Project Title:	ECOPOTENTIAL: IMPROVING FUTURE ECOSYSTEM BENEFITS THROUGH EARTH OBSERVATIONS
Project number:	641762
Project Acronym:	ECOPOTENTIAL
Proposal full title:	IMPROVING FUTURE ECOSYSTEM BENEFITS THROUGH EARTH OBSERVATIONS
Type:	Research and Innovation Actions
Work program topics addressed:	SC5-16-2014: "Making Earth Observation and Monitoring Data usable for ecosystem modelling and services"

Deliverable No: D9.2

Integrated overview of the Requirements and Quality of Protected Areas

Due date of deliverable:	31/07/2018
Actual submission date:	31/11/2018
Version:	v1

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This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 641762

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Deliverable title	D9.2. Integrated overview of the Requirements and Quality of Protected Areas
Deliverable number	9.2
Deliverable version	1
Previous version(s)	-
Contractual date of delivery	31/07/18
Actual date of delivery	31/07/18
Deliverable filename	D9.2. Integrated overview of the Requirements and Quality of Protected Areas
Nature of deliverable	R = Report
Dissemination level	Public
Number of pages	35
Workpackage	WP9
Partner responsible	NIOZ
Author(s)	Herman Hummel, Valerie Kalle, Louise Bienfait, Yolande Boyer, Rutger de Wit, Christiaan Hummel
Editor	Herman Hummel
EcoPotential Auditor	Magnus Andresen
EC Project Officer	Gaëlle Le Bouler

Abstract	An inventory and analysis of the Requirements and Quality of Protected Areas (PAs) on the basis of the EcoPotential WP9 Essential Variables (EVs) and Important Variables (IVs), is presented. To this end, in addition to the major WP9 surveys (reported in Hummel *et al.* 2018, i.e. Deliverable 9.1) a dedicated survey was carried out in 2018 among participants to the previous surveys. PA managers and EcoPotential scientists were requested to indicate the availability of required data and their perception of the PA quality based on the EVs and IVs. PA managers and scientists of 18 PAs, of which 16 European, and 2 near/in Africa, participated in the survey. The level of the data availability as indicated by the PA managers and scientists was 62 % for the required (17) EVs and (13) IVs. The environmental quality of the PAs was perceived as being in general average to good. It was shown that at higher data availability the

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	quality of the PAs was perceived to be at a higher level. This urges for a high availability of data. A set of additional requirements was derived from links with the IUCN reports on management effectiveness and from the earlier EcoPotential WP9 survey in 2017. In summary the following requirements are recommended to be taken into account to ensure the environmental quality, and to allow for a proper management, of current PAs and for new PAs to be establish in future,: • Assess the full range of 17 Essential and 13 Important Variables, including: - "Ecosystem Functions and Structure" variables on Habitat suitability, Biodiversity, Population dynamics, Primary production, Land- and sea-scape, Hydrodynamics, Gene pool, Climate regulation, Weather, Element cycling, and Secondary production - "Ecosystem Services" variables on Leisure activities, Education and research, Habitat for feeding and breeding, Charismatic landscape, Biodiversity conservation, Charismatic species, Spiritual significance, Animals of economic use, and Climate regulation - "Threats" variables on Overexploitation, Disturbance, Tourism, Change in species, Climate change, Bad management, Exotic species, Habitat loss, Change in land use, (Illegal) human activities • Acquire a high data availability for the EVs and IVs. • Emphasise (and lobby for) rules, tools, and support embedded in directives and legislation at National, European or global levels • Acquire a single integrated management authority and a high degree of autonomy for the PA management. • Assess the political support and will to protect a specific area. • Acquire insight into the role and influence of the different stakeholders in the area • Reach a more harmonised indication of the geographic delineation and the categorisation of the level of protection
Keywords	Essential variables, Ecosystem Services, Ecosystem Functions, Habitat, Threats, Biodiversity, Tourism, Charismatic landscape, Education, Spiritual significance, Overexploitation, Disturbance, Climate change, Biotic, Abiotic, Socio-economic, Data availability, Requirements for Protected Areas

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This report has been based on 1 new survey and partly the previous 4 surveys focussing on 26 Protected Areas, and thereby has been established with the strong support of a very high number of colleagues, being scientists, PA managers, or rangers of the Protected Areas, or scientists at institutions studying those PAs.

These colleagues are:

With respect to the last survey

Abel Ramoelo, Tiago Domingos, Caros Teixeira, Vânia Proença, Christina Marta Pedroso, Tiago Ramos, Lucian Simionesei, Lia Laporta, Felix Manuel Medina, Dimitris Poursanidis, Cláudia Carvalho-Santos, Joao Honrado, Ramona Viterbi, Cristiana Cerrato, Thomas Dirnböck, Johannes Kobler, Franziska Pöpperl, Ana Stritih, Juraj Svajda, Vladimir Klc, Emiliana Valentini, Orhideja Tasevska, Elizabeta Veljanoska Sarafiloska, Sasha Trajanovski, Suzana Patcheva, Goce Kotoski, Dafina Guseska, Monika Radevska, Ajman Almalla, Pablo Méndez, Constantin Cazacu, Sander Wijnhoven, Gerard Janssen, Lina Dikšaitė

With respect to the previous surveys

Philippe Isenmann, Clarisse Brochier, Brigitte Poulin, Hélène Fabrega, Julien Caucat, Marco Heurich, Christian Binder, Teresa Schreib, Florian Porst, Franziska Pöpperl, Hartmann Pôlz, Elmar Prôll, Regina Buchriegler, Simone Mayrhofer, Angelika Stûckler, Christoph Nitsch, Johannes Kobler, Johannes Peterseil, Stein Byrkjeland, Christian Rossi, Ruedi Haller, Ramona Viterbi, Bruno Bassano, Christiana Cerrato, Antonis Barnias, Antonis Tsakirakis, Dimitris Kontakos, Dimitris Poursanidis, Nektarios Chrysoulakis, Arthur Herbreteau, Zilvinas Grigatis, Lina Diksaite, Arturas Razinkovas Baziukas, Rasa Morkūnė, Robertas Kubilius, Jūratė Dulkytė, Arturas Razinkovas Baziukas, Rasa Morkūnė, Edgaras Ivanauskas, Irina Baran, Aurel Nastase, Cristina Despina, Adrian Burada, Mihai Marinov, Mihai Adamescu, Mihai Doroftei, Diana Bota, Eugenia Cioaca, Alexe Vasile, Constantin Cazacu, Asaf Tsoar, Amir Shafir, Daniel Orenstein, Pedro Azenha Rocha, Fernanda Rodrigues, Guilherme Santos, Vânia Proença, Carmen Cabrera, Blanca Ramos Losada, Havza Redzep Kakel, Antonio Baleski, Jasminka Trajkovska Momiroska, Orhideja Tasevska, Goce Kostoski, Sasha Trajanovski, Dafina Guseska, Suzana Patcheva, Elizabeta Veljanoska Sarafiloska, Trajce Talevski, Ajman Al Malla, Orhideja Tasevska, Goce Kostoski, Dafina Guseska, Suzana Patcheva, Elizabeta Veljanoska Sarafiloska, José Juan Chans Pousada, Guyonne Janss, Felix Manuel Medina, Antonio San Blas Alvaros, Angel Palomares Martinez, Juan Antonio Bermejo, Gerard Janssen, Lies van Nieuwerburgh, Paolo Lupino, Stefano Cresta, Emiliana Valentini, Anna Chiesura, Federico Filipponi, Fabrizio Piccari, Alma Rossi, Alessandra Nguyen Xuan, Marzia Mirabile, Astrid Raudner, Armando Loureiro, Luisa Jorge, Henrique Carvalho, Alexandre Oliveira, Ana Fontes, Claudia Santos, Salvador Arenas-Castro, Antonio Monteiro, Leo Adriaanse, Kees van Westenbrugge, Vladimir Klc, Anton Potas, Stanislav Rak, Margareta Malatinova, Juraj Svajda, Jaap van der Meer, Sander Wijnhoven, Arno Nolte, Matthias Jurek, Magnus Andresen, Carl Beierkuhnlein, João Honrado, Ana Stritih, Tessa Bargmann, Alex Ziemba, Francisco Bonet-García, Thomas Dirnboeck, Tiago Domingos, Javier Cabello, Pablo Mendez, Abel Ramoelo, Izak Smit, Antonello Provenzale, Lisette Luif, Laura Soissons

(details on the contributors to the 1st and 2nd surveys are mentioned in Hummel *et al.* 2017)

(details of participants in the 3rd and 4th surveys are presented in Hummel *et al.* 2018)

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Executive summary

The present report is deliverable 9.2 of the EcoPotential project, which is funded by the European Union's Horizon 2020 Programme under Grant Agreement 641762.

EcoPotential aims to blend Earth Observations from remote sensing and field measurements, data analyses and modelling of current and future ecosystem conditions and services. The project focuses its activities on a targeted set of on internationally recognized Protected Areas (PAs) in Europe, the majority being mountainous, semi-arid, and coastal areas, marked as a UNESCO World Natural Heritage Site, Biosphere Reserve, National Parks and/or Natura 2000 site.

In this report, an inventory and analysis of the Requirements and Quality of Protected Areas (PAs) on basis of the EcoPotential WP9 Essential Variables (EVs) and Important Variables (IVs), is presented. To this end, in addition to the major WP9 surveys (reported in Hummel et al. 2018, i.e. Deliverable 9.1) a dedicated survey was carried out in 2018 among participants to the previous surveys. PA managers and EcoPotential scientists were requested to indicate the availability of required data and their perception of the PA quality based on the EVs and IVs.

PA managers and scientists of 18 PAs, of which 16 European, and 2 near/in Africa, participated in the survey.

The level of the data availability as indicated by the PA managers and scientists was 62 % for the required (17) EVs and (13) IVs.

The environmental quality of the PAs was perceived as being in general average to good. It was shown that at higher data availability the quality of the PAs was perceived to be at a higher level. This urges for a high availability of data.

A set of additional requirements was derived from links with the IUCN reports on management effectiveness and from the earlier EcoPotential WP9 survey in 2017.

In summary the following requirements are recommended to be taken into account to ensure the environmental quality, and to allow for a proper management, of current PAs and for new PAs to be establish in future,:

- Assess the full range of 17 Essential and 13 Important Variables, including:
  - "Ecosystem Functions and Structure" variables on Habitat suitability, Biodiversity, Population dynamics, Primary production, Land- and sea-scape, Hydrodynamics, Gene pool, Climate regulation, Weather, Element cycling, and Secondary production.
  - "Ecosystem Services" variables on Leisure activities, Education and research, Habitat for feeding and breeding, Charismatic landscape, Biodiversity conservation, Charismatic species, Spiritual significance, Animals of economic use, and Climate regulation.
  - "Threats" variables on Overexploitation, Disturbance, Tourism, Change in species, Climate change, Bad management, Exotic species, Habitat loss, Change in land use, (Illegal) human activities.
- Acquire a high data availability for the EVs and IVs,
- Emphasise (and lobby for) rules, tools, and support embedded in directives and legislation at European or global level,
- Acquire a single integrated management authority and a high degree of autonomy for the PA management,
- Assess the political support and will,
- Acquire insight in the role and influence of the different stakeholders in the area,
- Reach a stronger harmonised indication with regard to the geographic delineation and the categorisation of the level of protection.

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1. Introduction

In a series of EcoPotential WP9 surveys during 2017 along a set of internationally recognised protected areas (PAs), including ecosystems in three domains of crucial interest to Europe, i.e. mountainous, semi-arid, and transitional water systems, the variables required to indicate the quality of the ecosystems and its biodiversity were selected (Hummel *et al.* 2018).

The PAs selected in EcoPotential span all of Europe and beyond, are characterized by widely different environmental conditions, and play a central role for conservation and management strategies in rapidly changing environments. The type of protection of the PAs includes primarily UNESCO World Heritage Sites and Biosphere Reserves, National Parks, Natura 2000 sites, and LTER sites (see table 2).

The variables selected by Hummel *et al.* (2018; i.e. EcoPotential Deliverable 9.1) characterise the ecological functioning and structure (EF), the ecosystem services (ES), and the pressures (Threats) acting on the PAs. The underlying measurements include a blend of Earth Observation data, both remote sensing and *in situ* field measurements.

The most important variables, judged to be required to indicate the PA quality, were called the Essential Variables (EVs), which were indicated to be of high or very high importance (4 resp. 5 at a scale from 0 to 5) in at least 75% of the (26) surveyed PAs. The Important Variables (IVs) were judged to be of high or very high importance in 50 to 75 % of the surveyed PAs.

The large suite of PAs surveyed (26) covering three different geographic domains, helped to sufficiently avoid idiosyncracies and to work out generality across a broad range of biogeographical settings and environmental conditions. Also because of their general occurrence in the majority of the PAs, it can be stated that the selected EVs and IVs form the preferable basis for further studies and comparisons on the current and future status and changes in the quality and requirements of PAs.

An overview of the required variables according Hummel *et al.* (2018) is given in appendix 1.

For a PA it would be optimal if the EVs and IVs with regard to EFs and ES are in an optimal state. For most variables this means often as high as possible, yet for some it follows an optimum curve; e.g. an increase of fish-catch or tourism as an ES may be seen positive, whereas above a certain threshold level it may become more and more negative. With regard to Threats the EVs and IVs would have to be as low as possible.

For assessing the quality of a PA through the required EVs and IVs as indicators, sufficient data are needed. In fact data-availability thereby becomes a requirement too.

To assess the present situation regarding the requirements and quality of PAs, and to assess what will be needed for the future, the managers and EcoPotential scientists of PAs were questioned on the availability of information regarding the EVs and IVs in their area. Therefore, in addition to the previous WP9 surveys, reported in Hummel *et al.* 2018, i.e. Deliverable 9.1, a subsequent dedicated EcoPotential WP9 survey (the fifth) was carried out in May 2018 among participants to the previous surveys. PA managers and EcoPotential scientists were requested to indicate the availability of data on these required EVs and IVs, and their perception of the PA quality based on these EVs and IVs.

The aim of this report , Deliverable 9.2, is to present an overview on the status of the data availability of the required EVs and IVs, and to assess, based on these variables, how the current quality of the PAs is perceived, as judged by the management of the PAs and by EcoPotential scientists of various PAs that participate in EcoPotential.

Moreover, a comparison is made with the management requirements for PAs as advised by IUCN, since some management requirements do link to the requirements as presented in this study, and also link to issues that were enquired about in the earlier surveys that may help to strengthen recommendations on the requirements for future PAs.

On the basis of the present findings, and discussions including IUCN recommendations, a final list of factors is presented that could be considered as a recommendation for future PAs, and also could be taken into account to compose in the next phase the Roadmap (Task 9.3).

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2. Material and methods

2.1 The fifth survey

The availability of concrete data on the various Essential and Important Variables (EVs and IVs) in the Protected Areas (PAs) participating in EcoPotential was assessed in the fifth EcoPotential WP9 survey during May 2018. The EVs and IVs were provided by Hummel et al. (2018) as being required for indicating the environmental quality status of PAs regarding their ecosystem functions and structures (EFs), ecosystem services (ES) and the threats. The PAs are located in 3 major domains, i.e. transitional waters (marine coastal waters, deltas, lagoons), mountains and semi-arid areas.

In this fifth survey, PA managers and EcoPotential scientists were asked to indicate whether concrete data regarding the EVs and IVs were actually available.

Moreover, they were asked to indicate, on the basis of the EVs and IVs to indicate how they perceived the quality of their PA.

An example of the survey is given in Appendix 2.

The participants in the survey were explicitely asked not to evaluate the usefulness or importance of the variable/proxy (because it was previously already agreed that these are very important variables), yet, next to whether data were available, how they score the situation in their PA once they had to use the specific variables in their PA as a quality measure. The valuation they had to use was ranging from 1 (the situation is very bad, i.e. the actual situation is very far from the desired situation) to 5 (the situation is very good, i.e. the desired situation or optimal reference level is reached).

In total 21 sureys were returned by PA managers and scientists of 18 PAs (table 1), of which 16 European PAs, and 2 near/in Africa.

2.2 The Protected Areas

Most Protected Areas surveyed are in Europe, and a couple are in or near Africa (figure 1).

All 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 1). Only Appia Antica did not have such a status and is a Regional Park, yet was included since it represents a PA with a very high socio-cultural value due to its history near Rome.

This broad range of PAs with different biogeographical settings and environmental conditions guarantees a proper overview of the major variables and outcomes that are important for environmental scientists and PA managers in Europe, as was also noted by Hummel *et al.* (2018) who stipulated "… because of the jointly high perception of importance of the selected .. variables, and their general occurrence in the majority of the PAs, they may form … the preferable basis for further RS and *in situ* studies and comparisons on the current and future status and changes in the quality and requirements of PAs.

The results thus do hold equally for PAs in Transitional Waters, Mountainous areas and lakes in those areas, and Semi-Arid areas.

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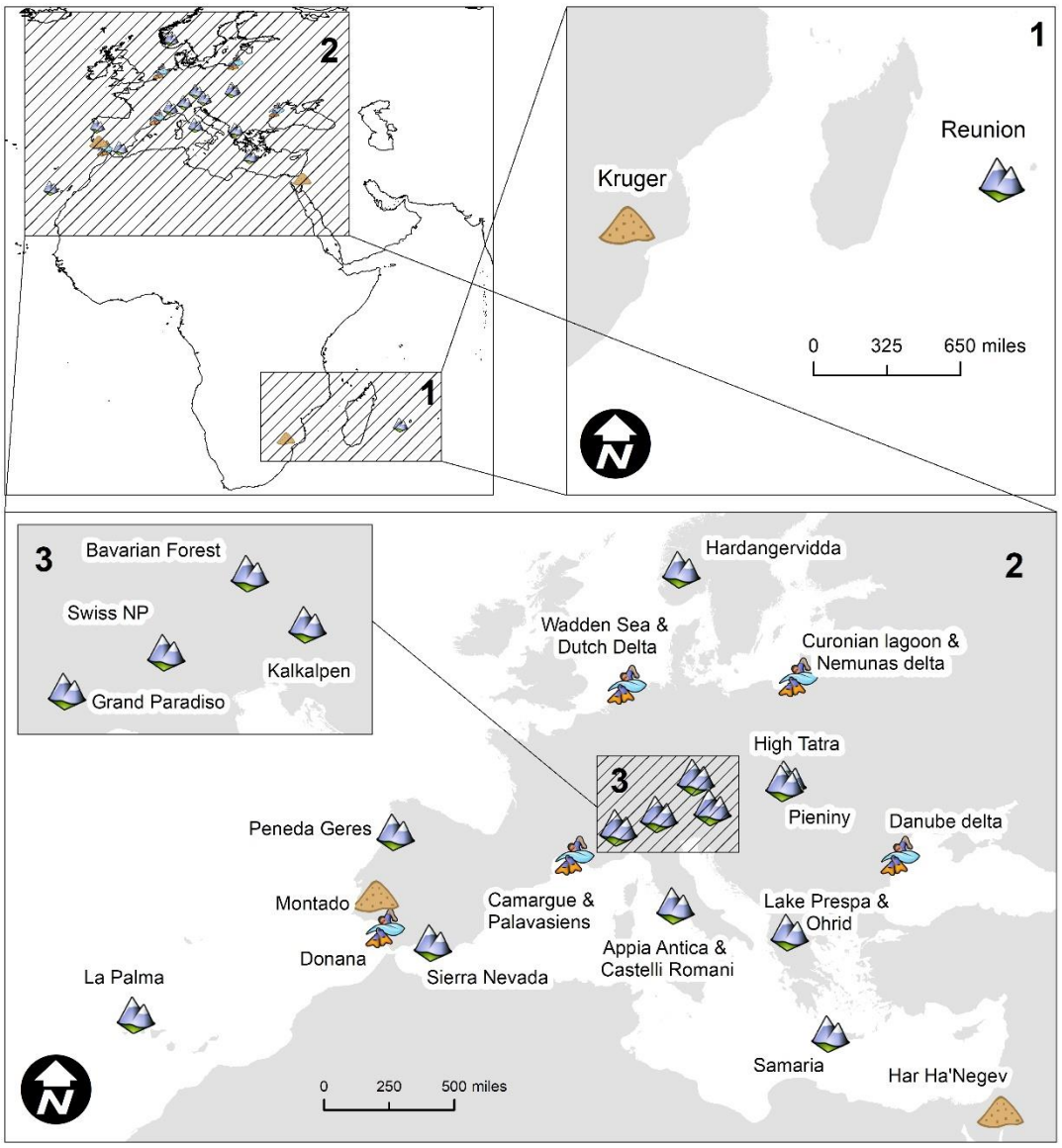

Figure 1: Overview of PAs surveyed in Europe and beyond. Mountain symbol = Mountainous PA, Wave symbol = Transitional Waters PA, Sand hill = PA in Semi-Arid area (graph composed by Dimitris Poursanidis, Foundation for Research and Technology, Crete, Greece).

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Table 1: PAs surveyed in the EcoPotential WP9 studies including country and Protection status.
The survey presented in this report is S5. The results of the other surveys are presented in Hummel *et al.* (2018).

	Country	Scientists			Managers			Protection status
		2015	2018	2018	2015	2017	2018	
		S1	S4	S5	S2	S3	S5	
Camargue	F	+			+	+		UBR, N2k
Curonian Lagoon	LT	+			+	+	+	NP, N2k, UWH
Danube Delta	RO	+	+	+		+		UBR, N2k, UWH
Doñana	E	+	+	+	+	+		NP, N2k, UBR, UWH
Eastern Scheldt*	NL	+	+	+		+		NP, N2k
Nemunas Delta	LT				+	+		N2k
Palavasiens	F					+		N2k
Wadden Sea	NL	+	+	+	+	+	+	NP, N2k, UBR, UWH
Western Scheldt*	NL	+		+				N2k
Samaria	GR	+	+	+	+	+		NP, N2k, UBR
Har Ha Negev	Isr					+		NP, UWH
Montado	P		+	+		+		N2k
Kruger	SA		+	+		+		NP, UBR
Appia Antica	I		+	+		+		**
Bavarian Forest	D					+		NP, N2k
Castelli Romani	I		+			+		N2k
Gran Paradiso	I	+			+	+	+	NP, N2k
Hardangervidda	N	+			+	+		NP
High Tatra	PL	+			+			NP, N2k, UBR
La Palma	E				+	+	+	NP, N2k, UBR
Kalkalpen	A	+	+	+	+	+	+	NP, N2k, UWH
Lake Ohrid	Mac		+	+		+		NP, N2k, UWH
Lake Prespa	Mac		+			+	+	***
Peneda-Gerês	P	+		+	+	+		NP, N2k, UBR
Pieniny NP	SK		+	+		+	+	NP, N2k
Reunion	F					+		NP, UWH
Sierra Nevada	E	+	+			+		NP, N2k, UBR
Swiss NP	CH		+	+	+	+		NP, UBR

S1 to S5 = EcoPotential WP9 Surveys nr 1 to 5; NP= National Park, UBR= UNESCO Biosphere Reserve, N2k= Natura 2000 site, UWH= UNESCO World Heritage; *The Western and Eastern Scheldt though separate water bodies are both part of the area called Dutch Delta; **Appia Antica is a Regional Park; *** Lake Prespa is in Greece and Albania a National Park, in Macedonia a Strict Nature Reserve.

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2.3 Calculations on data

For the data availability, questioned in the fifth survey among EcoPotential scientists and PA managers, for each EV and IV the 'yes, available' and 'no, not available' scores, and in some cases blank fields (called "no info"), summed up, reaching always the absolute value of 21 (equal to the number of surveys received back), and then transposed to 100 %. The relative scores were then 1) averaged per variable over all surveyed PAs, or 2) averaged per PA over all variables.

For the indication of the perceived environmental quality per variable in the PA, the PA managers and scientists were asked to give a quality score for each variable (EV and IV) using the standard 5 point Likert scale [Likert 1932]:

- 1 = the situation is very bad, i.e. the actual situation is very far from the desired situation, e.g. the environmental situation is at some parts highly impacted or even degraded, or an unacceptable socio-economic situation is created that impacts negatively the quality of the PA,
- 2 = the situation is still far from the desired situation but there is some hope for improvement,
- 3 = the situation is not good and not bad, i.e. almost acceptable but improvement can/should be made,
- 4 = the situation is good and almost, but not completely, the desired situation,
- 5 = the situation is very good, i.e. the desired situation (optimal reference level)).
- blank = no information available

The number of times a category was scored were summed up, reaching always the absolute value of 30 (equal to the number of EVs plus IVs), and then, without counting the blanks, transposed to 100 %. The relative numbers per score were then 1) averaged per variable over all surveyed PAs, or 2) averaged per PA over all variables.

Moreover, an average perceived quality per PA was calculated by means of a weighted multiplication of the value and the number of times it was scored, divided by the number of scores (max 30, without taking blanks into account).

The data and analyses of the fifth survey will be launched similarly through open access at publication in an international journal within the duration of the project.

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3. Results

3.1 Data availability

The response to the fifth survey covered the majority, yet not all, i.e. 18 out 26, PAs that have participated in the major third survey of EcoPotential WP9. These PAs are still covering all studied domains (mountains, transitional waters, semi-arid areas).

The availability of data per PA and per variable is indicated in Appendix 3, and is summarised and depicted in figures 2 and 3.

For the individual variable strong differences in data availability appear (Fig. 2). The highest data availability is found for 'Habitat suitability' (91 %), and the lowest for 'Gene pool' (14 %).

Though individual strong differences may occur, in general there is hardly any distinction in the degree of data availability between categories of variables. On an average the data availability for EVs is slightly higher than for IVs, 68 % versus 57 %. There is also hardly any difference between the availability of data for EFs (62 %), ES (65 %) or Threats (61 %). Nor is there a major difference between variables of abiotic nature (63 %), biotic nature (66 %), or of socio-economic nature (58 %).

The data availability may also differ strongly between PAs (Fig. 3), with the highest data availability found for the Kalkalpen and the Wadden Sea (90 %), and the lowest availability for Appia Antica (20%).

In general the data availability tends to be higher for the PAs in Transitional Waters (73 %) than in Mountains (52 %)(Fig. 3).

Figure 2: Data availability of the Essential Variables (EV; light blue shading) and Important Variables (IV; light green shading) for the Ecosystem Functions and Structures (EF), Ecosystem Services (ES) and Threats in Protected Areas (in green: percentage of variables for which data are available; in red: percentage of variables for which no data are available; in grey: percentage of variables for which not any information was given; A = Abiotic variable, B = Biotic variable, Se = Socio-economic variable).

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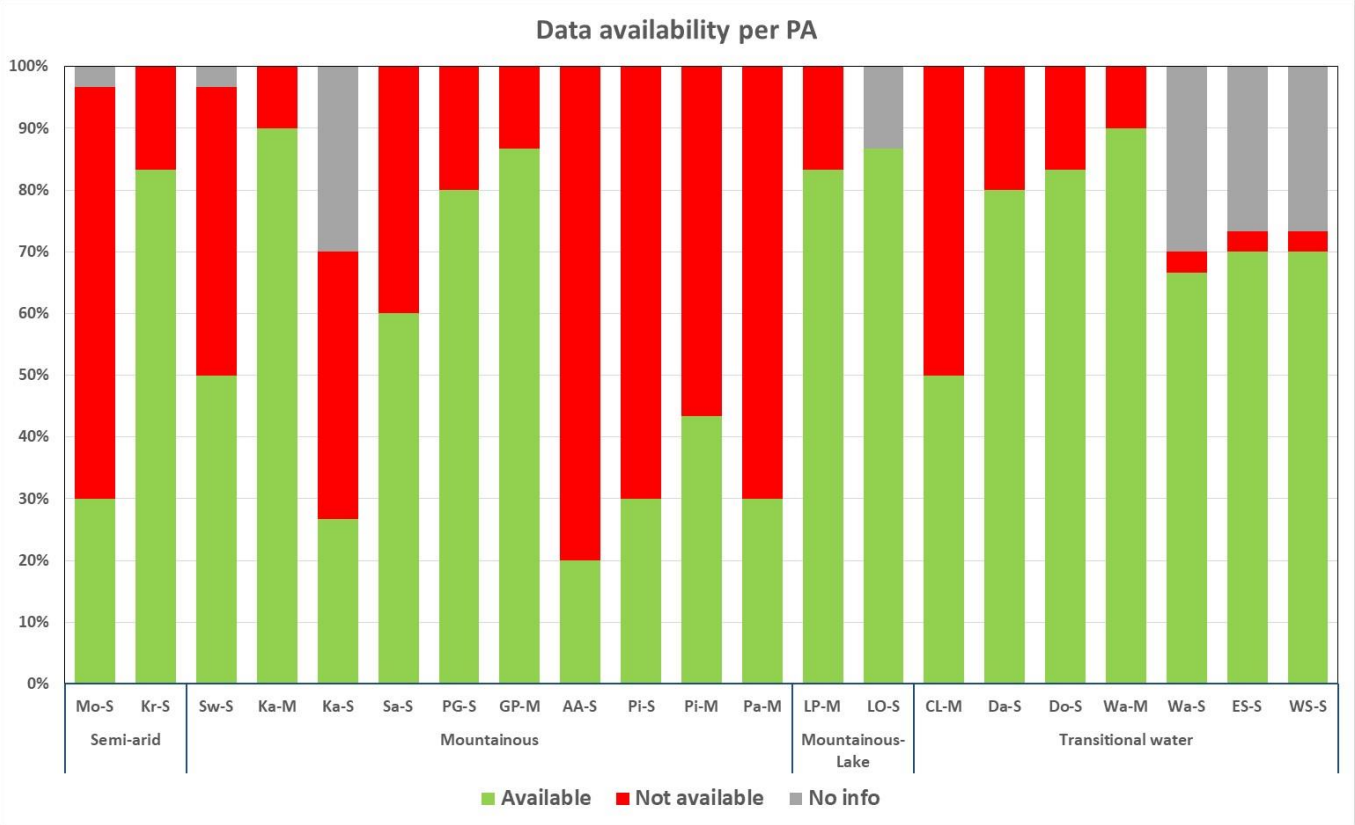

Figure 3: Data availability of the Essential Variables (EV) plus Important Variables (IV) for the Ecosystem Functions and Structures (EF), Ecosystem Services (ES) and Threats per Protected Area (in green: percentage of variables for which data are available; in red: percentage of variables for which no data are available; in grey: percentage of variables for which not any information was given; Mo = Montado, Kr = Kruger, Sw = Swiss NP, Ka = Kalkalpen, Sa = Samaria, PG = Peneda Geres, GP = Gran Paradiso, AA = Appia Antica, Pi = Pieniny, Pa = La Palma, LP = Lake Prespa, LO = Lake Ohrid, CL = Curonian Lagoon, Da = Danube, Do = Donana, Wa = Wadden Sea, ES = Eastern Scheldt, WS = Western Scheldt; -S = survey answered by scientist; -M = survey answered by PA manager).

3.2 Perception of the environmental quality of Protected Areas

The PA managers and EcoPotential scientists do perceive the environmental quality, based on the EVs and IVs, in general to be of average to good, i.e. the situation with regard to the EFs, ES and Threats in the PAs is almost acceptable but improvement can be made or it is almost, but not completely, the desired situation (Fig. 4).

There is hardly any difference in the perceived quality for any of the EVs or IVs, except for the quality of 2 more or less cultural elements, i.e. charismatic landscape and spiritual significance of the PAs, that are widely perceived as being of the highest quality.

Since hardly any differences on the basis of individual variables occured, also in general there is hardly any distinction in the degree of environmental quality between categories of variables. On an average the environmental quality for EVs is only slightly higher (3.5) than for IVs (3.3). There is also hardly any difference between the environmental quality for EFs (3.5), ES (3.6) or Threats (3.2). Nor is there a major difference in environmental quality variables of an abiotic nature (3.5), biotic nature (3.4), or of a socio-economic nature (3.4).

The perceived quality of the individual PAs does however differ strongly between the various PAs (Fig. 5). No obvious trends with geographic position, as latitude or domain, are visible.

The perceived quality of Kruger NP (score 4.9) and Swiss NP (score 4.8) are very good, i.e. equivalent to the desired situation and thereby of an optimal reference level. At the other hand for La Palma and Pieniny the perception of the environmental quality is still far from the desired situation but there is hope for improvement.

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The low perceived quality of the last 2 PAs may be partly connected to a low data availability (Fig. 6). With an increase of the data availability among the surveyed PAs the perceived quality of the PAs increased. This increase could be 1 point at the scale of 5 points in quality perception, and thus bring a PA from being perceived as of average quality to a PA being of good quality.

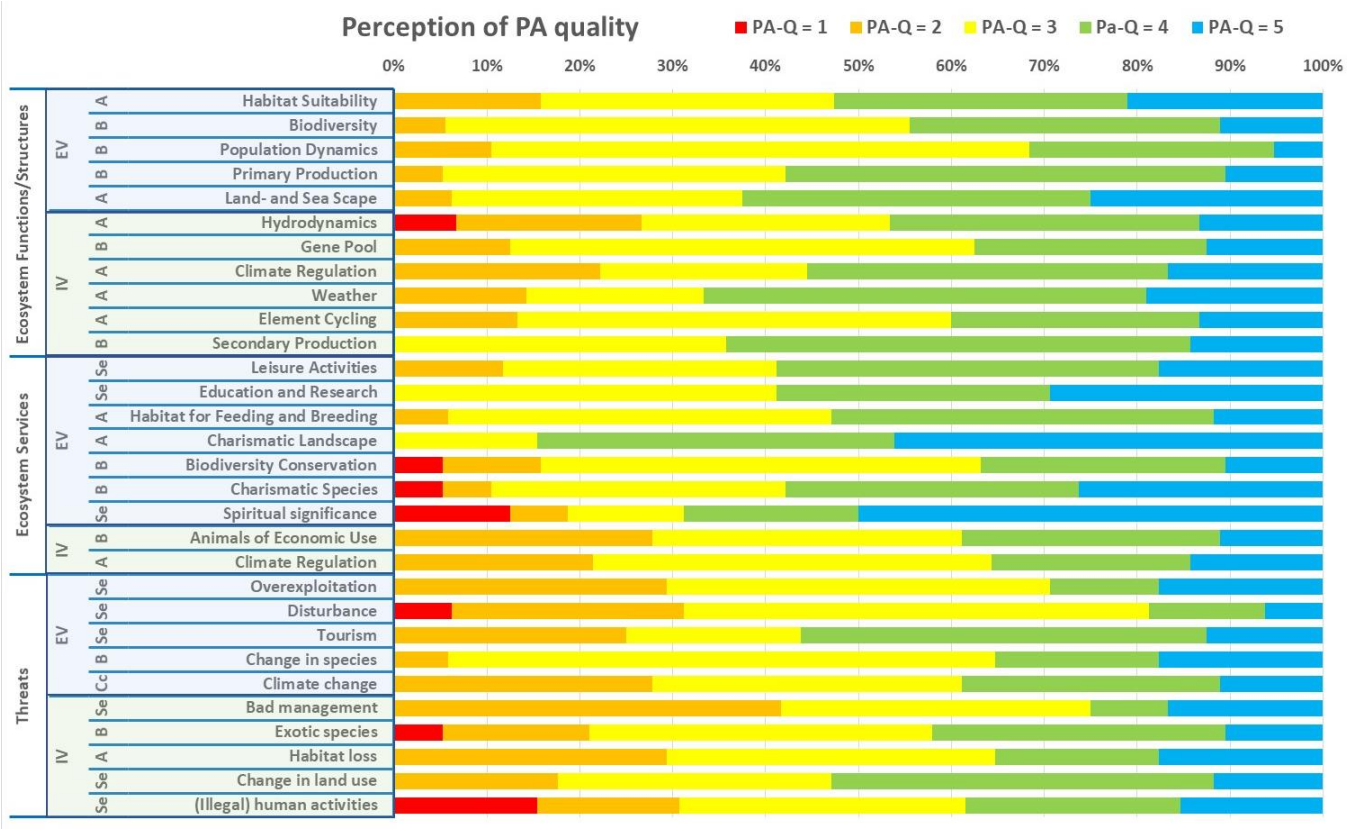

Figure 4: Perceived PA quality based on a scoring of the environmental quality status of the Essential Variables (EV; light blue shading) and Important Variables (IV; light green shading) for the Ecosystem Functions and Structures (EF), Ecosystem Services (ES) and Threats in Protected Areas (in red: percentage of variables for which a very bad score (1) was indicated; in orange: percentage of variables for which the situation is far from the desired (score 2); in yellow: percentage of variables for which the situation is not good and not bad, i.e. almost acceptable but improvement can/should be made (score 3); in green: the situation is good and almost, but not completely, the desired situation (score 4); in blue: percentage of variables for which the situation is very good; excluded are variables for which not any information was given; A = Abiotic variable, B = Biotic variable, Se = Socio-economic variable).

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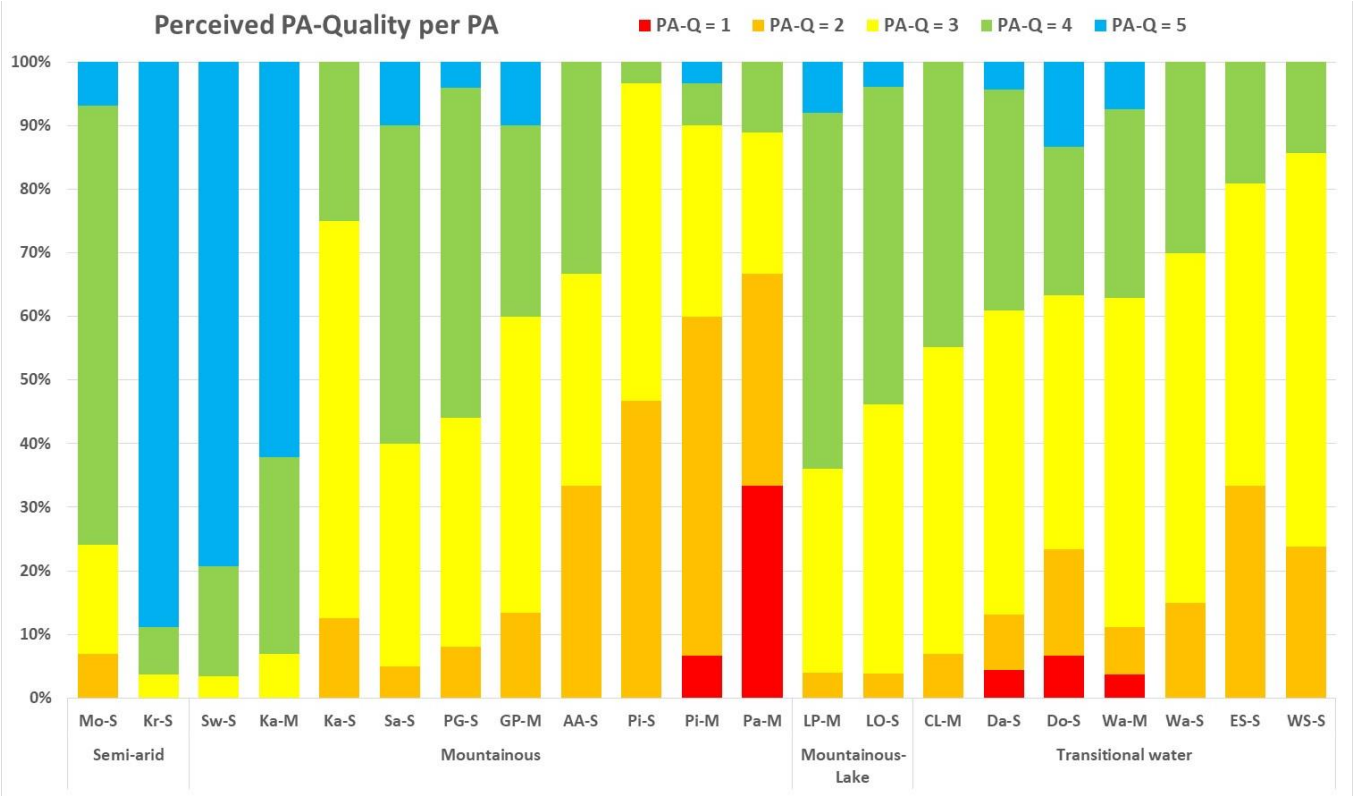

Figure 5: Perceived PA quality based on a scoring of the environmental quality status of the Essential Variables (EV; light blue shading) and Important Variables (IV; light green shading) for the Ecosystem Functions and Structures (EF), Ecosystem Services (ES) and Threats per Protected Areas (in red: percentage of variables for which a very bad score (1) was indicated; in orange: percentage of variables for which the situation is far from the desired (score 2); in yellow: percentage of variables for which the situation is not good and not bad, i.e. almost acceptable but improvement can/should be made (score 3); in green: the situation is good and almost, but not completely, the desired situation (score 4); in blue: percentage of variables for which the situation is very good; excluded are variables for which not any information was given; A = Abiotic variable, B = Biotic variable, Se = Socio-economic variable; Mo = Montado, Kr = Kruger, Sw = Swiss NP, Ka = Kalkalpen, Sa = Samaria, PG = Peneda Geres, GP = Gran Paradiso, AA = Appia Antica, Pi = Pieniny, Pa = La Palma, LP = Lake Prespa, LO = Lake Ohrid, CL = Curonian Lagoon, Da = Danube, Do = Donana, Wa = Wadden Sea, ES = Eastern Scheldt, WS = Western Scheldt; -S = survey answered by scientist; -M = survey answered by PA manager).

Figure 6: Perceived PA quality (scale 1 to 5) in relation to the data availability (as fraction of max 30 variables) (averages per PA; as linear regression r = 0,41, p= 0.06; as second order polynome r = 0,45, p = 0.04)

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4. Discussion

4.1 Level of participation

The response to the fifth survey covered the majority, yet not all, i.e. 18 out 26, PAs that have participated in the major third survey of EcoPotential WP9. The now participating PAs are still covering all studied domains (mountains, transitional waters, semi-arid areas), and thereby are expected to be sufficient representative.

This means however that the availability of data as we have found may in reality be lower, just because of not yielding any response to requests for data from several PAs. The graphs on data availability and the environmental quality may thus be different (coloured) then is now the case.

Nevertheless, the participation in the surveys remains much higher than expected (and contractually laid down for WP9). Instead of less than 10 PAs initially intended to be surveyed, finally 26 PAs were involved in the extensive third survey, and 18 in the final, fifth, survey, now including again some PAs that became interested in the research of EcoPotential after its start and participated without funding. This shows the strong interest in, and high relevance of, the aims and processes studied by EcoPotential.

4.2 Availability of data

On average, it can be stated that for about 60 % of the variables, required to indicate the environmental quality of a PA, data are available. Though a more ideal situation, with 100 % data availability might have been wished for, the situation of 60 % data availability, being roughly data for 18 out of 30 variables, is still a good start to evaluate the quality situation of a PA, and may yield a first glance on the quality status of a PA. As is clear that not 100 % of the required EVs and IVs can be supported with data, it may be debated to what extent it is allowable to have a lack of data. Expressed in a different way: What level of data availability is considered sufficient to indicate the quality of a PA? Further research on this issue has to be carried out to find a proper answer.

It is clear that a lack of data will, and does, hamper a proper evaluation of the environmental PA quality, as is also illustrated by the lower ranking of a PA once less data were available (Fig. 6). This shows that it is of utmost importance to have data available, and thereby factually a requirement, to reach a highly rated appreciation of a PA.

When overseeing the total pattern of data availability per category of variables (EFs <> ES <> Threats; or EVs <> IVs; or biotic <> abiotic <> socio-economic) then in general hardly any difference can be made in data availability. Only by summing up the gradual differences per category may yield some kind of difference: more data are available for the biotic Essential Variables of the Ecosystem Services (81 %), and less for the socio-economic Important Variables of the Threats (48 %). Yet, this may seem logical due to the aims of most PAs to protect nature, biodiversity, and/or socio-cultural values. Moreover, though cultural ES were considered generally most important for the PAs (Hummel *et al.* 2018) they are far less straightforward measurable than the biotic ES and therefore less data may be available for cultural ES. Similarly, this may be also a reason for the lowest data availability being found for socio-economic Threats, just because abiotic and biotic Threats are easier measurable than socio-economic threats.

The major differences in data availability for individual variables, as 91 % for 'Habitat suitability' and 14 % for 'Gene pool', may have to do with the degree of expertise and innovation needed to measure the variables. For example, 'Habitat suitability" can be scored with standardised classical research methods, such as the EUNIS habitat classification (Moss, 2008), whereas for 'Gene pool' more sophisticated techniques are required that will not be available for each PA.

As indicated in Hummel *et al.* (2018) the EVs as well as IVs can be both measured by means of Remote Sensing or *in situ* observation methods. However, as they have assessed (see their table 5) the majority of practical proxies and metrics underlying the variables, as proposed by the participans in the surveys, can be measured solely through *in situ* observation (about 70 %), partly by Remote Sensing as well as in situ observation methods (20 %), and the smaller part by solely Remote Sensing (10 %). Also in the case of the fifth survey, the majority of proxies indicated by particpants for the variables are to be measured with *in-situ* methods. This means that in order to increase the

data availability, and thereby to allow a proper vision on the environmental quality of current, or for future, PAs, the investment in *in situ* observations has to be intensified.

4.3 Perceived environmental quality of Protected Areas

Irrespective an only partial data availability, a reasonable vision on the environmental quality of most PAs could be reached. A score of "not good, not bad" to "good" for the PA quality is at the one hand positive, yet at the other hand it shows that improvements still can be made. Only 15 % of the PAs reached an average score of "very good". This also makes clear that a stronger view on the environmental quality of PAs, and availability of underlying data, is needed, instead of focussing PA evaluations mainly on the management efficiency (see chapter 4.4). This is also supported by the finding that with an increase of the data availability regarding the required EVs and IVs among the surveyed PAs also the perceived quality of the PAs increased. This increase could be 1 point at the scale of 5 points. The perception of PA quality follows thus also the rule "unknown makes unloved". For the management of current PAs, or for installing a new PA in the future, the availability of data on the EVs and IVs is thus of utmost importance.

We therefore conclude that sufficient information on the status and development of each of the 17 EVs and 13 IVs are required to yield a proper vision on the quality and management of a PA.

4.4 Comparison with IUCN tools on management efficiency of PAs

In a series of thorough reports, the IUCN is dealing with requirements for, and/or effectiveness of, the management or governance of a PA (Hockings *et al.* 2006, Dudley 2008, Appleton 2016). Since the subject that has to be managed is of course often of an environmental, socio-economic and/or cultural nature (Hockings *et al.* 2006), the IUCN reports and guidelines offer regularly a link with environmental or socio-economic requirements that may link to our search for such requirements, and thus may be taken into account. Especially regarding the part on the context of the management effectiveness evaluation cycle, i.e. the status and changes of the PAs, the basic elements acting in/on the PAs, such as the environmental and socio-environmental values and threats, come to the foreground (Hockings *et al.* 2006). Values and threats within the frame of management effectiveness can be similar variables as we have assessed to be essential, such as (the level of) biodiversity, population dynamics, landscape, tourism, spiritual significance, education and research as well as invading species.
Therefore, in the following paragraphs we will evaluate these relevant IUCN reports for our search on requirements for PAs (though stating clearly that we are in this deliverable not focussing on managerial requirements nor management effectiveness for PAs).

IUCN defines a PA as: A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley 2008).
As indicated by Dudley (2008) the definition of PAs is expanded by six management categories (one with a sub-division) as summarized below. The category should be based around the primary management objective(s), which should apply to at least three-quarters of the protected area (the 75 % rule).

- Ia. Strict nature reserve: Strictly protected for biodiversity and also possibly geological/ geomorphological features, where human visitation, use and impacts are controlled and limited to ensure protection of the conservation values
- Ib. Wilderness area: Usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, protected and managed to preserve their natural condition
- II National park: Large natural or near-natural areas protecting large-scale ecological processes with characteristic species and ecosystems, which also have environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities
- III Natural monument or feature: Areas set aside to protect a specific natural monument, which can be a landform, sea mount, marine cavern, geological feature such as a cave, or a living feature such as an ancient grove

IV Habitat/species management area: Areas to protect particular species or habitats, where management reflects this priority. Many will need regular, active interventions to meet the needs of particular species or habitats, but this is not a requirement of the category

V Protected landscape or seascape: Where the interaction of people and nature over time has produced a distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values

VI Protected areas with sustainable use of natural resources: Areas which conserve ecosystems, together with associated cultural values and traditional natural resource management systems. Generally large, mainly in a natural condition, with a proportion under sustainable natural resource management and where low-level non-industrial natural resource use compatible with nature conservation is seen as one of the main aims.

From these categories and the management criteria described in Dudley (2008) we at least can abstract some general requirements for PAs that touch on environmental or socio-economic variables as in our study:

- Exclusion or inclusion of socio-economic or cultural influences. Exclusion of socio-economic activities may yield the most strict protection category (Ia and Ib). With increasing level of human impact or socio-economic and cultural influence the protection category (mind: not the level of protection, which is reverse) is higher (though not following a linear relationship), with category 6 allowing for sustainable use of resources.
  This factor corresponds with most of the ES and Threats that are recognised in this report (and in Hummel *et al.* 2018) as EV or IV. For the IUCN categorisation, and its connected management, however, not only the factual uses and pressures, yet also the policy environment and political support will have to be captured to set the proper context for a PA. Also during the EcoPotential WP9 surveys of 2017 several PA managers indicated the need for a stronger political and policy support, preferably even at overarching European, for example at EC, level (as derived from question A.3.3 of the EcoPotential WP9 survey).
  We therefore note as a potential additional requirement for PAs to assess the political support and will, preferably at global or EC-level, in order to more or less mobilise, or if needed to exclude, economic or cultural influences from a territory being a current PA or from an area to become in future a PA.
- As part of the context of the PA management, it is needed to understand who is involved in, or affected by, the management.
  Among the interviewed PA managers this aspect was clearly acknowledged, whereby next to policy and political support, equally important was the involvement and sufficient support from other stakeholders, such as the local communities around the PA and the public at large (as derived from question A.8 of the EcoPotential WP9 survey). This may help to increase the support of a PA, or to prevent or to diminish eventual threats or exploitation or management practice that can be harmful to the objectives of the PA
  We therefore note as a potential additional requirement for PAs to acquire insight in the role and influence of the different stakeholders in the area.
- Clearly define the geographic space (3 dimensional) of the PA. To omit misinterpretations on what part of the area (with/without lakes, seafloor, air, ..) is intended and should carry which category of protection or what kind of management to apply in which part of the area.
  In the EcoPotential WP9 surveys of 2017 several PA managers, especially in the southern European countries, mentioned the vague geographic delineation and/or manifold of overlapping protection-categories in their PA (as derived from question A.1 of the EcoPotential WP9 survey), resulting in a lower impact of their management activities.
  We therefore note as a potential additional requirement for PAs a more harmonised indication with regard to the geographic delineation and categorisation of the level of protection for the current and future PAs. This does not mean that within a PA all territories should have the same category, they could differ, yet territories with different categories should not overlap with each other, and must have a logical geographical delineation from each other.

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4.5 Additional requirements revealed from the EcoPotential WP9 surveys, that may be addressed in order to increase the success of current and newly established PAs

In addition to the main requirements as derived from our studies, and those obtained from the IUCN reports, that did not specifically deal with requirements for the management, a couple of general issues will be addressed that were mentioned frequently by PA managers during the EcoPotential WP9 surveys as being essential boundary conditions for installing or safeguarding the ecological, socio-economic and cultural values of a PA:

- Emphasise (and lobby for) rules, tools, and support embedded in directives and legislation at European or global level (e.g. EC and UNESCO)(to ensure stability and to be less dependent on regional or national changing politics or policies (derived from question C.3 of the EcoPotential WP9 survey),
- Acquire a single integrated management authority and a high degree of autonomy for the PA management (derived from question A.3.4 of the EcoPotential WP9 survey). Otherwise, the ecological, socio-economic and cultural values of the PAs may be fragmented due to contrasting or even conflicting interests of various stakeholders, or due to the frequently changing national politics and policies regarding PAs.

4.6 Contribution to the knowledge output of EcoPotential

In this report, Deliverable 9.2, we address three out of six issues mentioned by Williams *et al.* 2017 (Deliverable 12.6) that are elementary in contributing to the knowledge output of the project and to the advancement of ecosystem studies and management of PAs:

- "Create a corpus of innovative, field-tested, peer reviewed and documented monitoring methodologies to define the ecological status of current and future protected areas, based on EO, both, remote and *in situ* data." The present report delivers part of that corpus, illustrating the use of the required EVs and IVs to indicate the environmental quality of PAs, which may be refined in next steps of the project
- "Address the issues related to cross-scale interactions and landscape-ecosystem dynamics, including biological, geomorphological, climatic, social and economic connections and emergent properties across scales and using concepts and approaches from the fields of Macrosystem Ecology."
  The standardised integrative and harmonised approach used in the previous and present report, resulting in a standard set of indicators and measure for ES, as well as the underlying EFs and eventually influencing Threats, present the issues potentially needed for defining the environmental and socio-economic interactions and connections across scales.
- "Quantify ecosystem services, taking into account social demand."
  In our report we have illustrated on which ES to focus in due consultation with the PA managers and scientists, taking into account environmental drivers as well as socio-cultural and economic demands and impacts.

This report thus fullfils a significant part of the core aims of the EcoPotential project.
We therefore can summarise that on basis of a standardised integrative and harmonised approach, taking into account environmental, socio-cultural and economic factors, WP9 selected and illustrated a concrete and robust set of indicators, the EVs and IVs, that are required to monitor the ecological status, ecosystem services, pressures, and changes, in PAs, enabling thereby PA managers and scientists of PAs to identify the current and future issues at stake and to plan the (adaptive) management for their area.

4.7 Recommendations

In summary, in order to ensure the environmental quality, and to allow for a proper management, of current PAs and for new PAs to be establish in future, we recommend to take into account the following requirements for PAs, as assessed and reviewed in this report:

- Assess the full range of 17 Essential and 13 Important Variables, including:
  - "Ecosystem Functions and Structure" variables on Habitat suitability, Biodiversity, Population dynamics, Primary production, Land- and sea-scape, Hydrodynamics, Gene pool, Climate regulation, Weather, Element cycling, and Secondary production

  - "Ecosystem Services" variables on Leisure activities, Education and research, Habitat for feeding and breeding, Charismatic landscape, Biodiversity conservation, Charismatic species, Spiritual significance, Animals of economic use, and Climate regulation
  - "Threats" variables on Overexploitation, Disturbance, Tourism, Change in species, Climate change, Bad management, Exotic species, Habitat loss, Change in land use, (Illegal) human activities
- Acquire a high data availability for the EVs and IVs. Though 60 % data availability on the required EVs and IVs gave in this report a good impression of PA quality, the required level for data availability should be determined in a further study
- Emphasise (and lobby for) rules, tools, and support embedded in directives and legislation at European or global level (e.g. EC and UNESCO)
- Acquire a single integrated management authority and a high degree of autonomy for the PA management
- Assess the political support and will to protect a specific area
- Acquire insight into the role and influence of the different stakeholders in the area
- Reach a more harmonised indication of the geographic delineation and the categorisation of the level of protection

As Apleton (2013) indicated for the Competence Register of PA managers also our recommendations on, and overview of, environmental, socio-economic and cultural requirements for PAs is designed as a "tool not rule", flexible and adaptable to local needs and priorities. The recommendations should be used as a guide for understanding and carefully acting, and not as a fixed rule that should be followed blindly.

4.8 Next steps towards a Roadmap for PAs

The results of this report on the environmental, socio-economic and cultural requirements for PAs may be a guide to further focus on the factors to take into account for Deliverable 9.3 (Task 9.2), i.e. the impact of changes. Moreover, this report may be a basic tool to address the major EVs and IVs in order to assemble the Roadmap for PAs (Deliverable 9.4) that may form a guideline for managers and policy involved in the management of PAs aiming to secure the best environmental quality in those areas and a sustainable use of its services (Task 9.3).

5. Rules for use of data (IPR, Privacy)

Due to the intense and detailed character of the queries of the EcoPotential WP9 surveys, a couple of special rules for the use of the data have been agreed. The most important rules are the following.

Regarding the Privacy, i.e. the use of Personal data, it was stated that: "The collected personal data information will never be provided to third parties without your explicit unambiguous consent." During the course of the survey the management of 4 PAs already on beforehand has stated that with regard to the use of Personal and/or General Data the free/open use/access of the data by third parties cannot be granted. The consequence is that the use of data from this report can be granted for part of the data only after consultation of the lead of the surveys, i.e. Herman Hummel of NIOZ

Regarding Copyright, it has been stated that the survey materials can be used solely with the permission of the responsible partners (Herman Hummel and Christiaan Hummel (NIOZ) and Rutger de Wit and Yolande Boyer (UMontpellier)), and that copies, adaptations, translations, edits, changes to all or part of the survey, in any form or by any means, are strictly prohibited, unless prior written permission has been granted by those responsible partners.

Therefore, although for most data holds that Open Access may be the case, for each (re-)use of data mentioned in this report, and in connected databases, the main lead of the surveys, Prof.Dr. Herman Hummel, of the NIOZ at Yerseke, NL (email: herman.hummel@nioz.nl), has to be contacted in order to clear any case of doubt on the use and copyrights of the data.

All underlying data and analyses of the first and second survey have already been made available through open access at https://doi.org/10.6084/m9.figshare.5513530.v1. The data and analyses of the third, fourth, and fifth survey will be made public through open access at publication in an international journal within the duration of the EcoPotential project.

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6. Acknowledgements

This report and the underlying surveys were made possible by funding received from the European Union's Horizon 2020 research and innovation programme under grant agreement No 641762.

As this report is also partly based on the earlier surveys held in EcoPotential WP9, as reported in Deliverable 9.1, we want to thank for their support to the five surveys the following colleagues: Abel Ramoelo, Tiago Domingos, Caros Teixeira, Vânia Proença, Christina Marta Pedroso, Tiago Ramos, Lucian Simionesei, Lia Laporta, Felix Manuel Medina, Dimitris Poursanidis, Cláudia Carvalho-Santos, Joao Honrado, Ramona Viterbi, Cristiana Cerrato, Thomas Dirnböck, Johannes Kobler, Franziska Pöpperl, Ana Stritih, Juraj Svajda, Vladimir Klc, Emiliana Valentini, Orhideja Tasevska, Elizabeta Veljanoska Sarafiloska, Sasha Trajanovski, Suzana Patcheva, Goce Kotoski, Dafina Guseska, Monika Radevska, Ajman Al Malla, Pablo Méndez, Constantin Cazacu, Sander Wijnhoven, Gerard Janssen, Lina Dikšaitė, Philippe Isenmann, Clarisse Brochier, Brigitte Poulin, Hélène Fabrega, Julien Caucat, Marco Heurich, Christian Binder, Teresa Schreib, Florian Porst, Hartmann Pôlz, Elmar Prôll, Regina Buchriegler, Simone Mayrhofer, Angelika Stûckler, Christoph Nitsch, Johannes Peterseil, Stein Byrkjeland, Christian Rossi, Ruedi Haller, Bruno Bassano, Antonis Barnias, Antonis Tsakirakis, Dimitris Kontakos, Nektarios Chrysoulakis, Arthur Herbreteau, Zilvinas Grigatis, Arturas Razinkovas Baziukas, Rasa Morkūnė, Robertas Kubilius, Jūratė Dulkytė, Arturas Razinkovas Baziukas, Rasa Morkūnė, Edgaras Ivanauskas, Irina Baran, Aurel Nastase, Cristina Despina, Adrian Burada, Mihai Marinov, Mihai Adamescu, Mihai Doroftei, Diana Bota, Eugenia Cioaca, Alexe Vasile, Asaf Tsoar, Amir Shafir, Daniel Orenstein, Pedro Azenha Rocha, Fernanda Rodrigues, Guilherme Santos, Vânia Proença, Carmen Cabrera, Blanca Ramos Losada, Havza Redzep Kakel, Antonio Baleski, Jasminka Trajkovska Momiroska, Trajce Talevski, Ajman Al Malla, José Juan Chans Pousada, Guyonne Janss, Antonio San Blas Alvaros, Angel Palomares Martinez, Juan Antonio Bermejo, Lies van Nieuwerburgh, Paolo Lupino, Stefano Cresta, Anna Chiesura, Federico Filipponi, Fabrizio Piccari, Alma Rossi, Alessandra Nguyen Xuan, Marzia Mirabile, Astrid Raudner, Armando Loureiro, Luisa Jorge, Henrique Carvalho, Alexandre Oliveira, Ana Fontes, Salvador Arenas-Castro, Antonio Monteiro, Leo Adriaanse, Kees van Westenbrugge, Anton Potas, Stanislav Rak, Margareta Malatinova, Jaap van der Meer, Arno Nolte, Matthias Jurek, Magnus Andresen, Carl Beierkuhnlein, Tessa Bargmann, Alex Ziemba, Francisco Bonet-García, Thomas Dirnboeck, Javier Cabello, Pablo Mendez, Izak Smit, Antonello Provenzale, Lisette Luif, Laura Soissons

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8. Glossary

EEVPA Essential Environmental Variables for Protected Areas (EVs and IVs of abiotic and biotic nature)

EF Ecosystem Functions and Structure

EO Earth Observation (includes Remote Sensing and *in situ* observation)

ES Ecosystem Services

ESVPA Essential Socio-Economic Variables for Protected Areas (EVs and IVs of socio-economic or cultural nature)

EV Essential Variable (variable in 75-100 % of PAs indicated as (very) important (score 4 or 5 in range 0-5))

IV Important Variable (variable in 50-75 % of PAs indicated as (very) important (score 4 or 5 in range 0-5))

PA Protected Area

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9. List of appendices

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9.1 Appendix 1. The selected Essential and Important Variables required to assess the quality of Protected Areas

Selected Essential Variables (EV; blue; high or very high importance, i.e. rating 4 or 5 at a scale from 0 to 5, in at least 75% of the 26 surveyed PAs) and Important variables (IV; green; high or very high importance, i.e. rating 4 or 5 at a scale from 0 to 5, in 50 to 75 % of the 26 surveyed PAs) of Biotic (B), Abiotic (A) or socio-economic (S) nature (after Hummel *et al.* 2018).

EV /IV	Variable	Alternative descriptions and examples	B/A/S
	Ecosystem Functions and Structures		
EV	Habitat suitability	Habitat availability, Feeding and breeding grounds, Ecotypes, Salinity	A
EV	Biodiversity	Status, Changes, Endemism, protected species	B
EV	Population dynamics	Recruitment, Reproduction, Pollination, Succession, Resilience, Predation	B
EV	Primary production		B
EV	Land- and sea-scape		A
IV	Hydrodynamics	Currents, Water flow, Water regulation and retention	A
IV	Gene pool	Genetic resources	B
IV	Climate regulation	Change of microclimate	A
IV	Weather	Temperature, Evaporation	A
IV	Element cycling	Biogeochemical cycling, Hydro-geo-eco processes	A
IV	Secondary production		B
	Ecosystem Services		
EV	Leisure activities	Recreation and tourism, Birdwatching	S
EV	Education and research		S
EV	Habitat for feeding and breeding		A
EV	Charismatic landscape		A
EV	Biodiversity conservation	Protection of species, habitat and genetic resources	B
EV	Charismatic species		B
EV	Spiritual significance		S
IV	Animals of economic use	Aquaculture, Bait, Beekeeping, Cattle, Fishing, Shellfish	B
IV	Climate regulation	incl. Carbon sequestration	A
	Threats		
EV	Overexploitation	Intensive agriculture, Overfishing, Too high tourist density	S
EV	Disturbance	Anthropogenic disturbance, Off-road vehicles, Transport	S
EV	Tourism	Recreational activities	S
EV	Change in species	Species loss, Successional stagnation, Aging of wild stocks, Prey decline	B
EV	Climate change	Change in snow cover, Droughts, Sea level rise, Global Warming	C
IV	Bad management	Inappropriate water management	S
IV	Exotic species	Invading species	B
IV	Habitat loss	Habitat fragmentation, Forest decay, Reduction of salt-marshes	A
IV	Change in land use	Abandonment of farming, Urbanisation, Harbour Extension	S
IV	(Illegal) human activities	Poaching, Picking of plants, Illegal logging, Illegal fisheries	S

9.2 Appendix 2. Example of fifth survey

Example of the fifth survey sent on May 4, 2018, to the PA managers and EcoPotential scientists working on Protected Areas, inventorying the data availability and PA quality based on the Essential and Important Variables (EV and IV).

(Explanation giving to the last column of the survey: You thus need not to valuate the usefulness or importance of the variable/proxy (because we all agreed that it are very important variables), yet if you could/would use this specific variable/proxy to measure the situation in your PA, how good or bad would your PA score then?
1 = is very bad, i.e. the actual situation is very far from the desired situation, e.g. the environmental situation is at some parts highly impacted or even degraded, or an unacceptable socio-economic situation is created that impacts negatively the quality of the PA,
2 = still far from the desired situation but there is some hope for improvement,
3 = not good and not bad, i.e. almost acceptable but improvement can/should be made,
4 = good and almost, but not completely, the desired situation,
5 = very good, i.e. the desired situation (optimal reference level))

	Variable	Examples / Synonyms	Indicators / proxies (to perform concrete measurements)		Do you have in your PA data for this variable and proxy	If yes, for which specific variable/proxy you have data		If you would valuate the situation or the quality in your PA by means of this variable how would the score for your PA then be (see explanation) 1 = very bad 2 = bad 3 = not good/not bad 4 = good 5 = very good
					Yes / No	Type of variable/proxy		Fill in a 1, 2, 3, 4 or 5
Ecosystem Functions								
EV	**Habitat Suitability**	Habitat availability, Feeding and breeding grounds, Ecotypes	Habitat classification (e.g. EUNIS), Carrying capacity					
	Biodiversity	Biodiversity status, Biodiversity changes, Endemism, Protected species	Shannon Index (H), Diversity Index					
	Population Dynamics	Recruitment, Seed dispersal, Predation, Reproduction, Pollination, Succession, Grazing	Vegetation cover changes, Population structure (age, sexes)					
	Primary Production	UNESCO World Heritage	Chlorophyll a, Net primary production					
	Land- and Sea Scape		Habitat heterogeneity (EUNIS)					

IV	**Hydrodynamics**	Currents, Water flow, Water regulation, Water retention	Snow depth & water content,Flow velocity, Tidal amplitude, Flood duration					
	Gene Pool	Genetic resources	Genetic diversity					
	Climate Regulation	Change of microclimate	Land or Sea Surface Temperature, Air temperature, Relative humidity					
	Weather	Temperature, Evaporation	Precipitation, Cloud cover, Wind speed, Air temperature, Snow depth					
	Element Cycling	Biogeochemical cycling, Hydro-geo-eco processes	Nutrient budgets in soil, Mineralisation rates C,N, Element budgets					
	Secondary Production		Standing stock of secondary producers, P/B ratio					
Ecosystem services								
EV	**Leisure Activities**	Recreation and tourism, Birdwatching	Number tourists + tourist days, Number of pleasure crafts					
	Education and Research		Number of educational visits, Funding (on basis of GNP), Number of scientific projects, articles, studies					
	Habitat for Feeding and Breeding		Number of offspring of indicator species, Breeding success of indicator species, Suitable habitat for indicator species					
	Charismatic Landscape	Aesthetic values, Cultural heritage, Iconic landscapes	Density of charismatic landscape elements, Percentage of undisturbed view, Perception by inhabitants / visitors					
	Biodiversity Conservation	Protection of species, Habitat and genetic resources	(Change in) Indicator species, Historical biodiversity index (HBI)					
	Charismatic Species		Number of charismatic species					
	Spiritual significance		Number of locations of spiritual significance					
IV	**Animals of Economic Use**	Aquaculture, Bait, Beekeeping, Cattle, Fishing, Shellfish	Livestock biomass					
	Climate Regulation	(incl. Carbon sequestration)	Oceanic carbon sink, Terrestrial carbon sink, Surface/Air temperature, Relative humidity, Light intensity, Windspeed					

Threats								
EV	**Over-exploitation**	(Intensive agriculture, Overfishing, Too high tourist density)	Percentage fish below reproductive size, Fishing and harvesting above MSY, Reduction of adult size, Desertification, Number of visitors above desired amount					
	Disturbance	Anthropogenic disturbance, Off-road vehicles, Transport	Landscape disturbance, Noise disturbance (in ocean or at land), Number of dams, Number of vehicles, Soil sealing, Number of pleasure crafts					
	Tourism	Recreational activities	Number of visitors, Money spent by visitors, Spatial patterns of visitors, Crowd photos analysis					
	Change in species	Species loss, Successional stagnation, Aging of wild stocks, Food competition with cultured species, Prey decline	Species community composition					
	Climate change	Change in precipitation or snow cover, Droughts, Sea level rise, Global Warming	(change in) Acidification, Sea level, Hectares of wildfires, Precipitation, Temperature, Snow cover					
IV	**Bad management**	Inappropriate water management	Quotum and harvest above MSY, Disproportional influence of stakeholders, Mismatch perception degree of corruption and political stability in PA vs country					
	Exotic species	Invading species	Invasive species					
	Habitat loss	Habitat fragmentation, Loss of connectivity, Forest decay, Reduction of salt-marshes	Reduction in habitat amount, Habitat fragmentation, Accessible habitat (connectivity), Number, size and isolation of patches					
	Change in land use	Abandonment of farming, Decrease of crops, Urbanisation, Harbour Extension	Detrimental land use/cover change, Rate of urbanisation					
	(Illegal) human activities	Poaching, Picking of plants, Illegal logging, Illegal fisheries	Number of ceased fishing nets/gears, Number of penalties by police/guards, Deforestation					

9.3 Appendix 3. Data availability on Essential and Important Variables (EV and IV)

Appendix B.1: Data availability as obtained from EcoPotential scientists (S) and PA managers (M) in the Mountainous domain during the survey of May 2018

Category	EV/IV	Type of variable	Variable	PA	La Palma	Samaria	Peneda Geres	Gran Paradiso	Kalkalpen	Kalkalpen	Swiss NP	Pieniny	Pieniny	Appia Antica
				M/S	M	S	S	M	S	M	S	S	M	S
				Domain	Mountainous									
Ecosystem Functions (EF)	EV	Abiotic	Habitat Suitability		Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
		Biotic	Biodiversity		No	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes
		Biotic	Population Dynamics		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
		Biotic	Primary Production		No	No	Yes	No	Yes	No	Yes	No	No	No
		Abiotic	Land- and Sea Scape		No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No
	IV	Abiotic	Hydrodynamics		No	No	Yes	Yes	Yes	Yes		No	No	No
		Biotic	Gene Pool		No	No	No	Yes	No	Yes	No	No	Yes	No
		Abiotic	Climate Regulation		No	Yes	Yes	Yes	No	Yes	No	No	No	No
		Abiotic	Weather		Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
		Abiotic	Element Cycling		No	No	No	Yes	Yes	Yes	No	No	No	No
		Biotic	Secondary Production		No	No	No	No	No	Yes	No	No	No	No
Ecosystem Services (ES)	EV	Socio-economic	Leisure Activities		Yes	Yes	Yes	Yes		Yes	Yes	No	Yes	Yes
		Socio-economic	Education and Research		Yes	Yes	Yes	Yes		Yes	Yes	No	No	Yes
		Abiotic	Habitat for Feeding and Breeding		No	No	Yes	Yes		Yes	No	Yes	Yes	No
		Abiotic	Charismatic Landscape		No	Yes	Yes	Yes		Yes	Yes	No	No	No
		Biotic	Biodiversity Conservation		Yes	Yes	Yes	Yes		No	Yes	Yes	No	Yes
		Biotic	Charismatic Species		Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	No
		Socio-economic	Spiritual significance		Yes	Yes	Yes	Yes		Yes	No	No	Yes	No
	IV	Biotic	Animals of Economic Use		No	Yes	Yes	Yes		Yes	No	No	Yes	No
		Abiotic	Climate Regulation		No	No	No	Yes	Yes	Yes	Yes	No	No	No
Threats	EV	Socio-economic	Overexploitation		No	No	Yes	No	No	Yes	No	No	Yes	No
		Socio-economic	Disturbance		No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No
		Socio-economic	Tourism		Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No
		Biotic	Change in species		No	No	Yes	Yes	Yes	Yes	No	No	No	No
		Climate change	Climate change		No	No	Yes	Yes	Yes	Yes	Yes	No	No	No
	IV	Socio-economic	Bad management		No	No	No	No	No	No	No	No	No	No
		Biotic	Exotic species		Yes	Yes	Yes	Yes		Yes	No	Yes	Yes	Yes
		Abiotic	Habitat loss		No	Yes	Yes	Yes	No	Yes	No	No	No	No
		Socio-economic	Change in land use		No	Yes	Yes	Yes	No	Yes	No	No	No	No
		Socio-economic	(Illegal) human activities		No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No

Appendix B.2: Data availability as obtained from EcoPotential scientists (S) and PA managers (M) in the Transitional Water domain during the survey of May 2018

Category	EV/IV	Type of variable	Variable	PA	Donana	Danube	Western Scheldt	Eastern Scheldt	Wadden Sea	Wadden Sea	Curonian Lagoon
				M/S	S	S	S	S	S	M	N
				Domain	Transitional Water						
Yes	EV	Abiotic	Habitat Suitability		Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Biotic	Biodiversity		Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Biotic	Population Dynamics		Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Biotic	Primary Production		Yes	Yes	Yes	Yes	Yes	Yes	No
		Abiotic	Land- and Sea Scape		No	Yes	Yes	Yes	Yes	Yes	No
	IV	Abiotic	Hydrodynamics		Yes	Yes	Yes	Yes	Yes	Yes	No
		Biotic	Gene Pool		No	No	No	No	No	No	No
		Abiotic	Climate Regulation		Yes	Yes	Yes	Yes	Yes	Yes	No
		Abiotic	Weather		Yes	Yes	Yes	Yes	Yes	Yes	No
		Abiotic	Element Cycling		Yes	No	Yes	Yes	Yes	Yes	No
		Biotic	Secondary Production		Yes	Yes	Yes	Yes	Yes	Yes	No
Ecosystem Services (ES)	EV	Socio-economic	Leisure Activities		Yes	Yes				Yes	Yes
		Socio-economic	Education and Research		Yes	Yes				Yes	Yes
		Abiotic	Habitat for Feeding and Breeding		Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Abiotic	Charismatic Landscape		No	Yes				No	Yes
		Biotic	Biodiversity Conservation		Yes	No	Yes	Yes	Yes	Yes	Yes
		Biotic	Charismatic Species		Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Socio-economic	Spiritual significance		No	Yes				Yes	No
	IV	Biotic	Animals of Economic Use		Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Abiotic	Climate Regulation		Yes	No				Yes	No
Threats	EV	Socio-economic	Overexploitation		Yes	Yes	Yes	Yes	Yes	Yes	No
		Socio-economic	Disturbance		Yes	Yes	Yes	Yes		Yes	No
		Socio-economic	Tourism		Yes	Yes				Yes	Yes
		Biotic	Change in species		Yes	Yes	Yes	Yes	Yes	Yes	No
		Climate change	Climate change		Yes	Yes	Yes	Yes	Yes	Yes	No
	IV	Socio-economic	Bad management		No	Yes				Yes	No
		Biotic	Exotic species		Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Abiotic	Habitat loss		Yes	No	Yes	Yes	Yes	Yes	Yes
		Socio-economic	Change in land use		Yes	No	Yes	Yes	Yes	Yes	Yes
		Socio-economic	(Illegal) human activities		Yes	Yes				No	Yes

Appendix B.3: Data availability as obtained from EcoPotential scientists (S) and PA managers (M) in the Semi-arid and Lakes domain during the survey of May 2018

Category	EV/IV	Type of variable	Variable	PA	Kruger	Montado		Lake Ohrid	Lake Prespa
				M/S	S	S		S	M
				Domain	Semi-arid			Mountain Lakes	
Yes	EV	Abiotic	Habitat Suitability		Yes	Yes		Yes	Yes
		Biotic	Biodiversity		No			Yes	No
		Biotic	Population Dynamics		No	No		Yes	Yes
		Biotic	Primary Production		No	No		Yes	Yes
		Abiotic	Land- and Sea Scape		Yes	No			Yes
	IV	Abiotic	Hydrodynamics		Yes	No		Yes	Yes
		Biotic	Gene Pool		Yes	Yes			No
		Abiotic	Climate Regulation		Yes	Yes		Yes	Yes
		Abiotic	Weather		Yes	No		Yes	Yes
		Abiotic	Element Cycling		Yes	No			Yes
		Biotic	Secondary Production		Yes	No		Yes	No
Ecosystem Services (ES)	EV	Socio-economic	Leisure Activities		Yes	No		Yes	Yes
		Socio-economic	Education and Research		Yes	No		Yes	Yes
		Abiotic	Habitat for Feeding and Breeding		Yes	No			Yes
		Abiotic	Charismatic Landscape		No	No		Yes	Yes
		Biotic	Biodiversity Conservation		Yes	No		Yes	Yes
		Biotic	Charismatic Species		Yes	Yes		Yes	Yes
		Socio-economic	Spiritual significance		Yes	No		Yes	Yes
	IV	Biotic	Animals of Economic Use		Yes	Yes		Yes	Yes
		Abiotic	Climate Regulation		Yes	No		Yes	Yes
Threats	EV	Socio-economic	Overexploitation		Yes	No		Yes	Yes
		Socio-economic	Disturbance		Yes	No		Yes	Yes
		Socio-economic	Tourism		No	No		Yes	Yes
		Biotic	Change in species		Yes	No		Yes	No
		Climate change	Climate change		Yes	Yes		Yes	Yes
	IV	Socio-economic	Bad management		Yes	Yes		Yes	Yes
		Biotic	Exotic species		Yes	No		Yes	No
		Abiotic	Habitat loss		Yes	Yes		Yes	Yes
		Socio-economic	Change in land use		No			Yes	Yes
		Socio-economic	(Illegal) human activities		No	No		Yes	Yes