2010). Edge effects and the impact of non□protected areas in carnivore conservation: leopards in the Phinda–Mkhuze Complex, South Africa. Animal conservation, 13(3), 315-323.

Bennett, N. J., Di Franco, A., Calò, A., Nethery, E., Niccolini, F., Milazzo, M., Guidetti, P. (2019). Local support for conservation is associated with perceptions of good governance, social impacts, and ecological effectiveness. Conservation letters, 12(4), e12640.

BirdLife International (2006). Monitoring Important Bird Areas: a global framework, Version1.2. BirdLife International, Cambridge, UK.

Bishop, K. (2004). Speaking a Common Language: The Uses and Performance of the IUCN System of Management Categories for Protected Areas. IUCN, Cardiff University, Cardiff, UK

Blanco, R., Gabaldon, M. (1992). The evaluation of natural protected area systems: A numeric method. Parks, 3(1), 11-13.

Blom, A., Yamindou, J., Prins, H. H. (2004). Status of the protected areas of the Central African Republic. Biological Conservation, 118(4), 479-487.

Bonham, C. A., Sacayon, E., Tzi, E. (2008). Protecting imperiled "paper parks": potential lessons from the Sierra Chinajá, Guatemala. Biodiversity and Conservation, 17(7), 1581-1593.

Bovarnick, A., Fernandez-Baca, J., Galindo, J., Negret, H. (2010). Financial sustainability of protected areas in Latin America and the Caribbean: investment policy guidance.

Brandon, K., Redford, K. H., Sanderson, S. (Eds.). (1998). Parks in peril: people, politics, and protected areas. The Nature Conservancy, Island Press, Washington and California, USA.

Brooks, T. M., Da Fonseca, G. A., Rodrigues, A. S. (2004). Protected areas and species. Conserv. Biol. 616–618.

Brown, J. A., Lockwood, J. L., Avery, J. D., Burkhalter, J. C., Aagaard, K., Fenn, K. H. (2019). Evaluating the long-term effectiveness of terrestrial protected areas: a 40-year look at forest bird diversity. Biodiversity and Conservation 28: 811-826.

Bruschi, D., Garcia, D. A., Gugliermetti, F., Cumo, F. (2015). Characterising the fragmentation level of Italian's National Parks due to transportation infrastructures. Transportation Research Part D: Transport and Environment, 36, 18-28.

Butchart, S. H., Baillie, J. E., Chenery, A. M., Collen, B., Gregory, R. D., Revenga, C., Walpole,M. (2010). National Indicators Show Biodiversity Progress—Response. Science 329 (5994), 900–901.

Campos, M. T., Nepstad, D. C. (2006). Smallholders, the Amazon's new conservationists.
Conservation Biology 20 (5), 1553–1556.
Cardelús, C. L., Scull, P., Hair, J., Baimas-George, M., Lowman, M. D., Eshete, A. W. (2013). A preliminary assessment of Ethiopian sacred grove status at the landscape and ecosystem scales. Diversity 5 (2), 320–334.

Cazalis, V., Prévot, A. C. (2019). Are protected areas effective in conserving human connection with nature and enhancing pro-environmental behaviours?. Biological Conservation, 236, 548-555.

Cazalis, V., Princé, K., Mihoub, J.-B., Kelly, J., Butchart, S. H. M., Rodrigues, A. S. L. (2020). Effectiveness of protected areas in conserving tropical forest birds. Nature Communications 11, 4461, https://doi.org/10.1038/s41467-020-18230-0

CBD (1992). Convention on Biological Diversity. United Nations, Rio de Janeiro, Brazil (5 June 1992). https://www.cbd.int/doc/legal/cbd-en.pdf. Downloaded: 12 March 2021

Chape, S., Harrison, J., Spalding, M., Lysenko, I. (2005). Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philos. Trans. R. Soc. B 360 (1454), 443–455.

Chepesiuk, R. (2009). Missing the dark: health effects of light pollution. Environmental Health Perspectives, 117(1), 20-27.

Cifuentes, M., Izurieta, A., De Faría, H. (2000). Measuring protected area management effectiveness. Technical Series/WWF, nº2, WWF Centroamérica, GTZ, IUCN, Turrialba, Costa Rica.

Coad, L., Campbell, A., Miles, L., Humphries, K. (2008). The Costs and Benefits of Protected Areas for Local Livelihoods: A Review of the Current Literature. UNEP World Conservation Monitoring Centre, Cambridge, UK.

Coad, L., Leverington, F., Knights, K., Geldmann, J., Eassom, A., Kapos, V., Kingston, N., De Lima, M., Zamora, C., Cuardros, I., Nolte, C., Burgess, N. D., Hockings, M., (2015). Measuring impact of protected area management interventions: current and future use of the Global Database of Protected Area Management Effectiveness. Phil. Trans. R. Soc. B 370: 20140281. http://dx.doi.org/10.1098/rstb.2014.0281

Corlatti, L., Hacklaender, K., Frey□Roos, F. R. E. D. Y. (2009). Ability of wildlife overpasses to provide connectivity and prevent genetic isolation. Conservation Biology, 23(3), 548-556.

Courrau, J. (1999). Monitoring protected area management in Central America: a regional approach. Parks, 9(2), 56-60.

Ditmer, M. A., Stoner, D. C., Francis, C. D., Barber, J. R., Forester, J. D., Choate, D. M., Ironside, K. E., Longshore, K. M., Hersey, K. R., Larsen, R. T., McMillan, B. R., Olson, D. D., Andreasen, A. M., Beckmann, J. P., Holton, P. B., Messmer, T.A., Carter, N. H. (2020). Artificial nightlight alters the predator–prey dynamics of an apex carnivore. Ecography.

Draper, M., Spierenburg, M., Wels, H. (2004). African dreams of cohesion: elite pacting and
community development in transfrontier conservation areas in southern Africa. Cult.
Organ. 10 (4), 341–353.

Dudley, N., Hockings, M., Stolton, S. (1999). Measuring the effectiveness of protected area management. In: Stolton, S., Dudley, N. (Eds.). Partnerships for protection: New strategies for planning and management for protected areas. IUCN, Earthscan Publications Ltd., London, UK. pp. 249-257.

Dudley, N. (Ed.). 2008. Guidelines for Applying Protected Area Management Categories. IUCN, Gland, Switzerland.

Dudley, N., Shadie, P., Stolton, S. (2013). Guidelines for applying protected area management categories including IUCN WCPA best practice guidance on Recognising Protected Areas and Assigning Management Categories and Governance Types. Best Practice Protected Area Guidelines Series, (21).

Eklund, J., Coad, L., Geldmann, J., Cabeza, M. (2019). What constitutes a useful measure of protected area effectiveness? A case study of management inputs and protected area impacts in Madagascar. Conservation Science and Practice, 1(10), e107.

Ervin, J. (2003a). Rapid assessment of protected area management effectiveness in four countries. Bioscience, 53(9), 833-841.

Ervin, J. (2003b). WWF: Rapid Assessment and Prioritization of Protected Areas Management (RAPPAM) methodology. WWF, Gland, Switzerland.

ESRI (2020). ArcGIS Desktop: Release 10.8. Environmental Systems Research Institute, Redlands, CA, USA.

Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C. C. M., Elvidge, C. D., Baugh, K., Portnov, B. A., Rybnikova, N. A., Furgoni, R. (2016). The new world atlas of artificial night sky brightness. Science advances, 2(6), e1600377.

Friedrichs, M., Hermoso, V., Bremerich, V., Langhans, S. D. (2018). Evaluation of habitat protection under the European Natura 2000 conservation network – The example for Germany. PLoS ONE 13(12): e0208264.

Geldmann, J., Manica, A., Burgess, N. D., Coad, L., Balmford, A. (2019). A global-level assessment of the effectiveness of protected areas at resisting anthropogenic pressures. Proceedings of the National Academy of Sciences, 116(46), 23209-23215.

Henson, D. W., Malpas, R. C., D'Udine, F. A. C. (2016). Wildlife law enforcement in Sub-Saharan African protected areas–a review of best practices. Occasional Paper of the IUCN Species Survival Commission, No. 58IUCN, Cambridge, UK and Gland, Switzerland.

Hockings, M., Phillips, A. (1999). How well are we doing?- some thoughts on the effectiveness of protected areas. Parks, 9(2), 5-14. , Gland, Switzerland and Cambridge, UK.

Hockings, M., Stolton, S., Dudley, N. (2000). Evaluating effectiveness: a framework for assessing the management of protected areas. Best Practice Protected Area Guidelines Series No. 6, IUCN.

Hoffmann, S., Beierkuhnlein, C., Field, R., Provenzale, A., Chiarucci, A. (2017). Uniqueness of Protected Areas for Conservation Strategies in the European Union. Scientific Reports, 8 (1), 6445, https://doi.org/10.1038/s41598-018-24390-3

Holdgate, M. (2014). The green web: a union for world conservation. Routledge.

Hummel, C., Poursanidis, D., Orenstein, D., Elliott, M., Adamescu, M. C., Cazacu, C., Ziv, G., Chrysoulakis, N,, Van der Meer, J., Hummel, H. (2019). Protected Area management: Fusion and confusion with the ecosystem services approach. Science of The Total Environment, 651, 2432-2443. https://doi.org/10.1016/j.scitotenv.2018.10.033.

Hummel, H,, Bienfait, L., Kalle, V., Boyer, Y., De Wit, R., Hummel, C. A. (2018). Essential Environmental and Socio-economic Variables for Future and Current Protected Areas, EcoPotential Deliverable 9.1. https://doi.org/10.5281/zenodo.1404042.

Jones, N., Malesios, C., Kantartzis, A., Dimitrakopoulos, P. G. (2020). The role of location and social impacts of protected areas on subjective wellbeing. Environmental Research Letters 15: 114030.

Leroux, S. J., Krawchuk, M. A., Schmiegelow, F., Cumming, S. G., Lisgo, K., Anderson, L. G., Petkova, M. (2010). Global protected areas and IUCN designations: Do the categories match the conditions? Biological Conservation 143 (3): 609-616.

Leverington, F., Costa K. L., Pavese, H., Lisle, A., Hockings, M. (2010). A global analysis of protected area management effectiveness. Environmental Management. DOI 10.1007/s00267-010-9564-5.

Leverington, F., Hockings, M., Costa, K. L. (2008). Management effectiveness evaluation in protected areas: Report for the project 'Global study into management effectiveness evaluation of protected areas', The University of Queensland, Gatton, IUCN WCPA, TNC, WWF, Australia, 74 pp.

Lindsey, P. A., Romanach, S. S., Tambling, C. J., Chartier, K., Groom, R. (2011). Ecological and financial impacts of illegal bushmeat trade in Zimbabwe. Oryx, 45(1), 96-111.

Liu, J., Linderman, M., Ouyang, Z., An, L., Yang, J., Zhang, H. (2001). Ecological degradation in protected areas: the case of Wolong nature reserve for giant pandas. Science 292
(5514), 98–101.

Longcore, T., Rich, C. (2004). Ecological light pollution. Frontiers in Ecology and the Environment, 2(4), 191- 198.

Manning, R. E. (2014). Research to guide management of outdoor recreation and tourism in parks and protected areas. Koedoe [online] 2014, 56, 2: 1-7.

Marion, J. L., Reid, S. E. (2007). Minimising visitor impacts to protected areas: The efficacy of low impact education programmes. Journal of sustainable tourism, 15(1), 5-27.

McArthur, M. A., Brooke B. P., Przeslawski R., Ryan D. A., Lucieer V. L., Nichol S. L., McCallum A. W., Mellin C, Cresswell I. D., Radke, L. (2010) .On the use of abiotic surrogates to describe marine benthic biodiversity. Estuarine, Coastal and Shelf Science, 88.1: 21-32.

McNeill, J. R., 2007. The Mediterranean: An Environmental History. Environmental History, 12(1), 160-162.

Mikoláš, M., Tejkal, M., Kuemmerle, T., Griffiths, P., Svoboda, M., Hlásny, T., Leitão, P., Morrissey, R.,(2017). Forest management impacts on capercaillie (Tetrao urogallus) habitat distribution and connectivity in the Carpathians. Landscape Ecology 32: 163-179.

Negret, P. J., Maron, M., Fuller, R. A., Possingham, H. P., Watson, J. E. M., Simmonds, J. S. (2020). Deforestation and bird habitat loss in Colombia. Biological Conservation, 257, https://doi.org/10.1016/j.biocon.2021.109044

Parolo, G., Ferrarini, A., Rossi, G. (2009). Optimisation of tourism impacts within protected areas by means of genetic algorithms. Ecological Modelling, 220(8), 1138-1147.

Parrish, J. D., Braun, D. P., Unnasch, R. S., 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. Bioscience 53 (9), 851–860.

Phillips, A., 2007. A short history of the international system of protected area management categories. WCPA Task Force on Protected Area Categories.

Pomeroy, R. S., Parks, J. E., Watson, L. M. (2004). How is your MPA doing?: a guidebook of natural and social indicators for evaluating marine protected area management effectiveness. IUCN, Gland, Switzerland and Cambridge, UK.

ProtectedPlanet (2017). Increased growth of Protected Areas in 2017. https://protectedplanet.net/c/increased-growth-of-protectedare-as-in-2017. Downloaded: 12 March 2021.

R (2019) R version 3.6.0 (2019-04-26) -- "Planting of a Tree", The R Foundation for Statistical Computing, Platform: x86_64-w64-mingw32/x64 (64-bit)

Rangajaran, M., 2005. India's Wildlife History: An Introduction. Orient Blackswan (135pp).

Rich, S., 2013. Ship Timber as Symbol? Dendro-Provenancing and Contextualizing Ancient Cedar Ship Remains from the Eastern Mediterranean/near East. Unpublished Ph. D. dissertation. KU Leuven, Leuven.

Ries, L., Sisk, T. D. (2004). A predictive model of edge effects. Ecology, 85(11), 2917-2926.

Riggio, J., Jacobson, A. P., Hijmans, R. J., Caro, T. (2019). How effective are the protected areas of East Africa?. Global ecology and conservation, 17, e00573.

Rodrigues, A. S., Andelman, S. J., Bakarr, M. I., Boitani, L., Brooks, T. M., Cowling, R. M., Fishpool, L. D. C., Da Fonseca, G. A. B., Gaston, K. J., Hoffmann, M., Long, J.S., Marquet, P. A., Pilgrim, J. D., Pressey, R. L., Schipper, J., Sechrest, W., Stuart, S. N., Underhill, L. G., Waller, R. W., Watts, M. E. J., Yan X. (2004). Effectiveness of the global protected area network in representing species diversity. Nature 428 (6983), 640–643.

Sanders, D., Frago, E., Kehoe, R., Patterson, C., Gaston, K. J. (2021). A meta-analysis of biological impacts of artificial light at night. Nature Ecology & Evolution, 5(1), 74-81.

Scull, P., Cardelús, C. L., Klepeis, P., Woods, C. L., Frankl, A., Nyssen, J. (2017). The resilience of Ethiopian church forests: interpreting aerial photographs, 1938–2015. Land Degradation & Development, 28(2), 450-458.

Schulze, K., Knights, K., Coad, L., Geldmann, J., Leverington, F., Eassom, A., Marr, M., Butchart, S. H. M., Hockings, M., Burgess, N. D. (2018). An assessment of threats to terrestrial protected areas. Conservation Letters, 11(3), e12435.

Stoll-Kleemann, S. (2010). Evaluation of management effectiveness in protected areas: Methodologies and results. Basic and Applied Ecology, 11(5), 377-382.

Stolton, S., Hockings, M., Dudley, N., MacKinnon, K., Whitten, T. (2003). Reporting Progress in Protected Areas. A Site-Level Management Effectiveness Tracking Tool. World Bank/WWF Alliance for Forest Conservation and Sustainable Use.

Svobodova K., Monteiro, L., Vojar, J., Gdulova, K. (2019). Can trail characteristics influence visitor numbers in natural protected areas? A quantitative approach to trail choice assessment. Environmental & Socio-economic Studies, 7(2): 10-20

Terraube, J., Helle, P., Cabeza, M. (2020). Assessing the effectiveness of a national protected area network for carnivore conservation. Nature Communications, 11(1), 1-9.

Vreugdenhil, D. (2003). Protected areas system planning and monitoring. Wageningen Universiteit.

Wickham, H., Averick, M., Bryan, J., Chang, W., D'Agostino McGowan, L., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S. M., Müller, K., Ooms, J., Robinson, D., Paige, D., Spinu, V., Takahashi, K., Vaughan, D., Wilke, C., Woo, K., Yutani, H. (2019). Welcome to the tidyverse. Journal of Open Source Software, 4(43), 1686, https://doi.org/10.21105/joss.01686

Wild, R., McLeod, C. (2008). Sacred Natural Sites: Guidelines for Protected Area Managers. IUCN, Gland, Switzerland, p. 106.

Wolf, C., Levi, T., Ripple, W. J., Zárrate-Charry, D. A., Betts, M. G. (2021). A forest loss report card for the world's protected areas. Nature Ecology & Evolution, 5, 520-529. https://www.nature.com/articles/s41559-021-01389-0

Woodroffe, R., Ginsberg, J. R. (1998). Edge effects and the extinction of populations inside protected areas. Science, 280(5372), 2126-2128.

Worboys, G. L., Lockwood, M., Kothari, A., Feary, S., Pulsford, I. (Eds.). (2015). Protected area governance and management. Anu Press.

Appendix 1: The PLI questionnaire (questions 9 to 14 were abstracted from Remote Sensing images)

Developing the Protection Level Index (PLI)

Protection Level Index

5

Survey

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Part of the EcoPotential Project
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Privacy Statements

In this survey you are requested to provide some personal information (name, email, telephone, address details, affiliation) to EcoPotential.

EcoPotential and its partners respect the privacy of all the participants to the survey.

EcoPotential and its partners ensure that all personal information:

…shall never be provided to third parties without your explicit unambiguous consent.

…shall be excluded in case you did not agree on sharing that information.

To this end, we ask you, in advance of the survey, to declare your preferences regarding the handling of the personal information.

5

Participant 1 - Privacy statements - data availability

Name: ………………………………………………………………………………

E-mail address: ………………………………………………………………………………

	Accessible for EcoPotential partners		**Accessible for third parties**	
Personal information	☐ yes*	☐ no**	☐ yes*	☐ no**
General information	☐ yes***	☐ no****	☐ yes***	☐ no****

Signature:

5

* You authorise the use of your name in any future publications in which the results of this survey are used

** You do not authorise the use of your name in any future publications in which the results of this survey are used (you stay anonymous)

*** You authorise the use of your answers to this survey

**** You do not authorise the use of your answers to this survey

Name: ………………………………………………………………………………

E-mail address: ………………………………………………………………………………

	Accessible for EcoPotential partners		**Accessible for third parties**	
Personal information	☐ yes*	☐ no**	☐ yes*	☐ no**
General information	☐ yes***	☐ no****	☐ yes***	☐ no****

5

Signature:

* You authorise the use of your name in any future publications in which the results of this survey are used

** You do not authorise the use of your name in any future publications in which the results of this survey are used (you stay anonymous)

*** You authorise the use of your answers to this survey

**** You do not authorise the use of your answers to this survey

Name: ....

E-mail address: ....

	Accessible for EcoPotential partners		**Accessible for third parties**	
Personal information	☐ yes*	☐ no**	☐ yes*	☐ no**
General information	☐ yes***	☐ no****	☐ yes***	☐ no****

Signature:

5

* You authorise the use of your name in any future publications in which the results of this survey are used

** You do not authorise the use of your name in any future publications in which the results of this survey are used (you stay anonymous)

*** You authorise the use of your answers to this survey

**** You do not authorise the use of your answers to this survey

Disclaimer

The content of this survey has been compiled with the utmost care in the frame of the EcoPotential project.

Responsible partners for this survey are Yvette Agnes Maria Mellink (BSc), Christiaan Hummel (MSc) and Prof. Dr. Herman Hummel of the Royal Netherlands Institute for Sea Research (NIOZ), Yerseke, the Netherlands.

Although EcoPotential and the responsible partners aim to keep the information of the survey in its repositories permanently as accurate and up-to-date as possible, changes to the information are always reserved.

EcoPotential and its partners are in no way responsible and shall not be liable for any claims or damages that are the direct or indirect consequence of, or in connection with, the use of the information available in this survey.

Copyrights

5

1. General Information of the Protected Area

A. Official name

What is the official name for the Protected Area in question?

B. Location

In which country/countries is the Protected Area located?

C. Year of foundation

In which year was the Protected Area established? (in case of multiple foundation years, signify the oldest year)

D. IUCN Category

If applicable, what IUCN Category has been assigned to the Protected Area?

E. Surface area

What is the total surface area of the Protected Area?

……………………………………………………………………………………… hectares

G. Circumference of the Protected Area

What is the circumference of the Protected Area following the outline of the border?

………………………………………… *indicate unit!*

F. Shapefiles, satellite imagery and GIS-data

Can you provide us with a *shapefile* of the Protected Area?

☐ Yes

☐ No

Can you provide us with *satellite imagery* of the Protected Area?

☐ Yes

5

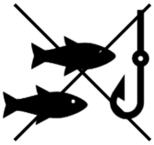
☐ No

Can you provide us with *GIS-data maps* of the Protected Area?

☐ Yes

☐ No

2. Illegal Activity Mitigation Index



GAME #1

A. Presence of illegal activities

Indicate for each activity listed below, whether this activity is illegal or not in the Protected Area (PA).

In case an activity is illegal, indicate to which extent this activity takes place in the Protected Area

1. This illegal activity takes place to a negligible extend
2. This illegal activity takes place to a small extend
3. This illegal activity takes place to a moderate extend
4. This illegal activity takes place to a large extend
5. This illegal activity takes place to a very large extend

	Not considered an illegal activity	Does not take place in the PA	1	2	3	4	5
Agriculture/Aquaculture	☐	☐	☐	☐	☐	☐	☐
Commercial extraction of wild biological resources	☐	☐	☐	☐	☐	☐	☐
Non-commercial extraction of biological resources	☐	☐	☐	☐	☐	☐	☐
Building infrastructure	☐	☐	☐	☐	☐	☐	☐
Recreation	☐	☐	☐	☐	☐	☐	☐
Poaching	☐	☐	☐	☐	☐	☐	☐
Extraction of non-renewable natural resources	☐	☐	☐	☐	☐	☐	☐
Drone flights	☐	☐	☐	☐	☐	☐	☐
Motorised access	☐	☐	☐	☐	☐	☐	☐
Littering	☐	☐	☐	☐	☐	☐	☐
Vandalism	☐	☐	☐	☐	☐	☐	☐

3. Enforcement Index

A. Number of enforcement employees

How many enforcement employees[1] are currently working/present in your PA?

………

B. Sufficiency of enforcement employees

Indicate to which degree the number of enforcement employees currently at your service, is sufficient in order to ensure well-functioning of the PA

- ☐ The number of enforcement employees is way too low in order to ensure well-functioning of the PA
- ☐ The number of enforcement employees is slightly too low in order to ensure well-functioning of the PA
- ☐ The number of enforcement employees is adequate
- ☐ The number of enforcement employees is slightly too high in order to ensure well-functioning of the PA
- ☐ The number of enforcement employees is way more than needed in order to ensure well-functioning of the PA

[1] Person that is authorised to arrest and/or enforce a penalty on an offender of the rules of the PA

4. Visitor Index

A. Number of visitors

How many visitors visit the Protected Area in one year on average?

……

B. Entrance ticket price

What is the entrance ticket price?

- ☐ Free entrance
- ☐ Ticket prices:

  ……………………………………………………………………………

  ……………………………………………………………………………

  ……………………………………………………………………………

  ……………………………………………………………………………

5. Controlled Visitor Behaviour Index

A. Visitor accessibility

Can visitors enter (and exit) the Protected Area at any location along the border?

- ☐ No, the Protected Area is fully fenced (or de facto protected due to geographical circumstances) and can only be accessed via a limited number of entrances
- ☐ Yes, the PA has no fence and can be accessed everywhere
- ☐ Yes, the PA has no fence, but we concentrate visitors by using designated entrances (e.g. parking lots, public transport connections, visitor centres, harbours)

B. Paths

Are there any paths / shipping-lanes present in the Protected Area?

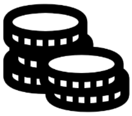
- ☐ No, visitors are allowed to distribute randomly over the area
- ☐ Yes, visitors are expected to stay on these paths / shipping-lanes

C. Indicated routes

What percentage of the paths / shipping-lanes is part of specified routes indicated with directional signs?

…………%

7. Funding Index



A. Gross National Income per capita

What is the Gross National Income (GNI) of the country in which the Protected Area is located?

…………………………………… *indicate currency!*

B. Available funding

How much funding does the Protected Area receive?

…………………………………… per year *indicate currency!*

C. Funding perception

Is the funding that you receive sufficient in order to execute proper management that results in a well-functioning Protected Area?

- ☐ Absolutely insufficient, critical lack of funding
- ☐ Partly insufficient, the PA management can go on but there is still a big lack of funding
- ☐ Sufficient, all management actions can be executed
- ☐ More than sufficient, enough funding for proper management and some additional actions
- ☐ Superfluous, more than enough funding for management and many additional actions

8. Corruption Index

A. Corruption Perception Index (CPI)

What is the most recent Corruption Perception Index published by the Transparency International organisation for the country in which the Protected Area is located?

………………

B. Corruption in reality

Does the CPI give a good representation of the level of corruption in reality?

☐	No,	the level of corruption is	much higher than	indicated by the CPI
☐	No,	the level of corruption is	slightly higher than	indicated by the CPI
☐	Yes,	the level of corruption is	correctly	indicated by the CPI
☐	No,	the level of corruption is	slightly less than	indicated by the CPI
☐	No,	the level of corruption is	much less than	indicated by the CPI

9. Biodiversity Index

A. Measuring biodiversity

Do you measure the biodiversity in the Protected Area?

- ☐ Yes
- ☐ No

If yes, how?

B. Groups/Classes

Which classes of species do you use for measuring biodiversity in the Protected Area?

C. Reference situation

Do you have a historical reference for the biodiversity in the Protected Area?

☐ Yes

☐ No → please continue at subsection D

If yes, for what species do you have historical biodiversity data?

………

………

………

Please estimate what percentage of the historical biodiversity (reference) situation is currently present in the Protected Area?

……………………………… %

……………………………… %

……………………………… %

……………………………… %

5

D. Exotic species

Are there any exotic species in the Protected Area?

☐ Yes

☐ No

If yes, do the exotic species, in your opinion, have an overall positive or negative impact on the ecosystems in the Protected Area?

☐ Positive

☐ Negative

10. Edge Effect Index

We will use the actual circumference of the Protected Area and the ideal circumference (a perfect circular Protected Area) in order to determine the edge effect index.

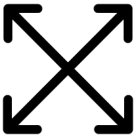
11. Naturalness Index

A. Up to date data?

Is the map of the Protected Area up to date regarding infrastructure and human settlements (e.g. villages & cities)?

- ☐ Yes
- ☐ No

12. Expandability Index



A. Up to date data?

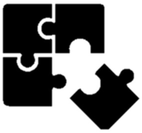
Is the map that includes the area that surrounds the Protected Area, up to date regarding infrastructure and human settlements (e.g. villages & cities)?

- ☐ Yes
- ☐ No

13. Light Pollution Index

We will use the Light Pollution Map (www.lightpollutionmap.info) in order to determine the level of light pollution in the Protected Area

14. Fragmentation Index



A. Up to date data?

Is the map of the Protected Area up to date regarding infrastructure?

- ☐ Yes
- ☐ No

15. Management Objectives Index

GAME #2

A. Management objectives

Indicate for each management objective, whether it is included in the official management plan of the Protected Area

Protection of endangered species	☐	☐
Protection of a nationally significant landscape	☐	☐
Protection of ecosystem services	☐	☐
Protection of cultural sites	☐	☐
Protection of natural resources for sustainable use	☐	☐
Providing food or other products for the markets/ Provide benefits to the local and national economy	☐	☐
Maintaining natural processes	☐	☐
Preserve significant natural features	☐	☐
Safeguard the genetic diversity	☐	☐
Provide recreation and tourism services	☐	☐
Provide education, research and environmental monitoring	☐	☐
Provide homes to human communities with traditional cultures and knowledge of nature	☐	☐

Thank you for your co-operation!

Appendix 2: R script for the AMOEBA diagrams

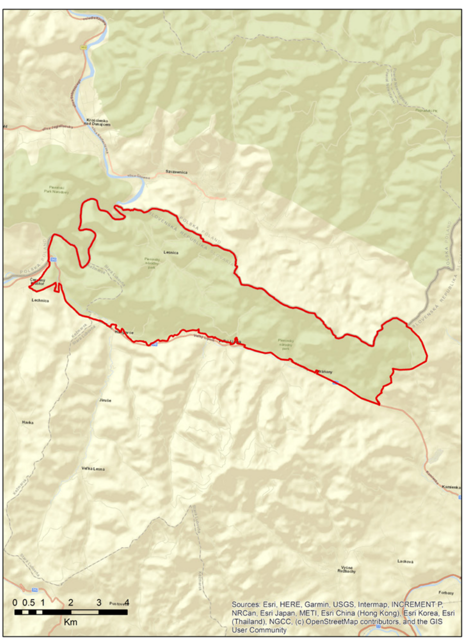
```
# library
library(tidyverse)

# Set workingdirectory
setwd(“workingdirectory”)

# Load data
data<-read.table(“documentname.txt”, dec=”,”, header = TRUE,sep = “\t”)

# Set empty bars to add at the end of each group to create gaps
empty_bar <- 1
to_add <- data.frame( matrix(NA, empty_bar*nlevels(data$group), ncol(data)) )
colnames(to_add) <- colnames(data)
to_add$group <- rep(levels(data$group), each=empty_bar)
data <- rbind(data, to_add)
data <- data %>% arrange(group)
data$id <- seq(1, nrow(data))

# Get the name and the y position of each label
label_data <- data
number_of_bar <- nrow(label_data)
angle <- 90 - 360 * (label_data$id-0.5) /number_of_bar
label_data$hjust <- ifelse( angle < -90, 1, 0)
label_data$angle <- ifelse(angle < -90, angle+180, angle)

# set colours
cols <- c(“A” = “#CC0000”, “B” = “#FF6600”, “C” = “#FFCC00”, “D” = “#006600”, “E” = “#000066”)

# Make the plot
p <- ggplot(data, aes(x=as.factor(id), y=value, fill=colour)) +
  geom_bar(stat=”identity”, alpha=0.5)+
  scale_fill_manual(values=cols)+
  ylim(-0.7,2) +
  theme_minimal() +
  theme(
    legend.position = “none”,
    axis.text = element_blank(),
    axis.title = element_blank(),
    panel.grid = element_blank(),
    plot.margin = unit(rep(-1,4), “cm”)
  ) +
  coord_polar()+
  geom_text(data=label_data, aes(x=id, y=1.2, label=facto, hjust=hjust), color=”black”, fontface=”-
bold”,alpha=0.6, size=4, angle= label_data$angle, inherit.aes = FALSE )

p
```

Appendix 3: Detailed description and maps of Protected Areas that participated in developing the PLI methodology.

Lake Prespa Monument of Nature

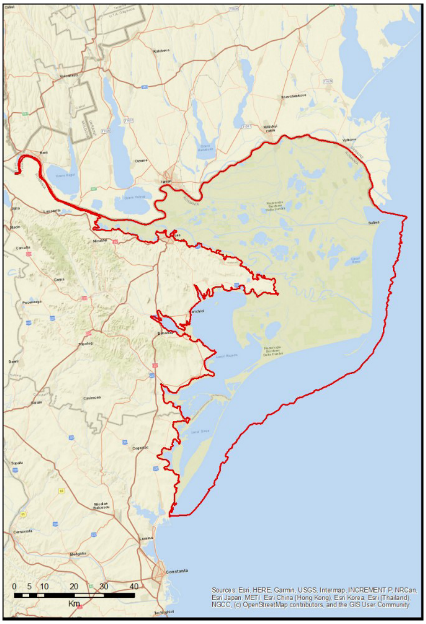
Lake Prespa Monument of Nature is a PA located in the south of North-Macedonia. It is established in 1995 and designated as an IUCN Category III PA. The border of the PA coincides with the boundaries of the municipality of Resen (16,825 inhabitants in 2002). Apart from the town Resen (9000 inhabitants in 2002) many other smaller villages are located in the PA. The PA has a total surface area of 784 km2, from which 176 km2 is taken up by the North-Macedonian part of Lake Prespa, which is shared with Albania and Greece in the south. Lake Prespa lies at 849 m above sea level, has a total surface area of 254 km2, a catchment area of about 1300 km2, a maximum water depth of 48 m and a mean water depth of 14 m. The total inflow of water is estimated to be 16.9 m3/s, with 56% originating from river runoff, 35% from direct precipitation and 9% from the smaller Lake Mikri Prespa in the south. Lake Prespa loses its water through evaporation (52%), irrigation (2%) and outflow through underground karst aquifers (46%) to the ~150 m lower lying Lake Ohrid in the west.

Pieniny National Park (Slovakia)



Pieniny National Park is a PA located in northern Slovakia. It is established in 1967 and designated as an IUCN Category II PA. The PA is located in the Slovak districts of Kežmarok and Stará Ľubovňa in the Prešov Region and only contains the village Lesnica (504 inhabitants in 2013). Pieniny National Park has a total surface area of 37 km2 and includes the Slovak part of the transboundary Pieniny mountain range, which is shared with Poland. Tourist attractions in Pieniny National Park are the hiking routes and the wooden raft trips through the Dunajec River Gorge, which is the border river between Poland and Slovakia. The Pieniny Mountains in Poland are also protected, however under the management of another PA called Pieniny National Park (Poland). This study only examined the (management of the) Pieniny National Park PA in Slovakia.

Danube Delta Biosphere Reserve



The Danube Delta Biosphere Reserve is a PA located in the east of Romania, where the Danube River flows in the Black Sea. It is established in 1991 and designated as a UNESCO Biosphere Reserve, containing IUCN Categories I to IV. The PA has a total surface area of 5,838 km2 which covers the Romanian part of the Danube Delta, the Ukrainian part in the north is excluded. Inside the PA live about 20,000 people, from which about 4,600 in the port of Sulina in the east and the rest is scattered among 27 smaller villages. The Danube Delta is a low alluvial plain with an average altitude of about 0.50 m. It is mostly covered by wetlands and water and is characterised by reed beds, marshes, channels, streamlets and lakes. This mixture of aquatic and terrestrial environments is situated on major bird migratory routes and provide the perfect conditions for nesting and hatching. From the 375 bird species in Romania, 320 live in the Danube Delta Biosphere Reserve or migrate to it in summer or winter (Gâştescu, 2009). At the western edge of the Danube Delta, just outside the borders of the PA, lies the city of Tulcea (73,707 inhabitants in 2011).

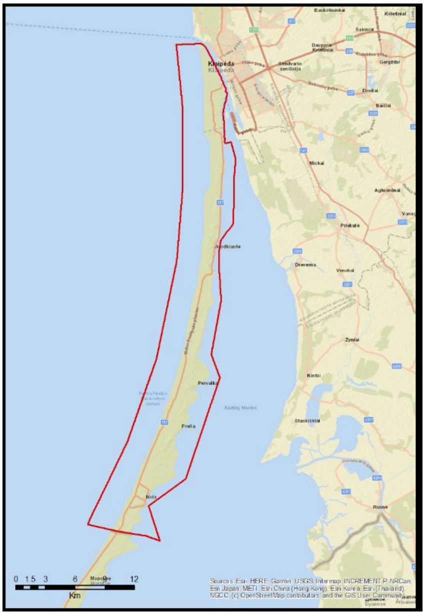
Island Network of Protected Areas – La Palma

The Island Network of Protected Areas is located on La Palma, the most north-westerly Canary Island (Spain). This PA Network consists of 19 “sub-PAs”, each with their own IUCN Category (Table app 5.1). The total surface area of the PA Network is 249 km2. La Palma has 81,863 inhabitants (2018), from which 15,674 live in the capital Santa Cruz de la Palma and about 20,000 in Los Llanos de Aridane. Unlike the other Canary Islands La Palma has instead of mass tourism, ecotourism. About 200,00 tourists visit La Palma each year, mainly because of the many hiking trails. The sub-PAs are dispersed over the entire island where some of them are directly adjacent to each other and others are isolated patches. Sub-PAs that share boundaries have been merged for this study into one (larger) sub-PA. The majority of the sub-PAs only contains small (parts of) villages, whereas the sub-PAs in the middle of the island are uninhabited. The Caldera de Taburiente National Park (P-0) lies in the middle of the island and contains the Caldera de Taburiente. It was already designated as a National Park in 1954. The Roque de los Muchachos (2426 m), the highest point on the island, is located on the northern wall of the caldera and close to this summit is the Roque de los Muchachos (astronomical) Observatory located. The other sub-PAs cover a wide range of environmental regimes from forests to volcanic ridges to beaches.

Name "sub-PA"	IUCN Category	
P-0	Parque Nacional de la Caldera de Taburiente	II
P-1	Reserva Natural Integral del Pinar de Garafía	I
P-2	Reserva Natural Especial de Guelguén	IV
P-3	Parque Natural de las Nieves	II
P-4	Parque Natural de Cumbre Vieja	II
P-5	Monumento Natural de Montaña de Azufre	III
P-6	Monumento Natural de Los Volcanes de Aridane	III
P-7	Monumento Natural del Risco de la Concepción	III
P-8	Monumento Natural de la Costa de Hiscaguán	III
P-9	Monumento Natural del Barranco del Jorado	III
P-10	Monumento Natural de los Volcanes de Teneguía	III
P-11	Monumento Natural del Tubo Volcánico de Todoque	III
P-12	Monumento Natural de Idafe	III
P-13	Paisaje Protegido de El Tablado	V
P-14	Paisaje Protegido del Barranco de Las Angustias	V
P-15	Paisaje Protegido de Tamanca	V
P-16	Paisaje Protegido de El Remo	V
P-17	Sitio de Interés Científico de Juan Mayor	IV
P-18	Sitio de Interés Científico del Barranco de Agua	IV
P-19	Sitio de Interés Científico de las Salinas de Fuencaliente	IV

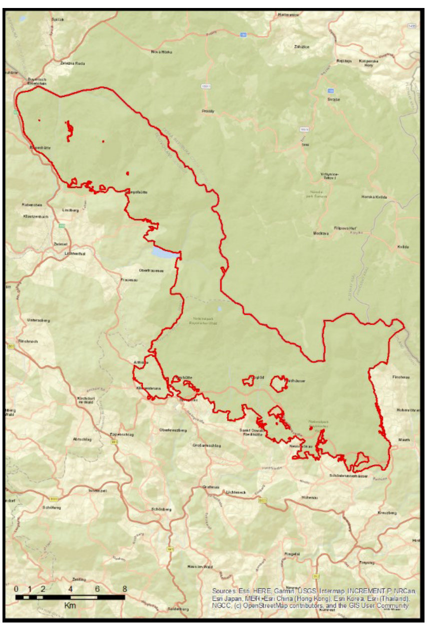
Table app 5.1. Names and IUCN Categories of the 19 "sub-PAs" of the Island Network of Protected Areas on La Palma.

Curonian Spit National Park



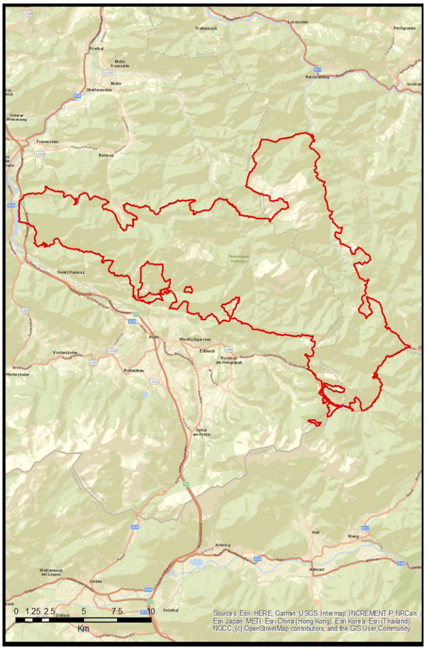
The Curonian Spit is a 93 km long sand-dune spit that lies parallel to the west coast of Lithuania and Russia. It is established in 1991 and designated as an IUCN Category II PA. The spit separates the Curonian lagoon in the east from the Baltic Sea in the west. The Curonian Spit PA comprises the northern 52 km of the Curonian Spit that belongs to Lithuania. It has a surface area of 272 km2 and a maximum width of 3,8 km. From south to north runs one main road that passes by the following settlements: the resort town Nida (~ 2,385 inhabitants in 2012), the village of Preila, Pervalka, Juodkrantė, Alksnynė and Smiltynė. In the north-east of the Curonian Spit, nearby Smiltynė, the Smiltynė Ferry forms a (transport) connection between the spit and the city of Klaipėda on the main land of Lithuania. The Curonian Spit PA consists of beaches, dunes, wetlands, meadows and forests and is a popular holiday destination for about 200,000 to 300,000 tourists each summer, mostly Lithuanians, Germans, Latvians, and Russians.

Bavarian Forest National Park



The Bavarian Forest National Park PA is located in Germany in the Eastern Bavarian Forest adjacent to the border with the Czech Republic. It was established in 1970 and designated as an IUCN Category II PA. The PA has a surface area of 242 km2 and its border have been drawn in such a way that most villages have been omitted/excluded, which created gaps. The Bavarian Forest National Park PA mainly consists of low and high mountain forests, but also includes some bog lakes and meadows. The PA offers visitors a large network of signposted trails, long-distance hikes, adventure trails and wooden boardwalks. In the Bavarian Forest live amongst others, lynxes, wildcats, beavers, otters, bats, red deer, moose and in 2016 a pair of wolves were discovered. However, since visitors often don't encounter these animals in the wild, a zoo (Tier-Freigelände) has been established in the south of the PA, where visitors can spot the native mammal and bird species.

Kalkalpen National Park



The Kalkalpen National Park is located in the state of Upper Austria, Austria. It is established in 1997 and designated as an IUCN Category II PA. The border of the PA has been defined in such a way that towns, villages and main traffic roads in the area have been excluded, creating gaps and fragments.

The Kalkalpen National Park PA has a total surface area of 208 km2 from which about 80% is covered by pines, spruces and beeches. The PA is located within the Northern Limestone Alps mountain range and contains Europe's largest forested area, as well as the largest karst region in Austria. Apart from forests, rivers, canyons, waterfalls and lakes can be found in the Kalkalpen PA. The park is home to about 50 species of mammals, among which the rare and endangered lynx, about 80 species of breeding birds, about 1000 species of flowering plants, moss and ferns and 1400 species of butterflies. The Kalkalpen National Park PA attracts tourists and offers in its visitors centre in the town of Molln an exhibition on the nature of the Kalkalpen, information on guided tours, maps of the extensive network of hiking/biking trails and other activities. In winter there are alpine skiing routes in the west of the PA.

5

6

Chapter 6 - General Discussion and Recommendations

6

Chapter 6 - General discussion and Recommendations

To be able to understand the implications of using the Ecosystem Services concept in Protected Area management, a literature review, several field surveys and interviews have been performed.

The Ecosystem Services approach

In the literature review (chapter 2), the various approaches that exist in Protected Area management and for categorising and measuring Ecosystem Services, have been brought together to elucidate the possibilities to combine the Ecosystem Services concept with Protected Area management. It appeared to be possible to combine the Ecosystem Services concept and Protected Area management, but in order to do this some major shortcomings of the Ecosystem Services concept as it is used today have to be dealt with.

It has been argued that the major shortcoming is that the Ecosystem Services concept is highly anthropocentric (McCauley, 2006; Sagoff, 2008; Redford and Adams, 2009), and thereby could easily lead to the commodification or selling out of nature (Kosoy and Corbera, 2010; Spangenberg and Settele, 2010).
This is contradictory to the view of Protected Area managers, who mostly consider nature to be something that should be protected for its own intrinsic value, and not only for the services, goods or benefits it could deliver to society (Sagoff, 2004; Redford and Adams, 2009; McAfee and Shapiro, 2010).
To accommodate for such a contradiction it is necessary to compose a standardised set of Ecosystem Services indicators including the intrinsic and aesthetic values of nature, while avoiding a too strong distinction between ecosystem functions and services since several ecosystem functions and processes overlap with services provided.

To come to this wider applicable set of Ecosystem Service indicators it is important to focus on a bottom-up approach when implementing the Ecosystem Services concept in Protected Area, management, including extensive communication with stakeholders and practitioners. This is needed because a top-down approach that excludes local practices or interests in Protected Area management will eventually lead to conflicts (West et al., 2006).
Moreover, in order to guarantee a practical useful tool instead of a theoretical concept a bottom-up approach is needed.
In creating such a bottom-up designed list of Ecosystem Services indicators it is important to reduce the tendency of over-complicating the description of Ecosystem Services in an effort to make a detailed classification system of all Ecosystem Services worldwide.
An example of this over-complication of Ecosystem Services is described in Landers & Nahlik (2013), where an Ecosystem Good or Service is first divided into 15 environmental classes, then by 10 different beneficiary categories, and subsequently by different beneficiary sub-categories, leading to in total 338 different beneficiaries. This in total leads to a possible 5070 combinations – scientifically probably very correct yet not practical for Protected Area managers nor for comparison of Protected Areas.

6

A different language

Aforementioned recommendations also connect to the observation of a strong difference in views between the scientists and the managers involved in Protected Area research (chapter 3). This difference was mainly found when touching upon the most important focal points of research in Protected Areas. Scientists and managers disagreed on what was most important. Scientists were inclined to have a more detailed view of a Protected Area, with specific topics, mainly abiotic and biotic environmental variables, differentiating strongly among the individual scientists. Protected Area managers had a more broad view including also socio-cultural and economic variables. Even a scientist and a manager that worked closely together (indicated with a light and dark green dot in figure 6.1) still differed markedly in their perception.

A potential explanation for the difference between scientists and managers could be related to the fact that managers deal with various stakeholders, like municipalities, local businesses, farmers and fishermen, in day to day management of a PA (Agardy, 2000; Parrish et al., 2003). Disturbance, tourism and agriculture are brought more to the foreground, since these elements managers are faced with on a regular basis. Scientists have less interaction with stakeholders, and seemingly focus more on the functional aspects underlying the Ecosystem Services (Pomeroy et al., 2005), and thereby regard these functional aspects to be of importance. The difference may also be caused by the spatial and temporal frame in which both scientists and manager observe a certain system. Scientists model and observe long-term, large-scale processes and changes, whereas managers commonly deal with decision-making on much shorter term, and at more local scale. Therefore, scientists are likely to pay more attention to long-term processes, while managers will give more weight to issues they deal with in their daily work, such as anthropogenic disturbance (Hein et al., 2006; Fisher et al., 2009; Bagstad et al., 2014).

A Principle Component Analysis on the perception of most important Ecosystem Functions, Ecosystem Services, and Threats in a Protected Areas by both scientists and managers (using the same data as in chapter 3), indicates this differentiation between scientists and Protected Area managers, and among scientists themselves, whereas Protected Area managers strongly agree with each other. Such differences in perception on the most important variables in Protected Area research should be overcome, before implementing an Ecosystem Services approach in Protected Area management.

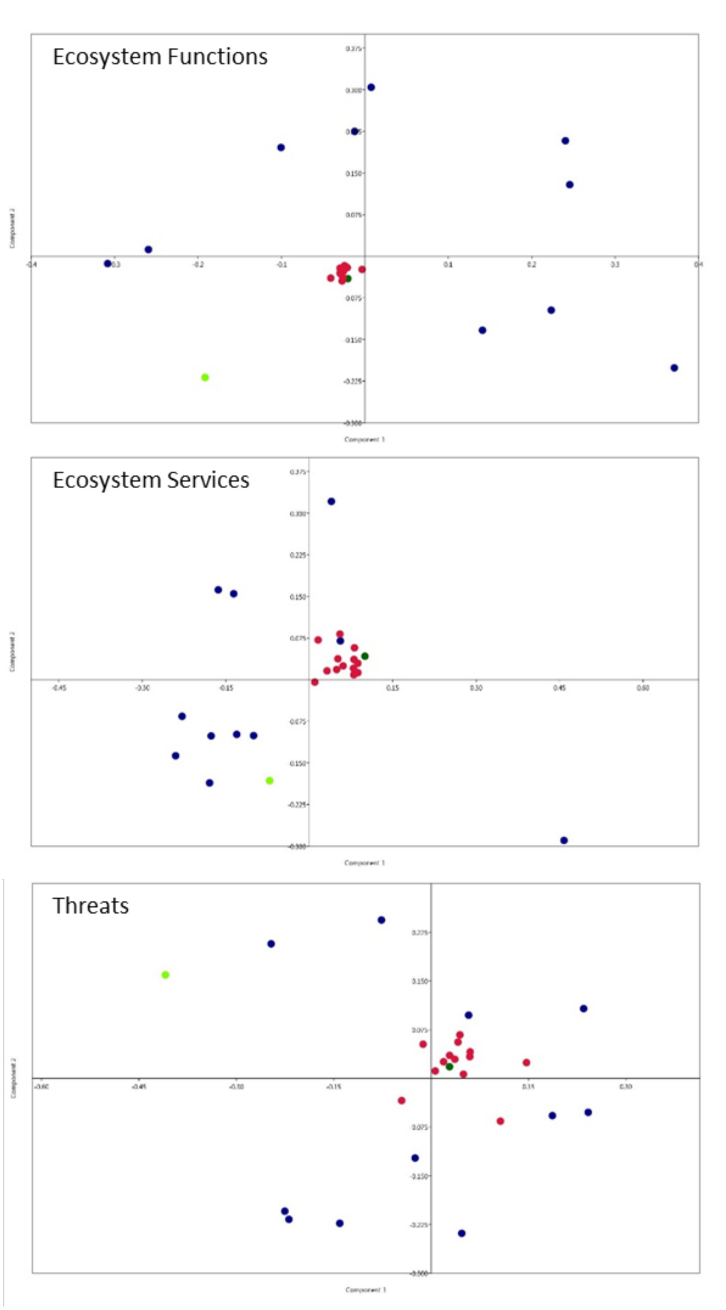


Figure 6.1: Principle component analysis (PCA) on important variables in Protected Area as perceived by Protected Area managers (red dots) and scientists (blue dots). The light and dark green dots are a scientist and a manager, respectively, who indicated to cooperate closely.

As a consequence of the strong differentiation in views of Protected Area managers and scientists on the importance of parameters essential to the functioning, services and threats, it remained difficult to indicate in the first part of my PhD study what the most essential variables to be measured and followed in order to enhance the protection in Protected Areas could be.

Therefore, the major conclusion from the study is that intensified communication across disciplinary and professional boundaries, with ample bottom-up involvement of practitioners and stakeholders, is urgently needed to arrive at a more focused, harmonised and user-friendly set of Ecosystem Services in order to implement an Ecosystem Services oriented management strategy. This contrasts with most studies where management strategies are suggested and installed in a top-down fashion (Polunin, 2002; Glaser, 2010; Mauerhofer, 2011). The exclusion of a bottom-up co-design of Protected Areas may explain why we found that most Protected Area managers, i.e. 24 out of 26 interviewed, are not interested in using the Ecosystem Services concept in Protected Area management.
Fisher and Brown (2014) found during interviews with PA managers that an Ecosystem Services approach was in some cases already in use in PA management, but not whole-heartedly. Some of the replies of the Protetected Area managers were: "I wouldn't say there has been any change in the central mission… nor how it looks on the ground, but there has been a lot of change in how we package it, promote it…the biggest change in that has been the Ecosystem Services stuff…." or "… I view with horror the idea that the way you protect nature is through communicating about it just in terms of services….".
Interviews held in the framework of this PhD research yielded the same results: besides the fact that only 2 out of 26 Protected Area managers used the concept of Ecosystem Services in the management of their Protected Area and both managers that did use an Ecosystem Services approach not knowing which framework (CICES, TEEB, etc.) was used, we also got a reply from one of the managers: "The ES framework is a capitalistic way of preserving nature, how can you put a value on nature?"
This indicates that the usage of an Ecosystem Services approach in Protected Area management is not common practice yet, and not greeted with big enthusiasm. This could be overcome by a bottom-up Ecosystem Services approach understood by the management, given that conflicts emerge when conservation strategies for Protected Areas follow a top-down approach that excludes local practices or interests (West et al., 2006).

To overcome the critiques to an Ecosystem Services approach in Protected Area management, I have focussed in the second part of my PhD research on developing a method to enhance the communication and co-design with stakeholders. Moreover, through a new harmonised survey with practitioners, managers and scientists of Protected Areas, the focal point has been a bottom-up, practitioner co-designed method to measure the protection level of their area, i.e. a new Protection Level Index (PLI).
This index is based on a commonly agreed basic set of the most essential variables, including several Ecosystem Services, ecosystem functions and structures, and threats to the Protected Areas that were judged to be important in the surveyed aquatic and terrestrial Protected Areas.

Stakeholder involvement

As a testing tool on how the bottom-up stakeholder involvement and communication with and among stakeholders can be inventoried and improved, in this thesis the technique of Fuzzy Cognitive Modelling (FCM) has been used. Twenty-three different Fuzzy Cognitive Maps were drawn up with stakeholders from the Wadden Sea Protected Area, one of the most prominent and well-known Protected Areas in The Netherlands (chapter 4), regarding their perception on the most important ecological, cultural and socio-economic factors and interacting processes in the Wadden Sea.
The technique of FCMs is often used for the understanding of the opinions of groups (Rouse and Morris, 1985). For creating such a group understanding mostly aggregated FCMs are used (Mazzuto et al., 2018). Aggregated FCMs are mathematically added or averaged FCMs that can represent a group opinion, without consulting stakeholders as a group, but as individuals.
In contradiction to most research using FCMs, the choice was made to not make use of aggregated FCMs of stakeholders, because when aggregating FCMs, the unique opinions of different stakeholders are added up mathematically, eventually leading to a non-existing artificial opinion. Because of the choice not to aggregate our FCMs, it became possible to indicate similarities and differences in the form and content of the FCM networks between individual stakeholders from different backgrounds. This also allowed for a better assessment of the occurrence and type of contrasts, if any, between different stakeholders, such as the above indicated discrepancies between scientists and Protected Area managers.

In the FCM interviews the participants could speak as freely as possible. No lists with predefined terms were used. Using harmonised lists may lead to better standardisation of FCMs, making it less difficult for the researchers to draw conclusions, but on the other hand, the reliability of the FCM structure and function may be biased since these predefined concepts already shape stakeholders' opinions, making it difficult to speak their own mind (Morris and Rouse, 1985; Pohl, 2004). Since we wanted to maximise the use of the surveys, and to create an inventory unbiased opinions, we have chosen to perform a harmonisation of terms post-hoc, although this option turned out to be more labour intensive.

The most often mentioned most central terms connected to the Wadden Sea are Nature, Regulations, Management, Wadden Sea experience, and Recreation, irrespective of the (type of) stakeholder that was interviewed. These terms seem logical, in an area such as the Wadden Sea, where nature is protected by several different international frameworks, such as Natura 2000, Ramsar convention, the UNESCO World Heritage programme and the UNESCO Man and Biosphere programme, and thus a proper management and regulations have been installed to safeguard the Wadden Sea nature. In addition, a strong Wadden experience and Recreation may also be quite obvious elements in the Wadden Sea known for the special experience it delivers to the millions of tourists each year.
The only difference between groups of stakeholders is related to the form of the networks, e.g. stakeholders from nationally orientated institutions indicated less interactions between important variables than those with a regional or local orientation who indicated many interactions.

The conclusion is therefore that differences exist in the way stakeholders may express the most important elements of the Wadden Sea, and how these elements are connected within the system-network. Despite this, there is an overall strong agreement among all stakeholders on the factual content of what are the most important ecological, socio-economic and cultural elements in the Wadden Sea and their level of importance in the structure and functioning of the Protected Area.
Differences among stakeholders are thus more semantic than real substantive contrasts. Such semantic differences can be easily tackled post-hoc keeping a list of harmonised terms on the background.

To come to a correct overview of the important ecological, socio-economic and cultural elements in a Protected Area several stakeholders have to be heard to arrive at a complete list of the factual content variables, i.e. the variables of importance in a Protected Area, because each of the stakeholders will mention only part of the variables.
In this study I found that 20 stakeholder interviews are sufficient to obtain an almost complete overview of the important variables, factors and their interactions in the Wadden Sea Protected Area. Other authors find largely different numbers of interviews needed to obtain the most complete list of possible important variables. Ozesmi and Ozesmi (2003) needed 35 interviews to arrive at the same stage this study did at 20 interviews. This means that when using FCMs to list the most important elements in Protected Area management, it is important to determine per case what the needed number of stakeholder interviews is.
Consequently, this also may mean that using the FCM method to inventory views and opinions among individual stakeholders could become more laborious than surveying the stakeholders as a group. Yet, the individual interviews yield a jointly shared and more complete and detailed picture on the interacting variables that are judged to be the important factors shaping the socio-economic and ecological conditions of the Protected Area. The higher quality of the results may outweigh the higher quantity of surveys needed to be performed.
This more complete and detailed insight based on the involvement of various individual stakeholders such as scientists, policy makers, managers, industry, and practitioners, who all have a stake in the management of a Protected Area, could be instrumental in the Protected Area managing process, not in the least by elucidating interacting factors, and eventual potential conflicts, that may hinder proper management of a Protected Area. Equally, such a bottom-up derived insight may also be the way to successfully incorporate the factors matching with the Ecosystem Services approach, that are judged to be important by the stakeholders, in Protected Area management.

Measuring status and progress

Once the important variables for the management of a Protected Area, and the way forward on how to incorporate an Ecosystem Services approach into Protected Area management are known, the question

remains how to measure the effects of a new management strategy on a Protected Area.
When reviewing the existing Protected Area quality measurement schemes, it became clear that most of these schemes measure the quality of management and not so much the quality of the Protected Area itself. In this way what has been termed ‘paper parks’, i.e.
Protected Areas that exist only on paper, with little to no protection on the ground, can exist (Brandon et al., 1998; Blom et al., 2004; Bonham et al., 2008).
The cause of this situation is, again, the top-down conception of most of the existing Protected Area management effectiveness measurement programmes, whereas for the correct implementation of any kind of new management approach, a bottom-up way of implementation is needed, as is already detailed in chapter 2. This is also needed to measure the effects of an Ecosystem Services approach in Protected Area management.

To overcome the flaws of existing measurement schemes, and to measure the quality of management and the effects on a Protected Area in a quick and cost-effective way, together with Protected Area managers, a novel bottom-up derived tool for measuring Protected Area quality: the Protection Level Index (PLI) was developed. PLI is innovative because it is conceived in a bottom-up fashion, and it incorporates the manager’s perception of a Protected Area in several of its components. This new tool was tested in seven Protected Areas in aquatic and terrestrial realms (chapter 5). With this tool, including managerial parameters as well as environmental factors and ecosystem services, an estimate of the quality of a Protected Area can be obtained within 1 day.
This also makes PLI an easy-to-use and cost-efficient tool to assess the present status, as well as annual changes, i.e. progress or decrease, in essential parameters of a Protected Area, thereby overcoming the caveats of various other management effectiveness methods.

Conclusions

The implementation of an Ecosystem Services approach in Protected Area management may seem not to be easy, because several obstacles can come to the foreground as indicated in this thesis:
Firstly, the combination of an approach that originally has a monetary background with Protected Area management that is built around the protection of the intrinsic value of nature, may lead to conflicts.
Secondly, views of researchers and practitioners regarding the type and importance of factors governing a Protected Area may differ strongly.
And thirdly, the ‘language’ of various groups of stakeholders may traditionally differ amongst each other.

The way forward

As is shown in this thesis the way forward to solve these obstacles could be easy, as follows:
First and foremost, the gap between practitioners and scientists working in Protected Area research can be closed by initiating intensified communication with prime stakeholders on the issues at stake regarding the protection and essential variables governing Protected Areas.
Secondly, in this intensified communication a bottom-up should be used, i.e. the managers in Protected Areas must have a prominent role in implementation of an Ecosystem Services approach in Protected Area management.
Thirdly, because many stakeholders have more or less the same opinion on important elements in Protected Areas, but the way of expressing them is different, at the start of the intensified communication a harmonised list of terms, encompassing the most important variables in a Protected Area, has to be established, in order to enable a “common language” concerning these elements.
Fourthly, it is advisable to use Ecosystem Services as a communication instrument to emphasise the importance of nature to mankind, rather than a way of emphasising the monetary value of nature.
Implementing the above solutions will help to align practitioners and scientists regarding the prime issues at stake in Protected Areas, to involve other stakeholders of these areas, and to avoid potential problems when using an Ecosystem Services approach as if it is about monetising the value of nature or even “selling out on nature”. Focussing more on a bottom-up approach for the introduction and eventually the implementation of an Ecosystem Services approach in Protected Area management will empower Protected Area managers, and will give them the chance to adopt the approach to their own needs, instead of trying to force a one-size-fits-all measure on them in a top-down way.

Future research

For future research on the implementation of the Ecosystem Services approach in Protected Area management further attention could be directed towards:
Developing a more unified approach in measuring Ecosystem Services in other ways than monetary terms.
Developing stakeholder participation platforms for Protected Areas.
Implementing the use of Ecosystem Services as a communication instrument to convey the importance of Protected Areas to the public at large.
More research on the various needs of managers active in different types of Protected Areas in different realms.

On the protection level of an area and the Protection Level index, future research is required on:
Developing marine Protection Level Index factors to be able to use the full potential of PLI in fully marine Protected Areas.
Measuring the Protection Level Index for a longer period of time in different Protected Areas to check PLI's potential for making an annual update of the protection status of a Protected Area.
Creating an online platform to facilitate the more efficient use of PLI, also for managers of Protected Areas in third world countries, or Protected Areas with little to no financial resources.

Concluding Remarks

Taking together the findings and techniques developed in this thesis, the conclusion can be drawn that the Ecosystem Services concept can be successfully embedded in Protected Area management if the concept is connected to the importance of nature to mankind, rather than emphasising the monetary value of nature. Basis to this conclusion is that a strong bottom-up communication approach with ample stakeholder participation is used, in this thesis by means of Fuzzy Cognitive Modelling (FCM), to determine the most important variables composing and controlling the ecological and socio-economic processes in the area, to make sure that all elements for an optimal protection of Protected Areas are included. Using the newly developed bottom-up derived Protection Level Index (PLI) makes it possible to keep track of the protection level of any kind of Protected Area during several years in a cost-effective and easy way. PLI can also be used to measure the impact of deploying a new approach such as an Ecosystem Services focused management strategy before and after its implementation in a Protected Area.

References (Introduction and General Discussion)

Adams, J.S. and T.O. McShane. (1996). The Myth of Wild Africa: Conservation without Illusion. University of California Press, Berkeley, CA, USA.

Agardy, T. (2000) Information needs for marine protected areas: scientific and societal. Bulletin of Marine Science, 66(3), 875-888.

Azoulay, A.A. (2021), https://news.un.org/en/story/2021/03/1088212, accessed 17-5-2021

Bagstad, K., Villa, F., Batker, D., Harrison-Cox, J., Voigt, B., Johnson, G. (2014) From theoretical to actual ecosystem services: mapping beneficiaries and spatial flows in ecosystem service assessments. Ecology and Society, 19(2).

Blom, A., Yamindou, J., & Prins, H. H. (2004). Status of the protected areas of the Central African Republic. Biological Conservation, 118(4), 479–487.

Bonham, C. A., Sacayon, E., & Tzi, E. (2008). Protecting imperiled "paper parks": Potential lessons from the Sierra Chinaj´a, Guatemala. Biodiversity and Conservation, 17(7), 1581–1593.

Boyd, J., & Banzhaf, S. (2007). What are ecosystem services? The need for standardized environmental accounting units. Ecological economics, 63(2), 616-626.

Brandon, K., Redford, K. H., & Sanderson, S. (Eds.). (1998). Parks in peril: People, politics, and protected areas. Washington and California, USA: The Nature Conservancy, Island Press.

Brooks, T. M., Da Fonseca, G. A., & Rodrigues, A. S. (2004). Protected areas and species. Conservation Biology, 616-618.

Burdon, D., Boyes, S.J., Elliott, M., Smyth, K., Atkins, J.P., Barnes, R.A. & Wurzel, R.K., (2018). Integrating natural and social marine science to sustainably manage vectors of change: Dogger Bank transnational case study. Estuarine, Coastal and Shelf Science 201: 234-247, http://dx.doi.org/10.1016/j.ecss.2015.09.012.

Butchart, S. H., Baillie, J. E., Chenery, A. M., Collen, B., Gregory, R. D., Revenga, C., & Walpole, M. (2010). National Indicators Show Biodiversity Progress—Response. Science, 329(5994), 900-901.

Campos, M. T., & Nepstad, D. C. (2006). Smallholders, the Amazon's new conservationists. Conservation Biology, 20(5), 1553-1556.

Cardelús, C. L., Scull, P., Hair, J., Baimas-George, M., Lowman, M. D., & Eshete, A. W. (2013). A Preliminary Assessment of Ethiopian Sacred Grove Status at the Landscape and Ecosystem Scales. Diversity, 5(2), 320-334.

Chape, S., Harrison, J., Spalding, M., & Lysenko, I. (2005). Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1454), 443-455.

Coad, L., Campbell, A., Miles, L., & Humphries, K. (2008). The costs and benefits of protected areas for local livelihoods: a review of the current literature. UNEP World Conservation Monitoring Centre, Cambridge, UK.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., ... & Raskin, R. G. (1997). The value of the world's ecosystem services and natural capital. Nature, 387(6630), 253-260.

Daily, G. (Ed.). (1997). Nature's services: societal dependence on natural ecosystems. Island Press.

De Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological economics, 41(3), 393-408.

Draper, M, M. Spierenburg and H. Wels. (2004). African dreams of cohesion: Elite pacting and community development in transfrontier conservation areas in Southern Africa. Culture and Organization 10(4): 341–353.

Dudley, N. (Ed.). (2008). Guidelines for applying protected area management categories. Iucn.

Dudley N. (ed.). (2013) Guidelines for Applying Protected Area Management Categories. Gland, Switzerland, IUCN. Available at https://portals.iucn.org/library/node/30018.

Elliott, M., Burdon, D., Atkins, J.P., Borja, A., Cormier, R., de Jonge, V.N., and Turner, R.K. (2017). "And DPSIR begat DAPSI(W)R(M)!" - a unifying framework for marine environmental management. Marine Pollution Bulletin, 118 (1-2): 27-40. http://dx.doi.org/10.1016/j.marpolbul.2017.03.049

Fisher, B., & Turner, R. K. (2008). Ecosystem services: classification for valuation. Biological conservation, 141(5), 1167-1169.

Fisher, B., Turner, R. K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. Ecological economics, 68(3), 643-653.

Fisher, J. A., & Brown, K. (2014). Ecosystem services concepts and approaches in conservation: Just a rhetorical tool?. Ecological economics, 108, 257-265.

Grove, R. (1996). Green imperialism: colonial expansion, tropical island Edens and the origins of environmentalism, 1600-1860. Cambridge University Press.

Glaser, M., Baitoningsih, W., Ferse, S. C., Neil, M., & Deswandi, R. (2010). Whose sustainability? Top–down participation and emergent rules in marine protected area management in Indonesia. Marine Policy, 34(6), 1215-1225.

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. Ecosystem Ecology: a new synthesis, 110-139.

Haines-Young, R., & Potschin, M. (2013). CICES V4. 3–Revised report prepared following consultation on CICES Version 4, August-December 2012. EEA Framework Contract No EEA (p. 34). IEA/09/003.

Harrison, P. A., Vandewalle, M., Sykes, M. T., Berry, P. M., Bugter, R., de Bello, F., ... & Jongman, R. H. (2010). Identifying and prioritising services in European terrestrial and freshwater ecosystems. Biodiversity and Conservation, 19(10), 2791-2821.

Hein, L., Van Koppen, K., De Groot, R.S., Van Ierland, E.C. (2006) Spatial scales, stakeholders and the valuation of ecosystem services. Ecological economics, 57(2), 209-228

Hockings, M., & Phillips, A. (1999). How well are we doing?- some thoughts on the effectiveness of protected areas. Parks, 9(2), 5-14.

IUCN. (2004). Speaking a Common Language, The uses and performance of the IUCN System of Management Categories for Protected Areas, ISBN: 1-902647-48-3

Jetter, A. J., & Kok, K. (2014). Fuzzy Cognitive Maps for futures studies—A methodological assessment of concepts and methods. Futures, 61, 45-57.

Kosoy, N. and Corbera, E., (2010), "Payments for ecosystem services as commodity fetishism", Ecological Economics, Vol. 69 No. 6, pp. 1228-1236.

Landers, D. H., & Nahlik, A. M. (2013). Final ecosystem goods and services classification system (FEGS-CS). Anonymous EPA United States Environmental Protection Agency. Report Number EPA/600/R-13/ORD-004914.

Liu, J., Linderman, M., Ouyang, Z., An, L., Yang, J., Zhang, H., 2001. Ecological degradation in protected areas: the case of Wolong nature reserve for giant pandas. Science 292 (5514), 98–101.

Mauerhofer, V. (2011). A bottom-up 'Convention-Check'to improve top-down global protected area governance. Land use policy, 28(4), 877-886.

Mazzuto, G., Bevilacqua, M., Stylios, C., & Georgopoulos, V. C. (2018, July). Aggregate experts knowledge in fuzzy cognitive maps. In 2018 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE) (pp. 1-6). IEEE.

McAfee, K., & Shapiro, E. N. (2010). Payments for ecosystem services in Mexico: nature, neoliberalism, social movements, and the state. Annals of the Association of American Geographers, 100(3), 579-599.

McCauley, D. (2006). Selling out on nature. Nature. 443. 27-8. 10.1038/443027a.

MEA. (2005). Ecosystems and human well-being: wetlands and water. World resources institute, Washington, DC, 5.

Morris, N. M., & Rouse, W. B. (1985). Review and evaluation of empirical research in troubleshooting. Human factors, 27(5), 503-530.

Özesmi, U., & Özesmi, S. (2003). A participatory approach to ecosystem conservation: fuzzy cognitive maps and stakeholder group analysis in Uluabat Lake, Turkey. Environmental management, 31(4), 0518-0531.

Panda, S. M. (1999). Towards a sustainable natural resource management of tribal communities: Findings from a study of swidden and wetland cultivation in remote hill regions of eastern India. Environmental management, 23(2), 205-216.

Parrish, J.D., Braun, D.P., Unnasch, R.S., 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. Bioscience 53 (9), 851–860.

Phillips, A. (2007). A short history of the international system of protected area management categories. WCPA Task Force on protected area categories.

Pohl, R.F. (ed.) (2004). Cognitive Illusions: A Handbook on Fallacies and Biases in Thinking, Judgment and Memory. Psychology Press, Hove

Polunin, N.V.C. (2002) Marine protected areas, fish and fisheries. In: Hart PJB, Reynolds JD, editors. Handbook of fish and fisheries, vol. II. Oxford, UK: Blackwell Science,p. 293–318

Pomeroy, R. S., Parks, J. E., & Watson, L. M. (2005). How is your MPA doing?: a guidebook of natural and social indicators for evaluating marine protected area management effectiveness. IUCN.

Rangajaran, M. (2005). India's Wildlife History: an introduction, Orient Blackswan, 135 pp.

Redford, K. H., & Adams, W. M. (2009). Payment for ecosystem services and the challenge of saving nature. Conservation Biology, 23(4), 785-787.

Rodrigues, A.S., Andelman, S.J., Bakarr,M.I., Boitani, L., Brooks, T.M., Cowling, R.M., ... Long, J.S., 2004. Effectiveness of the global protected area network in representing species diversity. Nature 428 (6983), 640–643.

Sagoff, M. (2004). Price, principle, and the environment. Cambridge University Press.

Sagoff, M. (2008). On the economic value of ecosystem services. Environmental Values, 239-257.

Scharin, H., Ericsdotter, S., Elliott, M., Turner, R.K., Niiranen, S., Rockström, J., Blenckner, T., Hyytiäinen, K., Ahlvik, L., Heini Ahtiainen, H., Artell, J., Hasselström, L., Söderqvist, T. (2016). Processes for the sustainable stewardship of marine environments. Ecological Economics. 128: 55-67.

Scull, P., Cardelús, C. L., Klepeis, P., Woods, C. L., Frankl, A., and Nyssen, J. (2017) The Resilience of Ethiopian Church Forests: Interpreting Aerial Photographs, 1938–2015. Land Degrad. Develop., 28: 450–458. doi: 10.1002/ldr.2633.

Spangenberg, J. H., & Settele, J. (2010). Precisely incorrect? Monetising the value of ecosystem services. Ecological Complexity, 7(3), 327-337.

Staub, C., Ott, W., Heusi, F., Klingler, G., Jenny, A., Hacki, M., & Hauser, A. (2011). Indicators for Ecosystem Goods and Services: Framework, methodology and recommendations for a welfare-related environmental reporting. Federal Office for the Environment, Bern. Environmental studies, (1102), 17.

Stoll-Kleemann, S. (2010). Evaluation of management effectiveness in protected areas: Methodologies and results. Basic and Applied Ecology, 11(5), 377-382.

TEEB, (2010). The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. In: Pushpam Kumar (Ed.), Earthscan, London and Washington

Turner, R.K. & Schaafsma, M. (Eds.) (2015) Coastal zones ecosystem services: from science to values and decision making. Springer Ecological Economic Series, Springer Internat. Publ. Switzerland, ISBN 978-3-319-17213-2.

Turnhout, E., Waterton, C., Neves, K., & Buizer, M. (2013). Rethinking biodiversity: from goods and services to "living with". Conservation Letters, 6(3), 154-161.

Wild R., McLeod C. (2008). Sacred natural sites: Guidelines for protected area managers. IUCN, Gland, Switzerland, pg. 106

West, P., Igoe, J., & Brockington, D. (2006). Parks and peoples: the social impact of protected areas. Annu. Rev. Anthropol., 35, 251-277.

Summary

Protected Areas are considered to be a key component of nature conservation. They can play an important role in counterbalancing the impacts of ecosystem degradation.
Recently, also societal aspects have been introduced into Protected Area management via the introduction of the Ecosystem Services (ES) approach. This thesis discusses the historical background of PAs, PA management, and the ES approach. Also the applicability and relevance of the ES approach for PA management is discussed.
The different definitions of ES will be presented, together with different classification methods and ways of measuring ES. The conclusion is that there are still major challenges ahead in using the ES approach in PA management and therefore recommendations are given on the way forward (Chapter 2).

For an optimal protection of a Protected Area it is essential to account for the variables underlying the major Ecosystem Services an area delivers, and the threats upon them. In this thesis I show that the perception of important variables differs between scientists and managers involved in Protected Area research.
We found that scientists emphasise variables of abiotic and biotic nature, whereas managers highlight socio-economic, cultural and anthropogenic variables. To be able to better protect a PA it is advisable to bring perception of scientists and managers closer together. This can be done by more Intensified and harmonised communication across disciplinary and professional boundaries (Chapter 3).

Involving stakeholders in PA management may enhance the protection of a PA. Fuzzy Cognitive Modelling (FCM) was used to assess stakeholders' opinions on the management of the Wadden Sea, one of the most important Protected Areas in the Netherlands.
Through FCM stakeholder's perceptions of the most important ecological, socio-economic and cultural processes, functions and threats in the Wadden Sea were inventoried and quantified. A wide variety of stakeholders was interviewed, belonging to industry, recreation, academic education and research, policy and governance, and NGO's.
The FCM networks drawn up during our research are generally similar for the various types of stakeholders. There is overall strong agreement among all stakeholders on the most important elements and their level of importance in managing the Wadden Sea. These important elements in the Wadden Sea management are: Nature, Regulations, Management, Wadden experience and Recreation. FCMs have proven to be a practical tool involve stakeholders in the management of Protected Areas (Chapter 4).

To keep track of the protection level of a PA, managers and policy makers need to determine the effectiveness of PA management in ways that are practical, scientifically sound and comparable among PAs in various terrestrial and aquatic environments. Most existing methods for measuring the managerial efficiency of PAs are however restricted to specific elements of the management or a limited number of detailed environmental aspects.
These methods are often developed without the participation of practitioners. To involve practitioners more in PA research, the Protection Level Index (PLI) was developed in close cooperation with PA managers.
PLI includes ecological, socio- economic, as well as managerial factors. Some factors in PLI are derived from interviews with PA managers, others are derived from GIS analyses.
PLI uses a fixed protocol, and face-to-face interviews with PA managers. PLI is wider applicable than other PA quality measurements and more cost-effective. Thus, PLI can be used on a yearly basis to keep track of the progress of management activities and conservation status within and among (networks of) PAs (Chapter 5).

Samenvatting

Beschermde gebieden worden beschouwd als een belangrijk onderdeel van natuurbehoud. Ze kunnen een rol spelen bij het tegengaan van de gevolgen van de aantasting van ecosystemen.
Recent zijn ook maatschappelijke aspecten in het beheer van beschermde gebieden geïntroduceerd met het gebruik van de Ecosystem Services (ES)-benadering. In deze thesis worden de historische achtergrond van natuurgebieden, het management ervan en de ES-aanpak besproken.
De toepasbaarheid en relevantie van de ES-aanpak voor het management van natuurgebieden zal worden besproken. De verschillende definities van ES worden genoemd, samen met verschillende classificatiemethoden en manieren om ES te meten.
De conclusie is dat er nog grote uitdagingen zijn bij het gebruik van de ES-benadering in beheer van natuurgebieden en dus worden er aanbevelingen voor de toekomst gegeven(Hoofdstuk 2).

Voor een optimale bescherming van een natuurgebied is het belangrijk om rekening te houden met de variabelen die ten grondslag liggen aan de belangrijkste ES die een gebied levert, en de bedreigingen daarop. De perceptie van belangrijke variabelen verschilt tussen wetenschappers en managers die betrokken zijn bij onderzoek naar natuurgebieden.
Belangrijk is dat wetenschappers variabelen van abiotische en biotische aard belangrijk vinden, terwijl managers socio-economische, culturele en antropogene variabelen belangrijk vinden.
Om een natuurgebied beter te kunnen beschermen is het aan te raden om de perceptie van wetenschappers en managers dichter bij elkaar te brengen. Dit kan door meer en geharmoniseerde communicatie over disciplinaire en professionele grenzen heen (Hoofdstuk 3).

Het betrekken van belanghebbenden bij het beheer van de PA kan de bescherming van een PA verbeteren. Om de mening van belanghebbenden over het beheer van de Waddenzee, een van de belangrijkste beschermde gebieden in Nederland, te beoordelen is gebruik gemaakt van Fuzzy Cognitive Modeling (FCM). Door middel van FCM werden de percepties van belanghebbenden van de belangrijkste ecologische, sociaal-economische en culturele processen, functies en bedreigingen in de Waddenzee werden geïnventariseerd en gekwantificeerd.
Er is een breed scala aan belanghebbenden geïnterviewd, behorend tot de industrie, recreatie, academisch onderwijs en onderzoek, beleid en bestuur, en NGO's.
De FCM-netwerken die tijdens het onderzoek zijn opgesteld, zijn over het algemeen vergelijkbaar voor de verschillende soorten belanghebbenden. Er is over het algemeen sterke overeenstemming tussen alle belanghebbenden over de belangrijkste elementen en het belang ervan bij het beheer van de Waddenzee.
Deze belangrijke elementen in het Waddenzeebeheer zijn: Natuur, Regelgeving, Beheer, Waddenbeleving en Recreatie. FCM's zijn een praktisch hulpmiddel gebleken om belanghebbenden bij het beheer van beschermde gebieden te betrekken (Hoofdstuk 4).

Om het beschermingsniveau van een natuurgebied te kunnen meten, moeten managers en beleidsmakers de effectiviteit van PA-beheer bepalen op een manier die praktisch, wetenschappelijk verantwoord en vergelijkbaar is tussen gebieden. De meeste bestaande methoden voor het meten van de efficiëntie van natuurmanagement zijn echter beperkt tot specifieke elementen, of een beperkt aantal gedetailleerde milieuaspecten.
Deze methoden werden ook vaak ontwikkeld zonder de deelname van mensen uit de praktijk. Om hen meer te betrekken bij onderzoek naar natuurgebieden, is in nauwe samenwerking met mensen uit de praktijk de Protection Level Index (PLI) ontwikkeld. PLI omvat ecologische, sociaaleconomische en managementfactoren. Sommige factoren in PLI zijn afgeleid van interviews met managers, andere zijn afgeleid van GIS-analyses.
PLI maakt gebruik van een vast protocol en interviews met managers van natuurgebieden. PLI is breder toepasbaar dan andere kwaliteitsmetingen en ook kosteneffectiever. Hierdoor kan PLI jaarlijks worden gebruikt om de voortgang van beheersactiviteiten van natuurgebieden bij te houden (Hoofdstuk 5).

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And last but not least: thank you Arthur for putting a smile on my face when times were hard, and for bringing joy to my life.

: Training and Education Statement

raining and education activities listed below the PhD candidate has ith the requirements set by the C.T. de Wit Graduate School for Production I Resource Conservation (PE&RC) which comprises of a minimum total of ?2 weeks of activities)

iterature (4.5 ECTS)
rotected area management: fusion and confusion with the ecosystem ervices approach (2019)

Project proposal (4.5 ECTS)
ne use of the ecosystem services approach in protected area management

ate courses (4.4 ECTS)
ımmer school: marine ecosystem services, management and governance: linking social and ecological research; evotes-Euromarine (2016)
troduction to R for statistical analysis; WUR (2017)
ayesian statistics; WUR (2017)
rasping sustainability; SENSE (2020)

refresh, brush-up courses (1.5 ECTS)
troduction to GIS; ESRI (2017)
se of ArcGIS Pro; ESRI (2017)

training and working visits (1.2 ECTS)
akeholder participation using Fuzzy Cognitive modelling; UNIBUC (2018)

ew of journal manuscripts (1 ECTS)
cience of the total environment: socioeconomic valuation of dry forest ecosystem services in the Colombian aribbean region (2019)

e strengthening / skills courses (0.3 ECTS)
ow to write a successful scientific paper?; NIOZ (2018)

tegrity/ethics in science activities (2 ECTS)
cientific integrity course; VU (2021)

ual meetings, seminars and the PE&RC weekend (0.9 ECTS)
E&RC Day (2019)
E&RC Last year weekend (2020)

groups / local seminars or scientific meetings (7.5 ECTS)
coPotential general assembly; Crete, Greece (2017)
coPotential meeting; Klaipeda, Lithuania (2017)
coPotential meeting; Sete, France (2017)
VOS/EcoPotential meeting; Tour du Valat, France (2017)
coPotential meeting; Pisa, Italy (2017)

al symposia, workshops and conferences (10.3 ECTS)
1st European Marine Biology Symposium; poster presentation; Rhodos (2016)
orth Sea Open Science Conference; poster presentation; Oostende (2016)
etherlands Annual Ecology Meeting; poster presentation; Lunteren (2017)
coPotential General Assembly; oral presentation; Matalascanas, Spain (2018)
4th European Marine Biology Symposium; poster presentation; Dublin (2019)

elevant exposure (0.3 ECTS)
uest lecture: ecosystem services and protected area management in the marine realm; Utrecht University (2019)

supervision; 2 supervisions (6 ECTS)
eveloping a protection level index for protected areas

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