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: D9.3 Overview of potential impacts of drivers of changes on the PAs

Due date of deliverable:	01/10/2018
Actual submission date:	After internal review, revised version 06/03/2019
Version:	V2

Main Authors: Rutger de Wit, Yolande Boyer, Herman Hummel, Valerie Kalle, Louise Bienfait, Christiaan Hummel

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

Project ref. number	**641762**
Project title	**ECOPOTENTIAL: IMPROVING FUTURE ECOSYSTEM BENEFITS THROUGH EARTH OBSERVATIONS**

Deliverable title	D9.3 Overview of potential impacts of drivers of changes on the PAs
Deliverable number	9.3
Deliverable version	1
Previous version(s)	-
Contractual date of delivery	01/10/18
Actual date of delivery	07/03/2019 revised version (after internal review): First submission 07/11/18
Deliverable filename	D9.3
Nature of deliverable	R = Report
Dissemination level	Public
Number of pages	
Workpackage	WP9
Partner responsible	CNRS
Author(s)	Rutger de Wit, Yolande Boyer, Valerie Kalle, Louise Bienfait, Christiaan Hummel, Herman Hummel
Editor	Rutger de Wit
EcoPotential Auditor	
EC Project Officer	Gaëlle Le Bouler

Abstract	The report comprises an inventory of drivers of changes in project PAs included in the story lines developed in the ECOPOTENTIAL project and complemented with PA manager interview findings.
Keywords	Drivers, Pressures, Threats, PA designations, perceptions, face-to-face interviews, PA managers

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

This report has been based on interviews 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 PA.

These colleagues are:

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

Table of Contents

1. Executive summary

The present report is deliverable 9.3 of the EcoPotential project, which is funded by the European Union's Horizon 2020 Programme under Grant Agreement 641762.

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

In Europe multiple designations are common for terrestrial and coastal PAs and this is also the case for most of the studied PAs. An analysis of creation dates, surfaces and subsequent extensions of PA designations showed that most areas are characterized by a nested organisation of PA designations whereby National and Regional Parks and Natura 2000 sites are combined with international designations such as UNESCO World Heritage Site and Biosphere Reserve. This results in institutional complexity and often in a nested structure of multiple designations, which may also present a public policy advantage with respect to spatial planning of conservation measures and sustainable development.

This report comprises an inventory of drivers of changes in project PAs included in the story lines developed in the ECOPOTENTIAL project and complemented with PA manager interview findings. The drivers have been grouped into six main categories based on a comparative analysis. The first two categories that are classically used in GIS and spatial modelling studies, i.e. 1) **Climate change** and 2) **Change of Land use** cover the majority of the reported drivers/pressures, with others represented by 3) **Pollution and nutrient over-enrichment**, 4) **Population growth/ tourism & recreation,** 5) **Invasive species and/or Pest species** and 6) **Fire risk.** These findings are very much in line with existing literature; the first two drivers also listed under the most relevant planetary boundaries (Rockström et al 2009). Except for climate change and tourism, all of these categories of drivers have also been listed as "impacts of human land use" in a major textbook on landscape ecology (Turner & Gardner, 2015, 2nd edition).

The categories 3) **Pollution and nutrient over-enrichment** and 4) **Population growth/ tourism & recreation** often demand analyses at a larger spatial scale covering an area much larger that the PA itself and its immediate surroundings as nutrients, pollutants and tourists travel over larger distances. The categories 5) **Invasive species and/or Pest species** and 6) **Fire risk** demand a more nuanced analyses as native pest species and a certain level of intensity of wildfires are often characteristic of the focal ecosystem and contribute to increasing biodiversity. In contrast, exotic species that become pest species and/or invasive and large-scale fires are a real problem for the PAs.

In this deliverable we analyse whether the threats to PAs perceived by the managers could be affiliated to one of the above-mentioned six direct drivers of change. These threats were identified in WP9 using a bottom-up approach with the managers (Hummel *et al.* 2018a,b, D9.1 and D9.2). Hence, among the top seven threats listed by the PA managers only three items could be related unequivocally to a main category of drivers - i.e. Change in land use, Tourism, Exotic species. The other items that could not be related unambiguously to a main category of drivers included - Bad management, Disturbance, Overexploitation, and Change in species. The latter could, however, in some cases be connected to 5) **Invasive species and/or Pest species.** Hence to a certain degree we identified a lack of congruency between drivers and threats identified by the scientists and the managers, respectively. This shows that a bottom-up approach is necessary in parallel with the theoretical frameworks to check that threats and pressures perceived as important by PA-managers are not overlooked and should be taken into account by the scientific community.

2. Introduction

The aim of this report, Ecopotential Deliverable 9.3, is to provide an inventory and categorisation of drivers of changes in PAs and to assess whether the categorisation can be operational for PA managers, for GIS and spatial modelling scientists and for the scientific community at large. This analysis was based to a large extent on a series of EcoPotential WP9 surveys, based on questionnaires and interviews realised during 2017 by WP9 scientists with PA managers during a workshop in Pisa (May, 2017) and on the spot in a set of internationally recognised protected areas (PAs). Furthermore the Ecopotential story lines were screened for drivers and pressures of changes. The Ecopotential PAs included ecosystems in the three domains of crucial interest to Europe, i.e. mountainous, semi-arid, and coastal systems (including marine and transitional waters) (Hummel *et al.* 2018a,b). The PAs selected in EcoPotential span 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 UNESCO World Heritage Sites and Biosphere Reserves, National Parks, Natura 2000 sites.

This report raises the question whether the categorisation of the drivers of change is congruent with the threats identified by PAmanagers during the interviews. This deliverable complements Hummel *et al.* (2018a), which is Deliverable 9.1, where a selection of variables has been presented to characterise the ecological functioning and structure (EF), the ecosystem services (ES), and the threats acting on the PAs. The underlying measurements include a combination of Earth Observation data, both remote sensing and *in situ* field measurements. Hummel *et al.* (2018b; i.e. EcoPotential Deliverable 9.2) presents an overview of the status of the data availability of required Essential Variables (EVs) and Important Variables (IVs), to assess on the basis of these variables how the current quality of the PAs is perceived, as judged by the management body of the PAs and by EcoPotential scientists from various PAs that participate in EcoPotential.

We analysed both the historical evolution and changing concepts with respect to PAs, the current interactions between scientists and PA managers, the way scientists are involved in the PA governance as well as the drivers of ecosystem changes and threats for the ecosystems in the PAs. The drivers of ecosystem changes were obtained from the eighteen Ecopotential storylines, the threats were abstracted from Deliverables 9.1 and 9.2. It was also necessary to briefly discuss what is meant by a “Driver” as no clear consensus on terms and definition exists in the scientific community. A final aim is also to contribute important elements of discussion that should be taken into account for task 9.3, i.e. A roadmap for Future PAs.

3. Methods

Twenty-six Protected Areas were considered for this Deliverable, twenty-two are in Europe, two are ultraperipheral territories of the European Union located in the Atlantic (La Palma Island of the Canary islands) and Indian (La Réunion island) oceans, one in the Middle-East (Negev desert) and one in South Africa (Krüger National Park) (figure 3.1). All areas but one 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 9.1). Only Appia Antica is classified as a Regional Park, but was included since it represents a PA with a very high socio-cultural value due to its history near Rome. The broad range of PAs with different biogeographic settings and environmental conditions supports a thorough 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.* (2018b) 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 for PAs in Transitional Waters, Mountainous areas and lakes in those areas, and Semi-Arid areas. Within the group of Mountainous areas, we created a new sub-group "Volcanic oceanic islands", i.e. La Palma and La Réunion islands, as these share some specific issues concerning drivers of change.

A first part is based mainly on the results from surveys with PA managers, which includes exchanges during the Pisa meeting (May 2017) and WP9 face-to-face interviews on site in the PA offices (2017 questionnaires and interviews. In this case the data base is restricted to twenty-five PAs, i.e., excluding the Krüger National Park for which we were not able to perform the interviews. These twenty-five PAs are listed in the Appendix Table 9.1. Historical developments, institutional organization and multiple designations of a PA has been retrieved mainly from the EcoPotential WP9 questionnaires of 2017, part A. In addition to the oral exchanges, the PA managers were requested to provide additional documents from which we extracted the factual information. On several occasions, such additional documents were available before the interviews. The information retrieved from such documents was used to pre-fill in the factual part of part A of the questionnaires. The correctness was checked with the interviewees, corrected if needed and finally approved by the PA managers. In contrast, all questions related to perceptions by PA managers were addressed during the face-to-face interviews only. The different designations for the PAs and the date of their creation/implementation are listed in Table 9.1 (in the Appendix) and graphically represented for a selection of PAs in the Result section (Figs. 4.1 and 4.2 as timelines). Designations have been categorized as 1- International (including both global as well as multilateral agreements except those of the EU), 2- European (i.e. derived from EU policies and EU directives), 3- National (within some countries the National Parks depend on an infra-national level, i.e. Autonomous communities (ES) and Länder (DE)), 4- Provincial (or anything equivalent according countries, i.e., Departments (FR)), 5- Municipal, with in addition a mention of NGOs.

A second part of the Results is based on a comparison of Ecopotential Storylines, DPSIR approaches described in WP7 (Deliverable 7.2, El Serafy et al., 2018) and results from the serious card game during the Pisa meeting and WP9 interviews (Hummel et al., 2018a,b, Deliverables 9.1 and 9.2). The eighteen storylines analysed are listed in Table 2.1, and corresponded to seventeen pilot PAs (Sierra Nevada appears two times in Storyline 12 and 13). Seventeen of the storylines could be compared with the results from the WP9 surveys. In the ECOPOTENTIAL project a general template was followed for the writing of the storylines. According this template the authors of the storylines were requested to provide a Table listing the main "divers of change/pressures that can describe the main human-induced pressures" clearly linking this to the DPSIR approach (European Environment Agency, 1999). This Table was used to compile Table 9.2. The term used in the storylines were attributed to a category constructed from a comparative analysis (see Results).

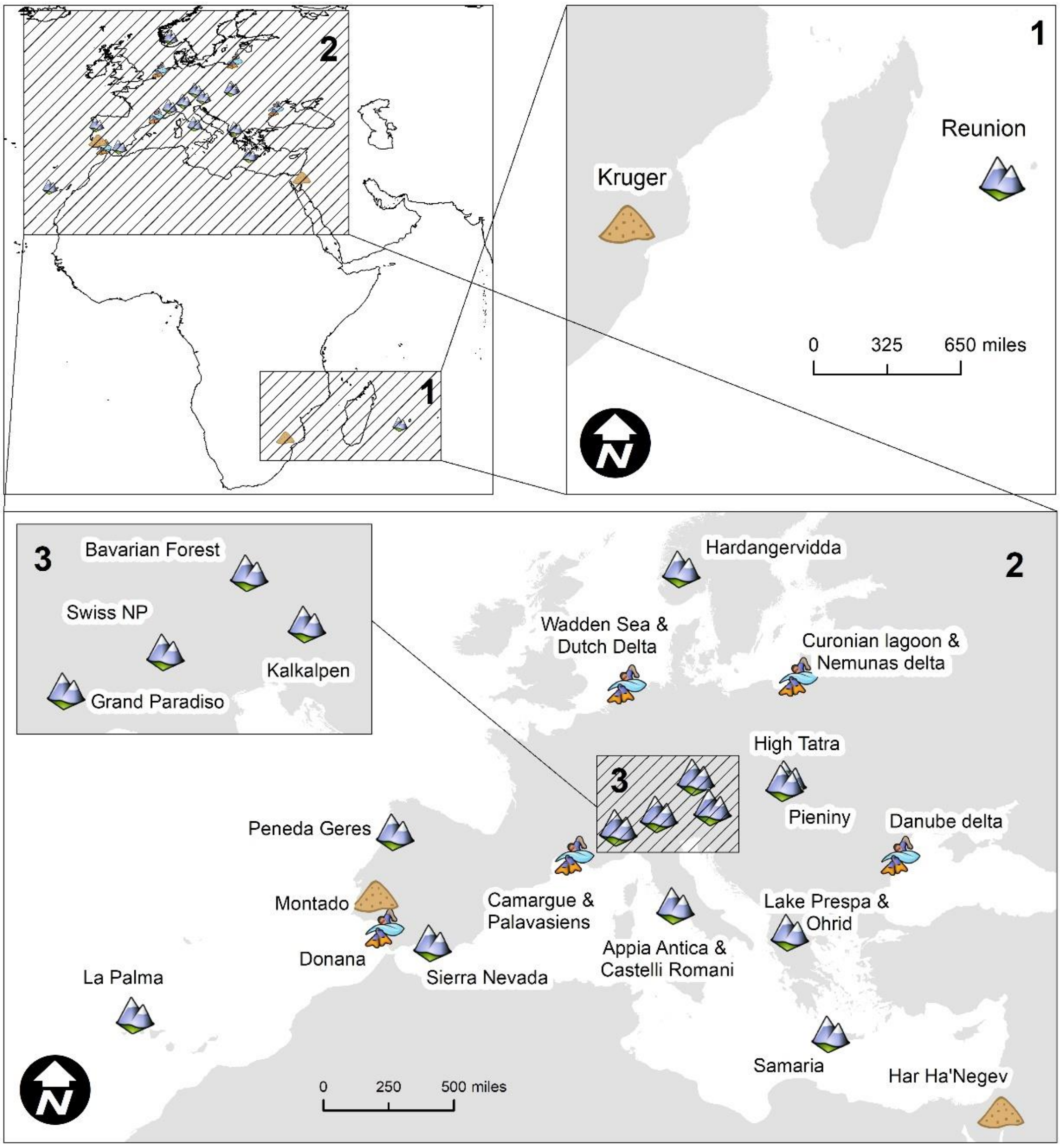


Figure 3.1: Overview of PAs surveyed in Europe and beyond. Mountain symbol = Mountainous PA, Wave symbol = Transitional Waters PA, Sand hill = PA in Semi-Arid area (graph composed by Dimitris Poursanidis, Foundation for Research and Technology, Crete, Greece).

Co-funded by the European Union

Table 2.1: List of Storylines analysed

N°	Title of the storyline	Pilot PA (Country ISO 3166-1 alpha-2 codes)
1	Impact of residential settlements on the life supporting capacity of Har HaNegev arid environment	Negev (IL)
2	Spatial-temporal dynamics of savanna ecosystems (tree-grass interactions, grass quality/quantity, biodiversity) as a life support system to wildlife and livestock production in and around Kruger National Park	Kruger NP (ZA)
3	Interaction between agro-ecosystems and natural grasslands: stone graining and loss of natural ecosystems	Alta Murgia NP (IT)
4	"Mediterranean wood-pasture for people and nature"	Alentejo Natura 2000 sites (PT)
5	"Dynamics of high-altitude environments as a life-support system to wild herbivores: carbon and moisture cycling, biodiversity and landscape modification"	Gran Paradiso NP (IT)
6	Managing mountain forests undergoing changing disease / disturbance dynamics	Northern Limestone National Park, Austria (AT)
7	Interaction between climate change driven bark beetle outbreaks and forest decline and nitrogen deposition driven inertia in ecosystem succession in mountain ecosystems	Bavarian Forest NP (DE)
8	Mountain Biodiversity as a sentinel of environmental change	Gran Paradiso NP (IT)
9	Ecosystem services and biodiversity crisis across mountain lakes	Ohrid/Prespa, Gran Paradiso NP (MK ,IT)
10	Comparing ecosystem services provided by protected areas with non-protected areas in mountainous areas of Europe using EO	Swiss NP (CH)
11	Vegetation Dynamics as a Proxy of Socio-ecological Transitions and Future Societal Benefits in Mountain PAs	Peneda-Gerês (PT)
12	Ancient irrigation channels as management tools to buffer the impact of climate change in Sierra Nevada ecosystem services	Sierra Nevada NP (ES)
13	Temporal evolution of ecosystem services in Sierra Nevada	Sierra Nevada NP (ES)
14	Improving coastal lagoon benefits under multiple pressures	Waddenzee (NL)
15	Conserving dynamic wetlands under combined global, regional and local stressors	Camargue (FR)
16	Conserving dynamic wetlands under combined global, regional and local stressors	Doñana (ES)
17	The impact of aquatic ecosystems provisioning services on tourism	Danube Delta (RO)
18	Invasive species impacting the functioning and services of island protected areas through losses of endemic species.	La Palma (ES)
	Legend color coding:	Semi-arid to arid area
		Mountainous area
		Transitional waters/coastal ecosystems

4. Results

4.1 Results from interviews with PA managers

4.1.1 Institutional changes, spatial planning policy and impacts for Protected Areas

The institutional structure of the PAs, together with spatial planning policy and other aspects of public policy have a strong impact on the organization, governance and management of the PAs and particularly the way how the PAs and their surrounding territories cope with changing environmental drivers. In Europe, multiple overlapping designations of PAs are common (Deguignet et al., 2017) and multiple designations are also common for the PAs included in Ecopotential (Hummel et al., 2017). The institutional organization and the multiple designations of a PA may be strong drivers of change in PA management, or exactly the opposite by restricting changes, and is consequently of influence on the PA quality.

Here, we present a description and analysis of historical developments, in order to better understand whether the institutional organization, including the level at which the designation is issued (International, National, Regional, Provincial, Municipal or by private NGO's), and multiple designations of a PA, impact the PA management and either promote or restrict the impact of drivers of change.

Box 4.1. Ten criteria for establishing a World Heritage Site (WHS), adopted since 2005. The four criteria related to nature conservation and biodiversity, so-called natural criteria, are written in green.

(i) to represent a masterpiece of human creative genius;

(ii) to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design;

(iii) to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;

(iv) to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;

(v) to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change;

(vi) to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this criterion should preferably be used in conjunction with other criteria);

(vii) to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;

(viii) to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;

(ix) to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals;

(x) to contain the most important and significant natural habitats for *in-situ* conservation of **biological diversity**, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

Since the 1970's and increasingly so since 2000, many selected PA's benefit from international designations (UNESCO World Heritage site, Man and Biosphere programme - UNESCO Biosphere reserves and Ramsar for wetland sites) and European (Natura 2000) designations. National Parks have been created early in the 20th century in some countries (e.g., Switzerland, Italy, Spain), while the status of a National Reserve was the first designation for a part of the Camargue (FR). National Parks are often considered as IUCN category II, with the exception of the Swiss National Park considered as IUCN category I.

At the international level, the Man and Biosphere programme (MAB) was launched by UNESCO in 1971, with the creation of a World Network of Biosphere Reserves since 1976 (comprising in April 2018 669 sites in 120 countries with fourteen transboundary sites). Ten of twenty-five Ecopotential sites obtained the MAB Biosphere

Reserve designation during a period which ranged from 1977 for the earliest (Camargue) and 2014 for the latests (Ohrid and Prespa). In addition, five of these MAB Biosphere reserves benefitted from extensions after 2006 (see Table 9.1). The World Heritage Convention (WHC) was adopted in 1972, representing the starting point for the creation of UNESCO World Heritage Sites (WHS) and links together the concepts of nature conservation and the preservation of cultural properties. Since 2005, with the adoption of the revised operational guidelines for the implementation of WHC, now ten criteria exist, among which four natural criteria; criterium #10 mentions biodiversity explicitly (see Box 4.1). Among the twenty-five PAs, eight benefit from the WHS designation, these have been created between 1993 (Danube Delta) and 2017 (Kalkalpen), while some have also benefitted from extensions. The Ramsar convention was adopted in 1971 and came into force in 1975. Among the studied twenty-five PAs, the Waddenzee was the first that has benefitted from the Ramsar designation since 1984.

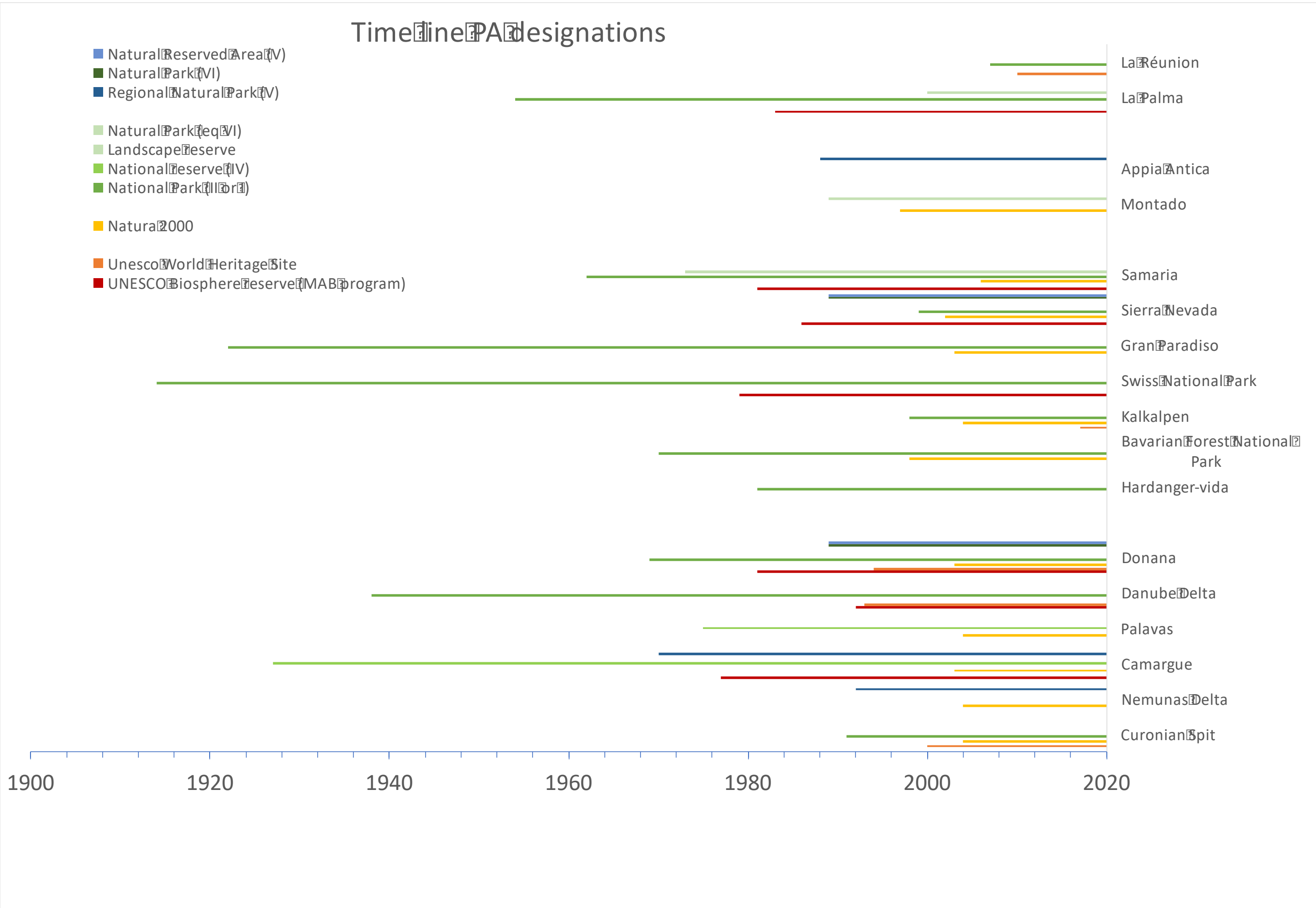


Fig. 4.1: Timeline of PAs designations for a selection of sites since 1900.

Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. It stretches across all 28 EU countries, both on land and at sea. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive (SCI=Site of Community Interest) and the Habitats Directive (SAC=Special Area of Conservation) (http://ec.europa.eu/environment//nature/natura2000/index_en.htm). The Natura 2000 PAs have been implemented between 1997 and 2006.

Different regional designations have been issued such as Regional Nature Park and Natural Reserve Area (IUCN category V) and Natural Parks (IUCN category IV). In addition, some areas benefit from municipal or provincial designations and some areas are privately owned by NGOs that have Nature Protection as a major aim.

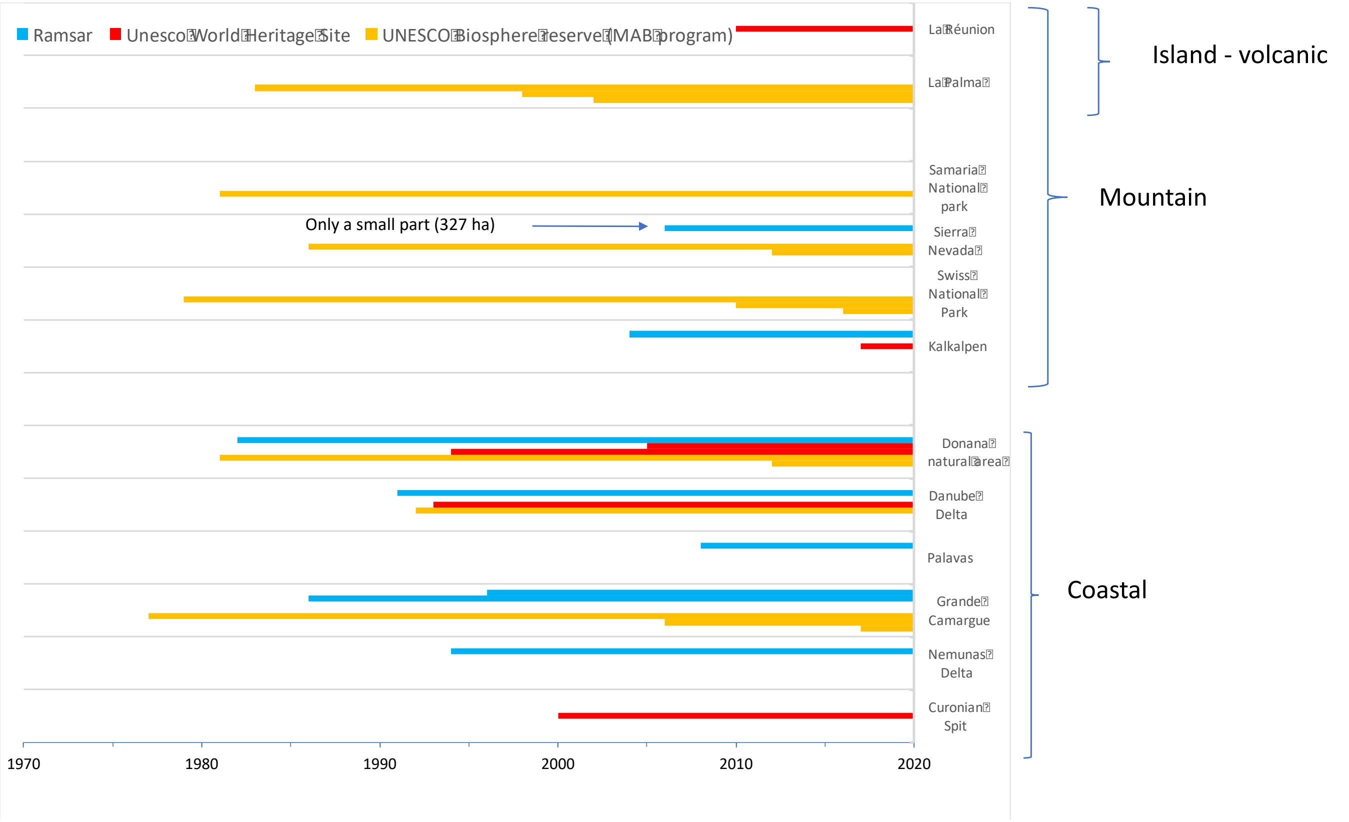


Fig. 4.2: Timeline since 1970 of international and European PA designations for selected EcoPotential PA sites. Extensions of areas under a given designation are indicated as a thickening of the lines. (La Réunion Island and Isla La Palma have been originally included in the mountainous systems, but also share the specificity of being volcanic islands).

Box 4.2 IUCN categories (mainly related to the PA management objectives (see Dudley, 2008)

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.

The above mentioned historical process has resulted in overlap of designations and multiple designations for large areas as highlighted by Deguignet et al. (2017) and most often in a nested organization of the different PA designations. Thus several sites (e.g. Camargue, Isla de la Palma, Swiss National Park, Ile de la Réunion, Curonian spit) show local, regional, national and European PA designations nested within International PA designations, that often cover larger areas than the earlier designations (see Fig. 4.3). For the Waddenzee even a whole network of PAs is imbricated within the Trilateral Treaty.

From the interviews and provided documentation it became apparent that a nested organisation is used in public policy to enlarge the protected area's coverage and organize it with a central zone and buffer zones, combined with areas where important human uses are planned according the principles of sustainable development. The latter should also be compatible with the main biodiversity conservation objectives. A nested organization has also been used as a solution for problems created by administrative boundaries and allowed to create transboundary PA's. Nevertheless, the trade-off of such a nested organization appears to be institutional complexity with working methods that are often different among the organisations in charge of the different PA's nested within the main PA structure.

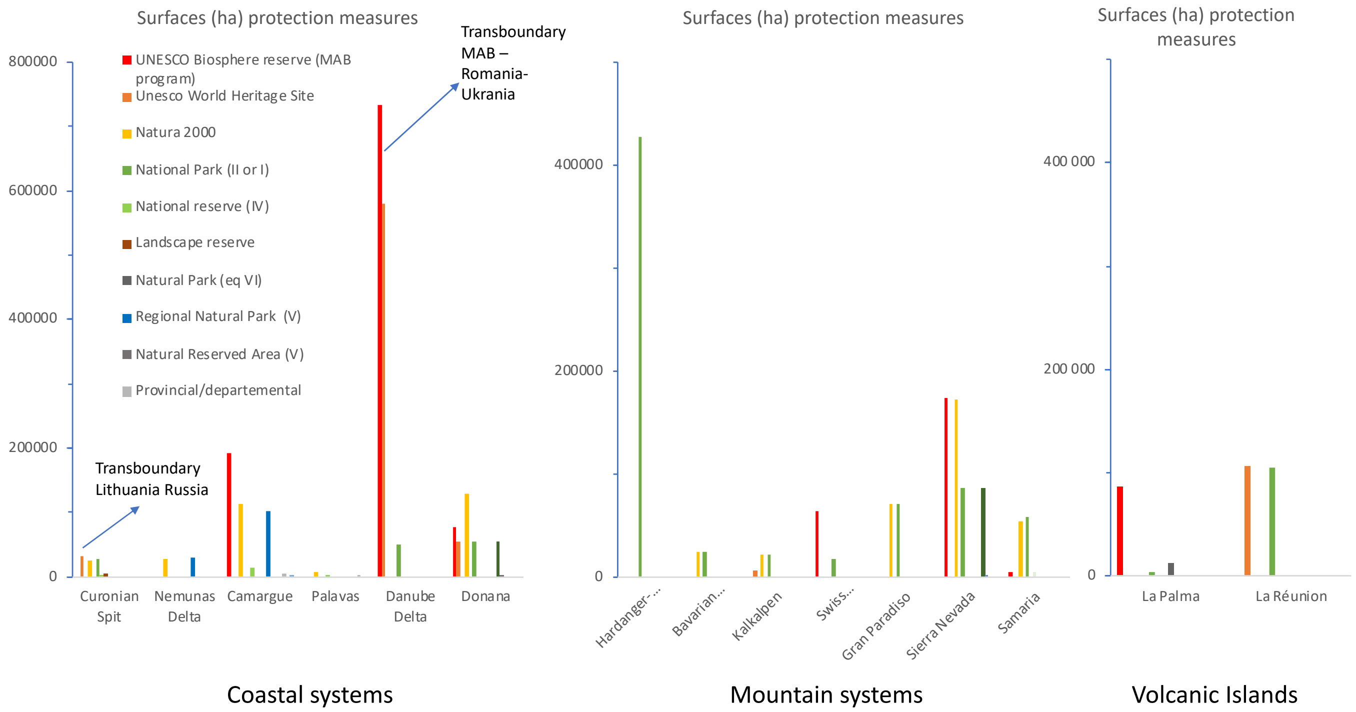


Fig. 4.3: Surfaces of the different PA designations for a selection of ECOPOTENTIAL PAs. This shows that the UNESCO designations and sometimes (e.g. Doñana and Sierra Nevada) the Natura 2000 designations cover larger areas than the national and regional designations. This is explained by the fact that the national and regional PA designations are often nested within the larger areas corresponding to the UNESCO and Natura 2000 designations.

It is, however, not strictly necessary that all the different PA designations in a given territory are managed by different management bodies as a single management body can be mandated for the management of multiple PAs with different designations. Examples of this are in Andalucía Spain, where the management of the National Parks, Doñana and Sierra Nevada are also responsible for the management of the adjacent Regional Natural Parks and the Natura 2000 sites included inside both the PN and the RNPs.

The chronology of PAs has been described in a historical political ecology context by Vaccaro et al. (2013) and from a socio-ecological point of view by Palomo et al. (2014). Hence, Vaccaro et al. (2013) describe how the original PA design was mainly conceived as a fortress of conservation, i.e., “the Yellowstone model”, based on excluding as much as possible human impacts and thus often resulting in conflicts with local populations that have been excluded and deprived of traditional resource uses (Brockington & Igoe, 2006). As this approach received a lot of criticism (and faced protests), later a so-called co-management concept was promoted for the PAs which allows for resource exploitation by local populations as far as it is sustainable. This last concept recognises that local communities have often played a major role in shaping and managing different habitats and environments within the PA and co-management often aims to use the PA for sustainable development (Berkes, 2007). A final stage appeared particularly after the economic crises of 2008, the so-called neoliberal conservation based on using market principles for gaining income for the maintenance and management of the PAs (Vaccaro et al. 2013).

Palomo et al. (2014) described how the original strategy can be considered as an island approach, which is equivalent to the fortress conservation *sensu* Vaccaro et al. (2013) or the Yellowstone model. Since the 1990’s this approach evolved into the Network Approach which focuses on the importance of connectivity and linking the different PAs through ecological corridors. Later the so-called landscape approach became in vogue and finally the authors plead for implementing a so-called social-ecological approach.

The neoliberal approach thus appeared as a result of thinking in terms of economic sustainability of PA management and conservation in general. On a global scale, it has resulted in privatization of some of the PAs and dismantlement of the existing public PA management structures (Vaccaro et al. 2013). In this respect, the EcoPotential questionnaires in 2017 revealed that 3 out of 26 interviewed management structures are private (Swiss National Park, Kalkalpen and Samaria), though the stockholders are still in every case public bodies (state, regional). Moreover, a mix of public and private management bodies is used for managing the Dutch Waddenzee, where parts of the territory are owned and managed by an NGO (Natuurmonumenten), and the Staatsbosbeheer management body that has been partly privatized. We explored whether some market-based mechanisms have been used to contribute to financing the management of the PA, i.e. by asking the PA managers 1) If Tour operators contribute to PA finances?, and 2) if Funding was obtained from entry fees? Only in four of twenty-five cases interviewees declared that a cash flow existed from Tour operators to the management body, but it was often (3 times) considered as a low degree contribution. For seven of 26 PAs the interviewees declared that entry fees contributed to financing the PA management, but most often this was of limited importance (only for 1 PA it was declared as a high degree contribution) and when used it was often restricted to parking fees. In some cases these were used for managing the parking places and/or to discourage road traffic in the PA.

The allocation of public funding and support is a matter of growing concern. Hence, in terms of allocation of means, the respondents informed that the number of permanent personnel for the management bodies of the studied PA's ranged from 6 to above 200 and the recurrent budget from 300.000,- € to 17 million €, for Pieniny (Slowakian part) and Bavarian forest, respectively. Nevertheless, many PA management structures are successful in obtaining additional funding from external programmes (e.g. Life projects). The perception of the respondents is that in most cases funding is not fully satisfactory for guaranteeing the conservation objectives of the PA and priorities for additional funding are mainly identified as a need for additional staff and the funding of action projects, the latter both including a guarantee for continuing on-going projects as well as starting new projects.

In conclusion, the EcoPotential interviews in 2017 showed that PAs have to adapt to institutional arrangements and funding opportunities. The nested organisation of multiple PA designations for an area results at the one hand in institutional complexity, while at the other hand it may also present an advantage for public policy with respect to spatial planning of conservation measures together with sustainable developments in PAs and their surroundings and creating transboundary PAs. Nevertheless, so far, we could in general not indicate a strong influence of such changes, nor of the historical context, on the PA management, let it be that in a few PAs the adoption of market-based approaches, i.e. receiving own income from fees, may help to achieve some of their aims as funding is shown to be mostly restricted. The final conclusion is thus that adapting the PA management may be in specific cases a driver of changes towards better facilitating the PA aims.

4.1.2 Changing concepts and practices for the management of PA's and links with scientists

Ecosystem services, connectivity, adaptive environmental management and stakeholder participation are relatively new concepts in science that have taken some time to percolate into the management practice. We asked the respondents whether such concepts have been adopted in their PA management, and what the impact was.

According the respondents, only three of twenty-five studied PAs have clearly adopted an Ecosystem framework, while for 8 areas this is in progress (see Fig. 4.4). The concepts of adaptive management and management targeting connectivity issues are much more widespread among the PA's studied by the interviews (see Fig. 4.4). The length of the adaptive cycle was reported by the interviewees to range from 1 to 12 years

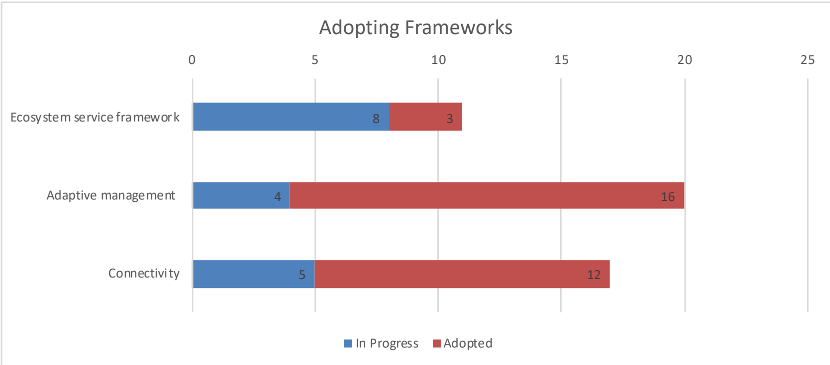


Fig. 4.4: Responses of Interviewees whether different frameworks have been adopted for the management of the PAs by the management bodies

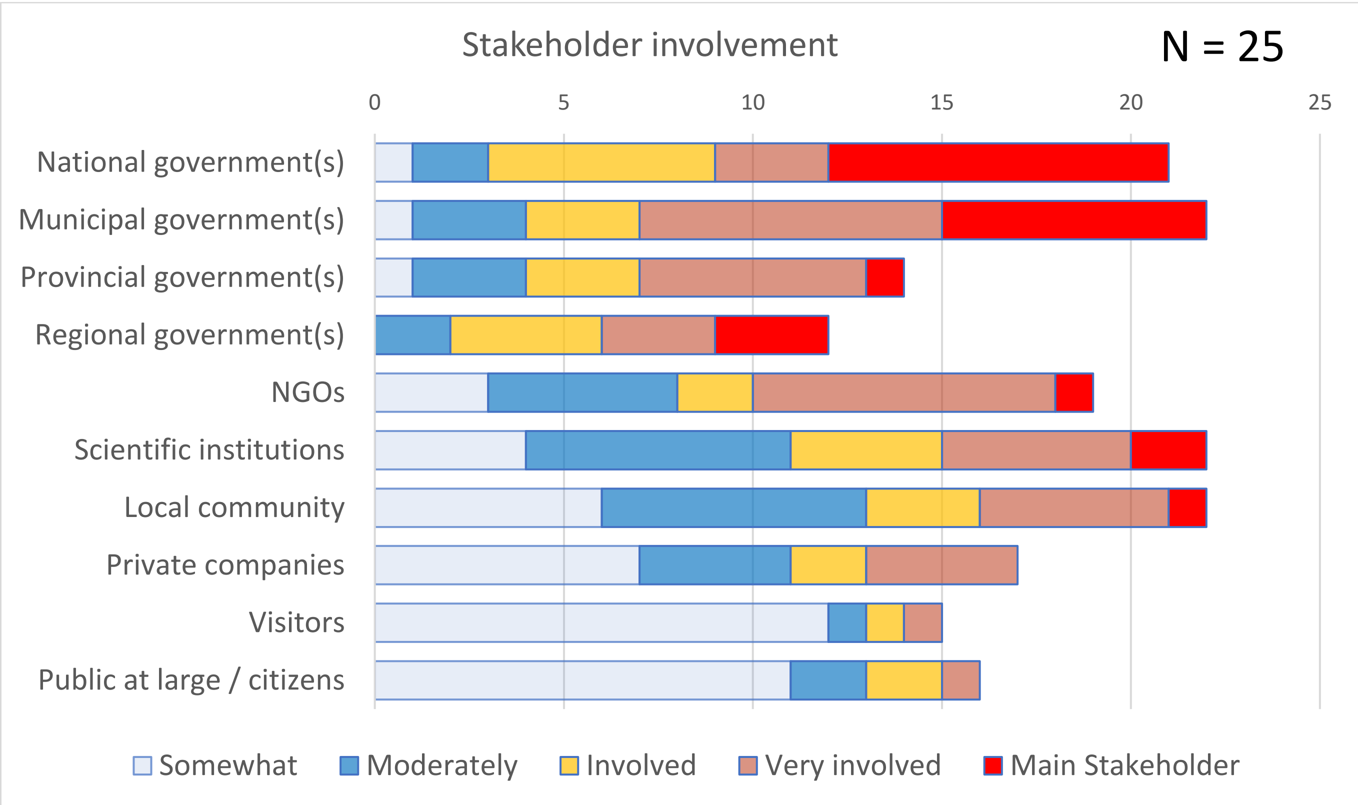


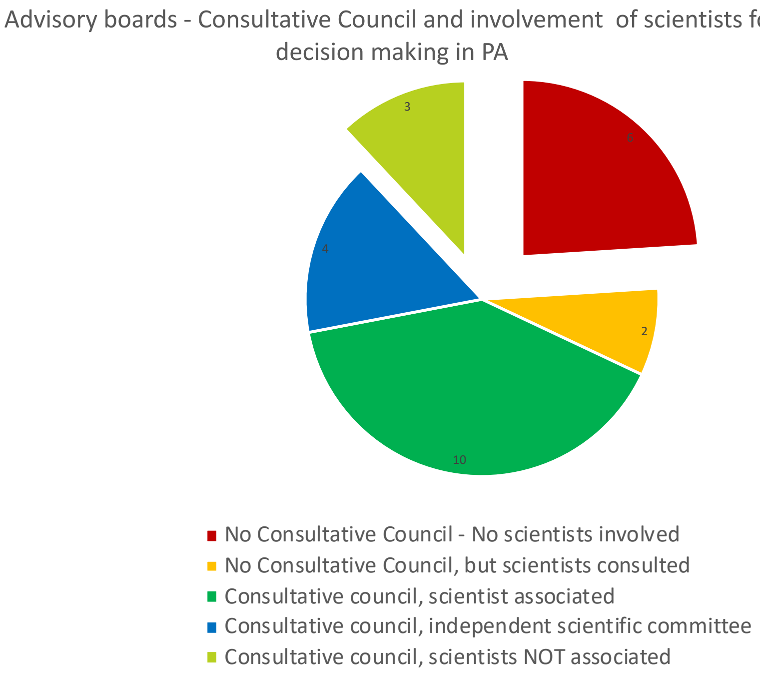
Fig. 4.5: Perception, by the interviewees of the management structures of the 25 PAs, of the importance of stakeholder involvement in PA management. The stacked bar indicates the number of PAs where the stakeholder group was recognised as being involved in the decision-making process in PAs; the colour indicates the level of involvement for these different PAs in the decision-making process of the PAs. Beside the listed categories, the following other stakeholders were mentioned in open questions: Land owners (3 times), Hunters fishermen (1), Syndicats (1).

depending on Management Plans and PA designation. In some cases shorter duration cycles were imbricated in longer cycles. PAs with multiple designations may present different cycle lengths as e.g. in La Palma Island where the Biosphere Reserve uses 10 years (with assessment steps at years 3, 5, and 8), while the National Park uses a 6 year cycle.

The IUCN World Commission on Protected Area (WCPA) published a Framework and guidelines for assessing the management of PAs (Hockings et al., 2006). This framework is based on the principle that good PA management should follow a cyclical process thus adopting the adaptive management cycle (Holling, 1978). This adaptive management principle has thus been adopted by half of the interviewed PAs.

In general it can be stated that new concepts are not strongly adopted in the PA management, and that at this moment new concepts as the Ecosystem Services concept are no real Drivers of Change and hardly have an impact on PAs, though the principles of Adaptive Management and Connectivity may yield some influence.

The degree of input of the various stakeholders in a PA varied greatly. In the majority, their involvement was low to moderate, whereby the importance of the national and municipal governments was the largest. In general, we can conclude that the various Stakeholders are no real strong Drivers of Changes in the PAs, though local and governmental government may exert some influence, mainly connected to the funding they provide.



Note in Bavarian Forest= an independent scientific committee exists for forestry, elsewhere scientists are associated with main Council

Fig. 4.6: Official involvement of scientists for advice in scientific advisory boards or councils

We assumed that a fluent adoption of novel scientific concept and working methods also may depend on the way how the scientists are associated, e.g. as advisors, to the management or directly participate in the governance. Therefore we checked whether scientists were associated in advisory boards and or consultative councils. In sixteen of the twenty-five PAs studied through the questionnaires, scientists were involved officially for the advice to the management, either by associating them to the consultative councils (#10, 40 %), or in independent scientific advisory boards (#4, 16 %) or by consulting them indirectly (and often individually). Hence, in nine cases (36 %), scientists were not officially involved for providing advice.

This finding may be combined with our question on Stakeholder involvement. The degree of involvement of Scientific institutions seen as Stakeholders by the interviewees was mostly considered as only somewhat to moderately involved in the PA (Fig. 4.5). The degree in which new concepts emanating from the scientific community as Ecosystem Services are adopted by the PA managers was only adopted in three of twenty-five PAS. The conclusion is that the impact of Scientists is in most cases at best on the edge of a merger to have some impact.

4.2 Results based on comparing Storylines, DPSIR approaches and interviews with PA managers

4.2.1 Overview of external drivers of change on the PA as identified in the storylines and interviews

The original idea was to align the description of Drivers (or Driving forces) on the DSIR framework (see e.g. European Environment Agency 1999). This technical report N° 25 of the European Environment Agency (1999) describes Drivers (or Driving forces) as "the social, demographic and economic developments in societies and the corresponding changes in life styles, overall levels of consumption and production patterns". Primary driving forces are population growth and developments in the needs and activities of individuals (European Environment Agency, 1999). However, it has become clear that climate change should be added to complete the set of drivers that result in Pressures on ecosystems. Concerning Drivers, some authors make a difference between "direct drivers of change" and "indirect drivers (e.g., sociopolitical, economic and cultural)", see e.g. Paloma et al. 2014. Several variants of DPSIR have been proposed as e.g. DPCER, DPSWR, DAPI(W)R(M) as reviewed in ECOP Deliverable 7.2 (El Serafy et al., 2018). This shows that confusion has been created in the literature of what is precisely meant by the different terms of the DPSIR framework in the different contexts and particularly no clear consensus seems to exist on what can be considered as a Driver and what not. Here we take a pragmatic approach and will try to align main categories of drivers in relation to the practices of spatial and temporal modelling of biodiversity and ESs according different scenarios of changes. Hence, the IPBES proposes to consider two main categories of drivers, i.e. 1) climate change and 2) land-use change (Kim et al., 2018). In a previous paper (Titeux et al., 2016) using these same categories, criticized that, until 2015 there has been a large bias in biodiversity modelling studies in favor of climate change and that there was a relative neglect of future land-use and land-cover changes in biodiversity scenarios.

An analysis of the items listed in the storylines (see Methods) showed that these corresponded in most cases to pressures (i.e. the spatial, biological, physical and chemical forcings on the ecosystems that are the localized for the ecosystems and pertinent consequences of the drivers) and often not to drivers (i.e. the social, cultural, demographic and economic developments in society, as well as global change), although some terms were clearly hinting towards the responsible drivers (table 4.1). Hence, climate change was often mentioned as such (mentioned in 7 of 18 storylines), while in some cases it was more specific describing an aspect of climate change directly related to the pressure on the ecosystem.

We tried to affiliate the different descriptions of "drivers of change/pressures that can describe the main human-induced pressures" to the categories 1) climate change and 2) land-use/land-cover change (see above). Nevertheless, it was necessary to add four additional categories of drivers to accommodate terms used in the storylines (see below for discussion). The six categories of drivers thus identified are listed in Table 4.1, and the affiliation of terms used in storylines to these main categories of drivers is presented in Table 9.2.

Table 4.1: Main category of drivers mentioned in story lines (cf Table 3 in Storylines)

Main Driver
Climate Change
Change of Land use
Pollution - Nutrient over-enrichment
Population growth / Tourism & Recreation
Main risk may be related to Driver
Invasive species and/or Pest species
Fire risk

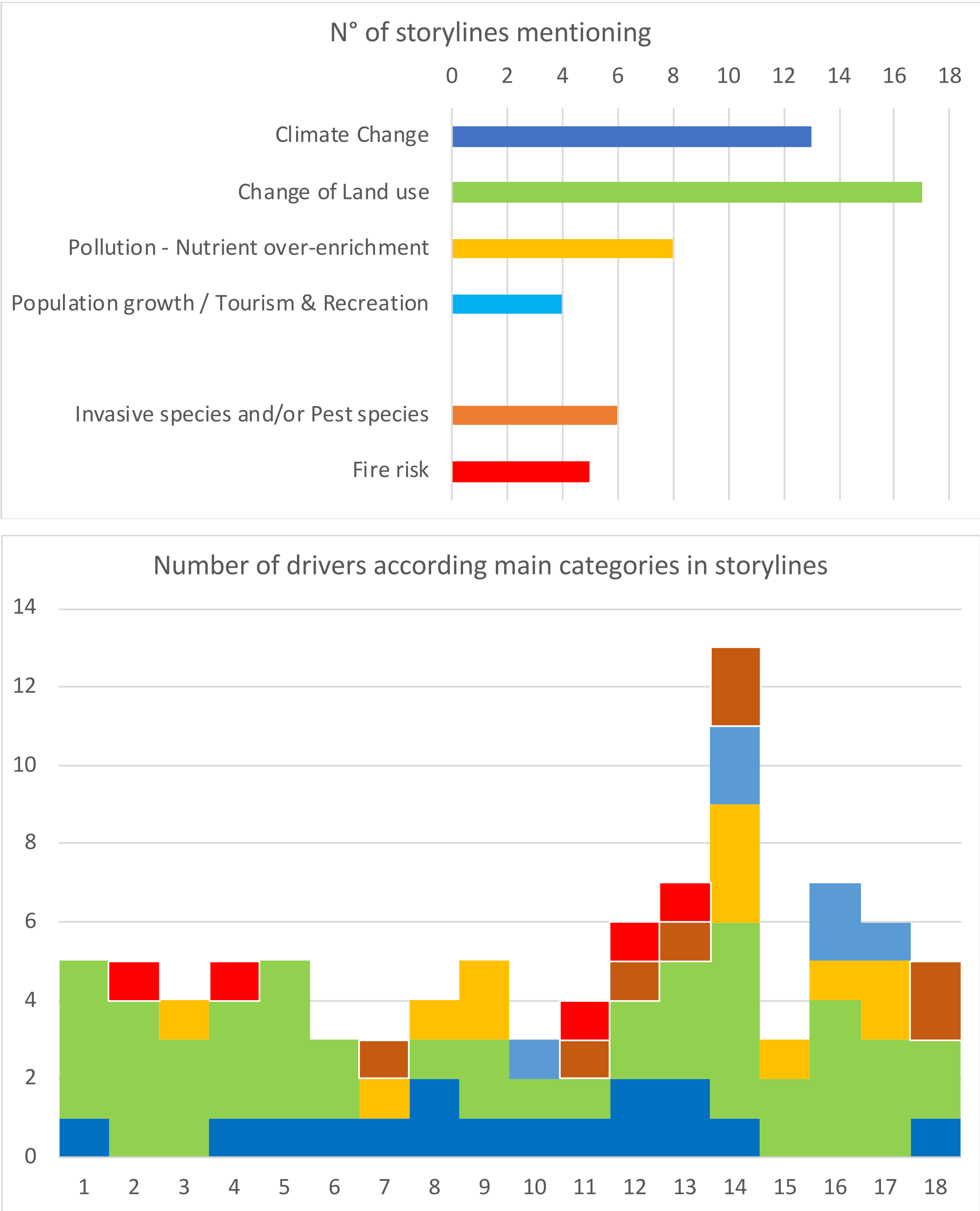


Fig. 4.7: The affiliation of drivers in the 18 storylines to main categories of drivers (see Table 4.2). Top panel: the number of storylines mentioning one or more drivers affiliated according the main categories. Bottom panel: number of drivers mentioned in storylines (see Table 4.1. for correspondence between N° and title of storyline) according to the main categories (colour coding same as top panel).

While, in some cases increased use of fertilizers and pesticides is considered as a change of land use, it is clear that in many cases the pollution and nutrient loading to PAs comes from elsewhere as these compounds are transported over long distances by water flows or through the atmosphere. To accommodate correctly for this phenomenon it was necessary to create an additional category, i.e., Pollution and Nutrient over-enrichment.

Similarly population growth/ tourism & recreation was added as a specific category as the people may travel over longer distances to visit the PA and in general a transfer of Ecosystem services can be observed from the PA to distant urban centers that may function as service benefitting areas (Paloma et al., 2013).

Some of the drivers of change/pressures mentioned in the story-lines are difficult to place in the DPSIR framework and often not unequivocally related to a driver of change, as these are more clearly referring to risks and risk-management. The first example is fire, which was often mentioned in the mountainous PAs. Fires are a natural phenomenon in most of the ecosystems (particularly in the semi-arid and Mediterranean climates and on islands with a volcanic origin); although their intensity, spatial extant and frequency of occurrence can increase dramatically due to i) climate change, ii) changing land use, particularly ii-a) changing management and ii-b) changes in the traditional uses of the ecosystems resulting in encroachment, and ii-c) increasing human occupation. Only in one case the issue of fire (i.e. formulated as changes of wildfire regimes, La Palma) could be clearly affiliated to the driver climate change. In the other cases it has been affiliated to the category “Fire risk”. Pest species and invasive species are also more related to risks and risk management and even to perceptions, rather than representing an unequivocal driver of change. Nevertheless, it is obvious that increased travelling and mass flow exchanges between human populations worldwide is a major driver behind increasing frequencies and severity of invasive species events caused by exotic species. Hence, from the ecological point of view it appears important to make a distinction between pests caused by native and pests/nuisances caused by exotic species. It is a difficult issue to address this issue according a simple DPSIR approach. For pragmatic reasons and in agreement with what has been mentioned in the storylines we decided to maintain a single category titled invasive species and/or pest species.

Climate change was indicated in seven of the 18 storylines, while in other cases more specific aspects related to climate change could be affiliated to this main category. Hence, specific issues that have been affiliated to the main category Climate change include: Drought and waterlogging events (Alentejo Natura 2000 sites), Mountain Biodiversity as a sentinel of environmental change (Gran Paradiso NP), Changes in the seasonal snow/ice/temperature cycle and in precipitation (Gran Paradiso NP and Ohrid/Prespa), Annual and monthly temperatures & precipitation, Drought Landslides / Soil loss / rain gullies (Sierra Nevada NP), Change in wildfire regime (La Palma).

Concerning Climate change note the importance of definition. According the European Environment Agency glossary (https://www.eea.europa.eu/help/glossary): Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines 'climate change' as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' Although this was not thoroughly checked it appeared that most storylines and PA managers apply the latter definition.

Changes in agricultural practices within the PA or immediate surroundings and traditional ecosystem uses within the PAs were systematically affiliated to “Change of Land Use”. In addition, planning infrastructure for renewable energy production, exploitation of fossil resources (gas winning in the Waddenzee) and mining activities within the PAs have also been included in the “Change of Land Use” category.

Figure 4.7 indicates the quantitative importance of the different drivers in the storylines. Hence, **Change of land use** was the most common category of drivers, mentioned by 17 of 18 storylines; this was followed by **Climate change** mentioned in 13 storylines. This confirms that a major focus on the combination of **Climate change** and **Change of land use** as considered a major focus in studies of Drivers of Changes according the IPBES approach (Kim et al., 2018) is also apparent from the storylines. Nevertheless, the storylines are not restricted to the combination of these two drivers. Such a restricted focus would certainly neglect important facets of environmental changes in PAs. Hence it is equally important to consider **Pollution and nutrient over-enrichment** (mentioned in 8 storylines) and the category **Population growth/ tourism & recreation** (mentioned in 4 storylines). The latter category can be confounded with aspects of **Change of Land use** when it results in increased housing, and infrastructure. However, not all aspects of **Population growth/ tourism & recreation** will be correctly captured by Change of Land use (e.g. increasing number of visitors, transfer of ecosystem services from service provisioning hotspots to service consumption areas (e.g., Paloma et al., 2013), and therefore should be considered as a separate Driver of Change. Contaminants and nutrients can travel over large distances and this example is particularly relevant for the coastal systems where the PA is the receptacle for nutrients and pollution that have their sources in the watersheds upstream. Nevertheless, airborne contaminants are also particularly important issues for mountainous and semi-arid systems. In general, our findings are very much in line with existing literature. While, the first two drivers from Table 4.1 are also listed under the most relevant planetary boundaries (Rockström et al 2009), all of these categories of drivers, with the exception of climate change and tourism, have also been listed as “impacts of human land use” in a major textbook on the landscape ecology textbook (Turner & Gardner, 2015, 2nd edition).

Fire may present an increased threat as it can act in synergy with other drivers of change. For example, in Réunion Island (questionnaire 2017) a negative interaction was highlighted between the occurrence of large-scale fires and invasive species, because the allochthonous invasive species are often more competitive in re-colonising burnt areas than many of the endemic species. Hence, the occurrence of fires exacerbates the problem of safeguarding the native and endemic species and strengthens the threat caused.

For example, the outbreaks of bark beetle (a native species) is perceived by the general public as a major problem responsible for forest decline and measures to combat them are requested from the management body (i.e. suppressing outbreaks by salvage logging). However, bark beetles play an important ecological role in shaping the long term trajectories of maintaining forest ecosystems (see Bavarian Forest story line) and highest biodiversity has even been found in the early successional stages of the forest after beetle attack. Hence, outbursts of some species can be perceived as pest species by some stakeholders, who consider that these create nuisance and represent a threat, while from the ecological point of view these species contribute to the natural processes in these ecosystems and even may have a positive impact on biodiversity.

In conclusion, the modelling and GIS community is strongly focused on the drivers **Climate change** and **Change of land Use**, and analysis showed that these two categories covered the majority of the drivers/pressures identified in the storylines. Nevertheless, other drivers were also identified as important like **Pollution and nutrient over-enrichment** (mentioned in 8 storylines) and the category **Population growth/ tourism & recreation** (mentioned in 4 storylines).

The extent of these drivers is often large, spatially as well as temporally, and most often beyond the actual boundaries of the PAs and their immediate surroundings, and beyond the capacity of PA management to control. **Climate Change** is beyond the control of the PAs spatially as well as temporally. PA management cannot counteract **Climate Change** itself and can only focus on adaptation management. **Pollution and nutrient over-enrichment** may enter the PA from outside, and thus the impacts are difficult to control through management, however, in consultation with neighbouring municipalities and regional authorities it may be feasible to implement mitigation. On the other hand, **Change of land Use** and **Population growth/ tourism and recreation**, irrespective they can yield a strong impact, can be fully controlled inside the PA. To mitigate the effects of some of, these Drivers of Change it will be needed to monitor the temporal and spatial developments, not only in the PA but also in its environments.

Hence, the EO methods should consider these larger scale linkages and in addition the use of *in situ* monitoring methods to detect for example the spreading of contaminants within a PA (often coming via water flows from the catchment or by atmospheric deposition). Tourism and recreation should be considered at these scales, while some of the assessment of use by visitors and tourists can often be monitored within the PA by EO. Fire risk and Invasive and/or Pest species should be dealt with nuance. The complete banning of fire and of native pest species is sometimes not a good option from the conservation point of view as these phenomena may belong to the natural functioning of the ecosystems and provide an intermediate degree of disturbance (Connell, 1978) that is favorable for biodiversity. On the other hand, non-native invasive species are definitely related to a driver of change, i.e. increased travelling and mass flow exchanges between human populations worldwide. Large-scale fire occurrences, clearly above a natural level of intensity and occurrence can be extremely destructive for PAs ecosystem functions and structures and are a matter of concern. Increasing occurrence of Fire can be related by different other drivers (e.g. climate change and change of land use) and interact synergistically with other drivers (e.g. invasive non-native species in Réunion island).

4.2.2 Linking Pressure/Threats (questionnaires) with drivers of change

In the questionnaires (part B) and in the serious card game realized during the Pisa workshop, PA managers were asked to score the importance of i) Ecosystem Structures or Functions, ii) Ecosystem services and iii) Pressures. The latter were defined in the questionnaires as those that can form a **threat** to the aforementioned Ecosystem Functions and Structures (question B1) or to the Ecosystem Services (question B2). This way of presenting was appealing to the PA managers as it supported the identification of threats by PA managers, who have less experience in working with DPSIR frameworks. A threat can be defined as pressure that pushes, or presents a high risk to push, the ecosystem state in a undesired state or undesired trajectory of that state. The homogenized list of threats was developed by a bottom-up approach., 15 environmental scientists from the Ecopotential project and 11 managers were interviewed and asked to list threats by open questions. Subsequently, this list was homogenized in order to prevent the use of multiple variables for designing the same or very similar threats (Hummel et al., 2017). This list has not been designed for its alignment on a DPSIR scheme, but rather as a way to capture the major threats as those are perceived by the PA managers in their daily practice. Table 3.3 lists the 25 pressure-threats that were given to the respondents. Among these, the top seven threats listed by the PA managers were Bad management, Change in land use, Disturbance, Exotic species, Tourism, Overexploitation, and Change in species. Fourteen of these pressure/threats can unambiguously be linked to one of the drivers of change identified in section 3.3 (cf. Table 3.2), i.e. Climate change (1 time using the same term), Change of land use (6 times), Pollution – nutrient over-enrichment (2 times), Population growth / tourism & recreation (1 time), Invasive species and/or Pest species (3 times) and Fire risk (1 time). However, for eleven pressure/drivers the correspondence is less evident and some pressure/threats may be related to multiple or different drivers.

Illegal human activities mainly include poaching, picking of plants, illegal logging and illegal fishing (Deliverable 9.1). Bad management, which includes bad water management (see Deliverable 9.1), is often related with the insufficiently managed intensity of uses (e.g., intensification of agriculture not always visible as a clear Change of Land use, overfishing and spoilage related to large bycatches, see also overexploitation), to strong pressure from visitors/tourist or recreation activities and application of measures that may be in conflict with best management practices due to overly influence of stakeholder groups (Deliverable 9.1). Change in species can be considered as a facet of ecosystem state (S) according the DPSIR approach; however, changing species composition also feeds back to ecosystem functioning and can thus be perceived as a threat/pressure. Changes in species composition can be related to many different drivers, the most influential depending on the specific case. In some specific cases the importance attributed to this driver was because of problems related to invasive species and/or pest species that replaced the native species. In these specific cases the driver can be affiliated to Invasive species and/or Pest species. Disturbance was mostly related to anthropogenic disturbance, off road vehicles transportation (Deliverable 9.1) and can thus be related partly to changing land use and tourism/recreation. Extreme weather may be related to climate change as this can increase the severity and frequency of extreme weather although this is not always the case (Herring et al., 2018). On the coastline extreme weather may result in storm surges where a clear interaction with climate change is evident related to sea-level rise. Increased salinization and sediment dynamic changes are typical for the coastal zone and can often be related to larger scale modification in the management of fresh and salt water flows, not necessarily restricted to the PA or its surroundings. Sediment dynamic changes have also included avalanches and their impacts in the mountains, erosion and embankments within wetlands. Predation can often become a problem when it is related to exotic species as rats and cats (Deliverable 3.2) showing that it may have a link with the driver Invasive species and/or Pest species.

Table 4.2: List of the possible Pressure/Threats to PA's submitted to the interviewees in the questionnaires to PA managers and corresponding Drivers of Change (yellow boxes indicate no clear unequivocal link between pressure/threat and a specific driver of change)

Pressure/Threats (Questionnaires)	Corresponding Driver of Change
(Illegal) human activities	Poaching, picking of plants, illegal logging and illegal fishing
Agriculture	Change of Land use
Bad management	Most often inadequate management of the intensity of uses or frequency of visits that is often not directly visible as a change of land use
Change in land use	Change of Land use
Change in species	A facet of the Ecosystem State that has a strong feedback on ecosystem functioning. Specific cases can be affiliated to Invasive species and/or Pest species
Civil engineering	Change of Land use
Climate change	Climate Change
Diseases	Invasive species and/or Pest species
Disturbance	Mostly related to anthropogenic disturbance
Encroachment	Change of Land use
Eutrophication	Pollution - Nutrient over-enrichment
Exotic species	Invasive species and/or Pest species
Extreme weather	Maybe related to climate change but not necessarilly, on the coast interaction with sea level rise (e.g., storm surges)
Fire	Fire risk
Fisheries	By-catch in gill nets, overexploitation of stocks
Habitat loss	Change of Land use
Harmfull Algae	Invasive species and/or Pest species
Hydrological changes	Change of Land use
Increased salinisation	Modification in the management of seawater and freshwater flows
Landscape disturbance	Visual contamination, jeopardizing scenic beauty
Overexploitation	Intensive agriculture, overfishing, too high density of tourists visitors (not always visible as a Change of land use.
Pollution	Pollution - Nutrient over-enrichment
Predation	May be related to exotic species
Sediment dynamics changes	Coastal sedimentation and erosion, avalanches in mountains
Tourism	Population growth / Tourism & Recreation

In conclusion, many of the pressures and threats that are considered important by the PA managers are difficult to link directly with a single category of the drivers identified in Table 3.2. In principle this may make it difficult to link the everyday management of ecosystems with academic approaches, which are often based on theoretical frameworks. Therefore, exchanges between PA managers and scientists are extremely important to reduce problems in terms of conceptual frameworks. The use of these conceptual frameworks is obviously of interest to describe general patterns and particularly to design future policies, which include the creation of new PAs based on conservation planning. Nevertheless, an overly implementation of these theoretical frameworks and their generalization introduces a risk of overlooking those threats and pressures that are not easily captured by the main category of drivers. ECOP Deliverable 9.1 (Hummel et al., 2018a) proposes, therefore, Essential Environmental Variables for Protected Areas (EEVPA) and Essential Socio-Economic Variables for Protected Areas (ESVPA) that can be used as indicators allowing monitoring of threats. Nonetheless, it is also important to try to link threats to drivers for obtaining an understanding of the processes behind, how these will evolve in the future and whether these can be managed or not by the PA management.

4.2.3 Indirect drivers

No consistent terminology is used in the literature when referring to “indirect drivers (e.g., sociopolitical, economic and cultural)”; these have been referred to as 1) Primary Drivers (European Environment Agency, 1999), 2) Indirect drivers and 3) Secondary drivers. The societal drivers behind climate change *sensu* UNFCCC have been described by the different IPCC assessment reports and will not be further developed in this deliverable. We will focus on a couple of important “indirect drivers”, and whether they impact PAs.

Changes in land use in PAs are often related to changes in agricultural practices, because many of the PAs are largely natural-cultural landscapes. Therefore, it makes sense to make a difference between changes driven by i) market-based agriculture or by ii) traditional agriculture and cattle raising including pastoralism. In this respect the so-called market-based agriculture integrates how the business responds to subsidies derived from the Common Agricultural Policy (CAP) particularly through the European Agricultural Guarantee Fund (EAFG, Pillar I of CAP) , whilst economic gain is the main motivation for the farmers. The traditional agricultural and cattle raising practices are often a mechanism responsible for favouring high biodiversity habitats in the PAs (Bignal & McCracken, 2000) and the management often aims to pursue these activities at a sustainable level . Nevertheless, the combination of high population growth and traditional agriculture and cattle raising can also lead to overexploitation, habitat degradation and loss of emblematic and threatened species (see example of Negev). In many cases traditional agriculture and cattle raising is not cost-effective and observed developments are related to a driver for change due to either abandonment or alternatively to intensification and changes of practices with a gradual shift towards market-based agriculture. Agri-environment measures have been designed in CAP, particularly by the European Agricultural Fund for Rural Development (EAFRD, Pilar II of CAP), and are in principle for counteracting these trends.

Mining and energy production based on concessions are still important drivers of changes in existing PAs (e.g., gas winning in the Waddenzee, small exploitations in Sierra Nevada). In addition, the developments of renewable energy extraction techniques create novel drivers and pressures in the form of wind farms and solar panels.

Both La Palma Island and La Réunion Island are volcanic oceanic Islands. Within the frame of Ecopotential these are often considered as representative of mountainous systems (see e.g. Table 3.1), although their specific character justifies the creation of a specific group, as volcanic oceanic Islands (see Figs. 4.1- 4.3). Both are characterized by a highly threatened endemic biodiversity suffering from competition and predation by invasive species which is clearly related to a main human driver: i.e. increased travelling and mass flow exchanges between human populations worldwide. The process of introduction of alien species has started with the colonization of both islands since centuries, but has strongly accelerated in the 20th century. This driver may interact synergistically with Change of Land use and Fires that may create new habitats for the invasive species at the expense of the native species.

5. Discussion

5.1 General part

For studying the future perspectives for PA creation and management, and particularly for proposing a roadmap for PA creation in the future (Task 3.3) it is important to consider the changes both of the governance and organization of PAs as well as the external drivers that threaten the ecosystems within the PA. This situation reflects in part the history, with the national parks being adopted in Europe since early in the 20th century. At the international level, the Man and Biosphere programme (MAB) was launched by UNESCO in 1971, with the creation of a World Network of Biosphere Reserves since 1976. The World Heritage Convention (WHC) was adopted in 1972, representing the starting point for the creation of UNESCO World Heritage Sites (WHS), and the Ramsar convention was adopted in 1971 and became operational in 1975.

The original National Parks followed mostly the fortress model, i.e., representing islands of wilderness or pristine ecosystems and excluding human uses as much as possible (IUCN categories I and II). Nevertheless, in Europe the wilderness concept (cf Yellowstone National park) is often not really pertinent as humans have inhabited these areas since ages; hence, the National Parks in Europe are often more focused on safeguarding the natural and cultural heritages (Maris, 2018), specific animals, or scenic beauty. Later policies since the 1970's focused on reconciling human uses and nature conservation. The latter is particularly the case for the Biosphere reserves, the WHS and many of the regional designations (IUCN categories V and VI). Multiple designations may complicate the management by creating competing management structures. However, multiple designations do not necessary imply the same number of management bodies (i.e. in some cases the same management body is responsible for the management of the areas under multiple designations).

The history of PAs has been described by American historical political ecologists as a sequence starting with Yellowstone according the fortress model – via co-management towards neoliberal conservation particularly during the last decade (Vaccaro et al., 2013). Predominant neoliberal conservation does not really apply to the 26 PAs studied in the questionnaires. The majority of the management structures are public bodies and while only three of them are private structures their finances depend largely on public funding based on non-market mechanisms. In addition, the questionnaires showed that methods to raise market-based funding (entry fees, parking fees, direct financial contributions from tour operators) are only of minor importance. In Deliverable D11.2 (Nolte et al., 2016) it has been reported that there are examples of payment for provisioning ecosystem services, such as 30 Euros per hunted reindeer in Hardangervidda, Norway and payment for timber at the Tatra Mountains and in Peneda Geres. Only the Tatra Mountains and Samaria provided total revenues of 2.15 and 1 million Euros, respectively).

Nevertheless, the PAs engage in market economy activities, as e.g., promoting Eco-labels, sustainable forms of tourism, commercial labels using the Park. The intention of these activities is to promote sustainable forms of market-oriented exploitation by local communities. Moreover, for the management bodies themselves, the interviewees often indicated a decrease of recurrent funding the last years, which may push them to envision the use of market-based solutions for increasing the funds (Vaccaro et al., 2013). Another indicator that supports the current predominance of public policies over neoliberal market-based mechanisms is the importance attributed by interviewees to groups of PA stakeholders (see Fig. 4.5). According to the perception of the interviewees, higher scores are attributed to national and municipal governments when compared to private companies.

Several sites (e.g., Camargue, Isla de la Palma, Swiss National Park, Ile de la Réunion, Danube Delta, Curonian spit) show local, regional, national and European PA designations nested within International PA designation, that often cover larger areas than the former designations. While overlap and multiple PA designations have been studied in the international literature (Deguignet et al., 2017) it appears that the nested organization of the different PA designations has been largely neglected in scientific studies so far. From the responses it became evident that such a nested organization can be used in public policy to organize the territory with areas that have a stricter protection level with buffer zones, and surrounding areas comprising areas for sustainable development and smaller nature reserves. In addition, this allows to create cross boundary PAs. It thus appears as an original aspect emerging from our study, that will be further studied by a Master student in Montpellier University (Mylène

Farge) in 2019. Potentially, the nested organization could be more in-line with the socio-ecological approach advocated by Paloma et al. (2014) as this demands good collaboration between the PA-management structures and a public body responsible for the spatial management of a large territory that includes the PAs. For example, In La Palma Island the UNESCO biosphere reserve has the important role to manage the spatial planning of the whole island in concert with the Government of the island, and to establish the important links with the National Park and the many smaller nature reserves on the Island. The governance of the PAs embedded in the landscape and socio-ecological ecosystems thus tends towards a polycentric approach (Ostrom, 2005) with power sharing, although a fluent collaboration among all these structures appears difficult to put into place.

All in all, the differentiation in historical background of the PAs, and as a consequence the eventually more or less nested organisation of PAs with various designations and different responsible organizational structures, does not seem to have a serious impact on the functioning of the PAs and may represent advantages in some cases for public policies.

In sixteen of twenty-five PAs (64 %) studied through the questionnaires, scientists were involved officially in advising the management, either by being on consultative councils, or independent scientific advisory boards or by being consulted indirectly (and often individually), in nine cases (36 %), scientists were not officially involved for providing advice. The situation is thus variable and does not systematically include scientists. This may explain why the PA managers have often not adopted the conceptual frameworks that have been proposed and are currently used by the scientific community. Among, the frameworks, adaptive management was most often adopted and an ecosystem framework less often (cf. Fig. 4.4). Nevertheless, managers are becoming increasingly aware of these theoretical frameworks and interested in adopting those for their management. It is also extremely important that the scientists remain open-minded and willing to listen to the practical pre-occupations of the PA managers as some of the threats they identify as most important are not captured very well by the main category of drivers that have been identified (see Table 4.2). Therefore, the bottom-up approach applied by Hummel et al. (2017) remains a valuable approach to capture the perception of the PA managers.

A consensual and coherent identification of Drivers or Driving forces along the DPSIR framework among the scientific community was hampered by the fact that different approaches for identifying Drivers coexist among the scientific community and by the fact that the DPSIR framework itself is challenged by the publication of different variants (e.g., DPCER, DPSWR, DAPI(W)R(M). An analysis of the items listed in the storylines showed that these corresponded in most cases to pressures (i.e. the spatial, biological, physical and chemical forcings on the ecosystems that are localized for the ecosystems and pertinent consequences of the drivers) and often not to main (or secondary) drivers (i.e. the social, cultural, demographic and economic developments in society, as well as global change). This was in part due to the formulated request in the template, i.e., “drivers of change/pressures that can describe the main human-induced pressures”. The current absence of scientific consensus on what is meant by a Driver particularly is a problem for developing multidisciplinary approaches and exchanging among disciplines. As an example, major societal drivers, i.e. the social, demographic and economic developments in societies and the corresponding changes in life styles, overall levels of consumption and production patterns, have been referred to as 1) Primary Drivers (European Environment Agency, 1999), 2) Indirect drivers and 3) Secondary drivers. This creates confusion and effort is needed to explain what is meant by the different terms. For PA conservation planning and management in the future, more insight is requested from socio-economic sciences on the social, cultural, demographic and economic developments in society, which together with Climate change represent main drivers.

The remote-sensing GIS community and current GIS approaches promoted by IPBES focus on two major categories of drivers, i.e. 1) **Climate change** and 2) **Change of Land use**. So far, the modelling community has put a major effort on Climate Change and arguably Change of Land use request more emphasis in the future (Titeux et al., 2016). Resuming the most important findings, we conclude that the majority of the specific “divers of change/pressures that can describe the main human-induced pressures” could indeed be affiliated to one of either categories (cf Table 9.2 in Annex).

Nevertheless, it was necessary to add additional categories, i.e., 3) **Pollution and nutrient over-enrichment**, 4) **Population growth/ tourism & recreation,** 5) **Invasive species and/or Pest species** and 6) **Fire risk.** This is an important take home message as it means that a focus only on 1) **Climate change** and 2) **Change of Land**

use does not fully capture the direct drivers of change in the PAs. **Pollution and nutrient over-enrichment** and **Population growth/ tourism & recreation** often demand considering larger spatial scale, often largely beyond the PA and its immediate surroundings. The contaminants enter the PAs from outside through large-scale water and sediment flows and atmospheric deposition, while Population growth/ tourism & recreation often includes demographic and socio-economic developments in very large areas with an impact on the PA. For the consideration of **Invasive species and/or Pest species** and **Fire risk** the PA management has to put into the balance different considerations. First, a natural level intensity wildfires and of occurrence of native pest species may often have a positive impact on biodiversity and should not be banned. Such naturally occurring phenomena should in principle even not be considered as drivers of change/pressures as these belong to the natural functioning of the ecosystems. Nevertheless, high levels of Fire and invasive and exotic pest species are indeed a major threat for the ecosystems, their frequency and intensity of occurrence as well as their dangerousness have often increased due other drivers.

Using a bottom-up approach (Hummel et al., 2018a,b, Deliverables D9.1, D9.2) threats were identified by the PA managers, some of which are difficult to link directly with a single category of the drivers identified in Table 4.2. Accordingly, the top seven threats listed by the PA managers comprised 3 items that could be related to a main category of drivers - i.e. Change in land use, Tourism, Exotic species – and 4 items that could not be related unambiguously to a main category of drivers - i.e. Bad management, Disturbance, Overexploitation, and Change in species. Hence, an overly implementation of theoretical frameworks with standardized variables and their generalization introduces a risk of overlooking several threats and pressures that are perceived as important by PA-managers. The challenge is thus to translate these perceived threats in terms that are operational for the frameworks. Some threats relate to multiple drivers that can interact in synergy. Other perceived threats, i.e. Change of species, could be considered as belonging to the State (S) of the ecosystem according the DPSIR approach, although another facet of this is that changing species feeds back to the functioning of the ecosystem and it is therefore justified to consider it also as a threat. The use of conceptual frameworks is obviously of interest to describe general patterns and particularly to design future policies, which include the creation of new PAs based on conservation planning. Nevertheless, ECOP Deliverable 9.1 (Hummel et al., 2018a) proposes, therefore, Essential Environmental Variables for Protected Areas (EEVPA) and Essential Socio-Economic Variables for Protected Areas (ESVPA) that can be used as an indicator allowing to monitor the persistence of the threat. Hence, bottom-up exchanges between PA managers and scientists are extremely important to rephrase problematics in terms of the conceptual frameworks. Nonetheless, it is also important to link the threats to drivers for obtaining an understanding of the processes behind, how these will evolve in the future and whether these can be managed or not by the PA management.

On a more comparative level it appears important to analyse what are the drivers beyond the pressures that have been identified in the story lines and in the interviews with the managers. Climate drivers are sufficiently documented by IPCC and downscaling of climate models. Changes in land use often relate to changes in agricultural practices, which are driven in Europe mainly through 1) market-based mechanisms, 2) the European Agricultural Guarantee (CAP, Pilar I) and agri-environmental measures (CAP, Pilar II). In addition, mining and energy production based on concessions are still important drivers of changes in existing PAs, both comprising the extractions of minerals of fossil fuels as well as facilities for the exploitation of renewable resources. The volcanic Islands La Réunion and La Palma are characterized by a highly threatened endemic biodiversity suffering from competition and predation by invasive species which is clearly related to a main human driver: i.e. increased travelling and mass flow exchanges between human populations worldwide. The process of introduction of alien species has started with the colonization of both islands since centuries, but has strongly accelerated in the 20th century. This driver interacts synergistically with Change of Land use and Fires that may create new habitats for the invasive species at the expense of the native species.

In conclusion, conservation planning and PA management have been confronted both with changing concepts concerning the role of PAs thus influencing their spatial extent and governance, as well as with pressures and drivers of change affecting the ecosystems that the PA intend to protect. Concerning the first point, PAs have been confronted with a major change of concepts after introducing international treaties and measures aiming to combine the conservation of the ecosystems with sustainable human uses of natural resources since the 1970's. In Europe, starting early in the 20th century with the creation of National Parks and National Reserves according the fortress model, this allowed 1) protection of much larger areas according the new principles, 2) obtaining of important international designations as e.g. UNESCO WHS and MAB Biosphere reserves, and achieve a nested organization of PA designations, whereby National Parks and other reserves have been nested within the WHS and/or Biosphere reserves. In addition, the European Natura 2000 sites have been added to this scene since the 2000's. This implies that most areas are now managed according the co-management concept implying that many stakeholders both including local and municipal governments as well as local populations should be taken into account. It also implies institutional complexity. While in some countries, the co-management model evolved into a market-based neoliberal model particularly after the 2008 economic crises, this is not the case for the European sites. Most of the PA management structures are public bodies and all rely mainly on recurrent public funding together with project-based money (e.g., Life projects) and sometimes only a minor contribution from market-based raised funding.

The changing scene mentioned above and the global change and increased anthropogenic drivers call for the development of scientific and technical support for PA managers as aimed by the Ecopotential project and also for enhanced exchanges between scientists and PA managers. This is reflected by the fact that in 56 % of the studied PAs the scientist were officially associated to the decision making. PA managers are also increasingly adopting novel scientific frameworks, although the application of an ecosystem service framework in PA management still appears in its infancy.

Climate change and **Change of Land use** cover the majority of direct drivers of change/pressures on ecosystem listed in the Ecopotential storylines. This is in agreement with the main focus by the remote-sensing (GIS) and spatial modelling communities. Nevertheless, not all of the direct drivers of change/pressures on ecosystem could be affiliated with one of these two main categories and four additional categories were proposed to accommodate for the latter, including **Pollution and nutrient over-enrichment**, **Population growth/ tourism & recreation, Invasive species and/or Pest species** and **Fire risk.** In addition, the bottom-up approach used in WP9 (D9.1 and D9.2) showed the identification of other major threats on PAs perceived by the managers. The top seven threats listed by the PA managers comprised 3 items that could be related to a main category of drivers - i.e. Change in land use, Tourism, Exotic species – and 4 items that could not be related unambiguously to a main category of drivers - i.e. Bad management, Disturbance, Overexploitation, and Change in species. This provides a challenge for the scientific community to take such threats into account. It also shows that a bottom-up approach is necessary in parallel with the theoretical frameworks in order to check that threats and pressures that are perceived as important by PA-managers are not overlooked.

5.2 Contribution to knowledge output of EcoPotential

In this report, Deliverable 9.3, we address one 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 protected areas (PA):

- "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". This deliverable is complementary to D9.1 and D9.2 which were focused on identifying standard set of indicators and measures for ES, as well as the underlying EF. In this report we studied the pressures, drivers and threats identified in the storylines and in direct face-to-face interviews with PA managers, and how these can be categorized in a set of main categories of drivers of change.

5.3 Recommendations

1- While 1) **Climate change** and 2) **Change of Land use** cover the majority of direct drivers of change/pressures on ecosystems, it is important to consider additional categories as these two main categories are not capable of capturing all the direct drivers and pressures correctly.

The additional categories proposed in this analysis include: 3) **Pollution and nutrient over-enrichment**, 4) **Population growth/ tourism & recreation,** 5) **Invasive species and/or Pest species** and 6) **Fire risk.**

2- The whole continuum ranging from the Primary driving forces *sensu* European Environment Agency (1999), to direct drivers of change should be clarified in a multidisciplinary debate. This is particularly important to better link the socio-economic, historical and political ecology disciplines to the research on PAs, which is particularly important when working on future developments in PAs and future conservation planning.

Traditionally, the study of the driver **Climate change** has been efficiently linked to climate research (see IPCC) and **Change of land use** to geography, while the linkages to other disciplines (e.g. socio-economic, history and political ecology disciplines) need to be developed more strongly in the future to get better information on drivers of change in human societies that have a strong impact on PAs.

3- The subject of multiple designations for PAs and the role of different PAs and surrounding landscapes should pay particular attention to the nested organization of PA's designations and issues of spatial planning.

A nested organization with multiple PA designations may have advantages for spatial planning, for example, by allowing inclusion of conservation planning in larger scale regional levels? In practice this leads to a polycentric organization, which may have an advantage in terms of power balance, while it may also suffer from inadequate cooperation among the different management structures. The latter may be exacerbated by the different historical traditions of the different PA designations (e.g. National Parks IUCN category 2 versus Regional Parks and Biosphere Reserves (often IUCN category 5).

Therefore, it is recommended to facilitate exchanges and collaboration among the different PA managers in different management bodies responsible for different PA designations in an area and to provide training on governance issues (i.e. coping with multiple designations) and identifying which are the major drivers of change related to the threats experienced by the PA managers to achieve a consensus of major issues among these different management structures.

4- Standardized coherent and homogeneous frameworks for linking drivers to ecosystem changes and use of Essential Variables should be accompanied by bottom-up approaches based on the free expression (i.e. using open questions) by PA managers, which will allow checking of whether the main drivers and variables identified in the International frameworks capture all the concerns of the PA managers of threats on the ecosystems.

At the moment the major part of threats and pressures mentioned by PA managers is not captured by drivers of Change mentioned by scientists.

5. It is essential to integrate and harmonise Drivers of Change and related threats and pressures that (can) act on/in PAs, in due consultation between PA managers and scientists, e.g. by means of a Community of Practice (CoP), in order to recognise which changes/threats/pressures can be acted on. This will be of practical use to the PA managers to select what measures can be taken to mitigate for the impacts.

It has to be taken into account that the recognized Drivers and pressures can be managed or mitigated in the PAs to a strong degree (**Change of Land use, Population growth/ tourism & recreation**, (illegal) Human activities, Disturbance, Fisheries, Overexploitation), or to a lesser degree (**Pollution and nutrient over-enrichment**, **Invasive species and/or Pest species, Fire risk**, Increased salinization, Landscape disturbance, Predation, Sediment dynamics changes), or some likely not at all because of their wide spatial and temporal occurrence (**Climate change**, Extreme weather).

5.4 Next steps towards a Roadmap for PAs

The results of this report, Deliverable 9.3 (Task 9.2), may be a basic tool to address the major EVs, IVs, and potential impacts of drivers of changes on the PAs in order to assemble the Roadmap for PAs (Deliverable 9.4). Such a roadmap 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).

6. Data providers

6.1 Rules for use of data (IPR, Privacy)

Data treatment is compliant with the EU General Data Protection Regulation (GDPR).

Due to the intense and detailed character of the queries of the EcoPotential WP9 interviews, 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 interviews, 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 interviews, 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.

6.2 Acknowledgements

This report and the underlying interviews 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 interviews held in EcoPotential WP9, as reported in Deliverable 9.1, we want to thank for their support to the interviews 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

7. References

Berkes F (2007). Community-based conservation in a globalized world. PNAS 104, 15188-15193

Bignal EM & McCracken DJ (2000). The nature conservation value of European traditional farming systems Environmental Revues 8: 149–171

Brockington D & Igoe J (2006) Eviction for conservation: a global overview. Conservation and Society 4, 424-470

Connell JH (1978). Diversity in tropical rain forests and coral reefs: high diversity of trees and corals is maintained only in a non-equilibrium state. Science 199, 1302−1310.

Deguignet M, Arnell A, Juffe-Bignoli D, Shi Y, Bingham H, MacSharry B, et al. (2017). Measuring the extent of overlaps in protected area designations. PLoS ONE 12(11): e0188681. https://doi.org/10.1371/journal.pone.0188681

Dudley N. (Editor) (2008). Guidelines for Applying Protected Area Management Categories. Gland, Switzerland: IUCN, 143 pp.

El Serafy G, Marta-Pedroso C, Ziemba A, Domingos T, Boon A, Wanke S, Schulz J, Laporta L, Orenstein D, Bonn A, Kleemann J, Carvalho-Santos C, Adamescu M and others. (2018) Framework for ESS based on DPSIR. Ecopotential Deliverable 7.2. 69 pp.

European Environment Agency (1999). Technical report No 25, Environmental indicators: Typology and overview. Copenhague, https://www.eea.europa.eu/publications/TEC25

Herring SC, Christidis N, Hoell A, Kossin JP, Schreck CJ III & Stott PA, Eds. (2018). Explaining Extreme Events of 2016 from a Climate Perspective. Bull. Amer. Meteor. Soc., 99 (1), S1–S157.

Hockings M., Stolton S., Leverington F., Dudley N. & Courrau J. (2006). Evaluating Effectiveness: A framework for assessing management effectiveness of protected areas. 2nd edition. IUCN, Gland, Switzerland and Cambridge, UK. xiv + 105 pp.

Holling C.S. (1978) Adaptive environmental assessment and management. London: John Wiley & Sons.

Hummel C, Provenzale A, Van der Meer J, Wijnhoven S, Nolte A, Poursanidis D, et al. (2017) Ecosystem services In European protected areas : Ambiguity in the views of scientists and managers? Plos ONE 12(11) : e0187143. https://doi.org/10.1371/journal.pone.0187143

Hummel H, Bienfait L, Kalle V, Boyer Y, de Wit R & Hummel C (2018a). Essential Environmental and Socio-Economic Variables for future and current Protected Areas, EcoPotential D.9.1, 162 pp.

Hummel H, Bienfait L, Kalle V, Boyer Y, de Wit R & Hummel C (2018b). Integrated overview of the Requirements and Quality of Protected Areas, EcoPotential D.9.2, 35 pp.

Kim H et al. (2018). A protocol for an intercomparison of biodiversity and ecosystem services models using harmonized land-use and climate scenarios, available at: Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2018-115, in review 2018, and as a non reviewed preprint at https://doi.org/10.1101/300632

Maris V (2018) Les aires protégées dans l'Anthropocène - quelques pistes pour penser l'adaptation aux changements climatiques. In: Beau R & Larrère C (Eds), Penser l'Anthropocène, Presses de Sciences Po, Paris. pp 265–282

Nolte A, Alfthan, B, Danks, FS, Andresen, M, Jurek, M, Kurvits, T, Bonn, A, Mantel, M & Westerveld L. (2016). Synthesis study on integration of EO data/tools in decision making. Analysis of Ecosystem Services and Earth Observation Understanding and Needs by ECOPOTENTIAL Protected Areas. Ecopotential Deliverable 11.2. 53 pp.

Ostrom E (2005). Understanding Institutional Diversity. Princeton University Press, NJ

Palomo I, Martín-López B, Potschin M, Haines-Young R & Montes C (2013). National Parks, buffer zones and surrounding lands: Mapping ecosystem service flows. Ecosystem Services 4: 104–116

Palomo I, Montes C, Martín-López B, González A, García-Llorente M, Alcarlo P & García Mora MA (2014). Incorporating the Social-Ecological Approach in Protected Areas in the Anthropocene. Bioscience 64, 181-191 - doi: 10.1093/biosci/bit033

Rockström J, Steffen W, Noone K, Persson Å, Chapin FS III, Lambin E and other (2009). Planetary boundaries:exploring the safe operating space for humanity. Ecology and Society 14(2): 32. [online] URL: http://www.ecologyandsociety.org/vol14/iss2/art32/

Titeux N, Henle K, Mihoub J-B, Regos A, Geijzendorffer IA, Cramer W, Verburg PH & Brotons L (2016). Biodiversity scenarios neglect future land-use changes. Global Change Biology 22, 2505-2515, https://doi.org/10.1111/gcb.13272

Turner MG & Gardner RH (2015) Landscape Ecology in Theory and Practice, Pattern and Process (2nd Edition). https://link.springer.com/book/10.1007%2F978-1-4939-2794-4. Springer, New York, NY. 482 pp

Vaccaro I, Beltran O & Paquet PA (2013). Political ecology and conservation policies: some theoretical genealogies. Journal of Political Ecology 20, 255-272 DOI: http://dx.doi.org/10.2458/v20i1.21748

Williams J, Kelly M, Caumont H, Gonçalves P, Provenzale A & Marangi C (2017). Plan for the exploitation of the Results. EcoPotential Deliverable No: D12.6., 28 pp.

8. Acronyms and abbreviations

CAP	the Common Agricultural Policy (CAP)
EAFG	the European Agricultural Guarantee Fund (Pillar I of CAP)
EEVPA	Essential Environmental Variables for Protected Areas (EV and IV of abiotic and biotic nature)
EF	Ecosystem Functions and Structure
EO	Earth Observation (includes Remote Sensing and *in situ* observation)
ES	Ecosystem Service
ESs	Ecosystem Services (plural)
ESVPA	Essential Socio-Economic Variables for Protected Areas (EV and IV of socio-economic or cultural nature)
EV	Essential Variable (variable in 75-100 % of PAs indicated as (very) important)
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IV	Important Variable (variable in 50-75 % of PAs indicated as (very) important)
MAB	UNESCO Man and Biosphere programme (creation of Biosphere Reserves)
PA	Protected Area
PAs	Protected Areas (plural)
WHS	UNESCO World Heritage Site

9. Appendix

List of Tables:

Table 9.1: Creation and extension dates for the different PAs according their designation. Dates corresponding to enlargements of area under the designation (added surfaces) are indicated in blue.

Table 9.2: Affiliation of pressures/drivers of change to main categories of drivers (cf. table 4.2)

Table 9.1: Creation and extension dates for the twenty-five different PAs according their designation. Dates corresponding to enlargements of area under the designation are indicated in blue

	Short Name (ECOP)	Curonian Spit	Nemunas Delta	Waddenzee	Oosterschelde	Camargue	Palavas	Danube Delta	Donana
	Full official name	Curonian Spit	Nemunas Delta			Grande Camargue	Palavas	Danube Delta	Donana natural area (Espacio natural de Donana)
International	UNESCO Biosphere reserve (MAB program)			1986		1977, 2006, 2017		1992	1981, 2012
	Unesco World Heritage Site	2000		2009				1993	1994, 2005
	Ramsar		1994	1984	1987	1986, 1996	2008	1991	1982
	IBA								
	IUCN Green List								
	International Landscape Park								
European	Natura 2000	2004	2004	2008	2016	2003, 2006, 2009, 2013, 2015, 2016	2004		2003, 2016
	Tri Lateral Treaty			1997					
	Europ Charter Sustainable tourism								2006
National	Strict Nature Reserve (Ia)								
	National Park (II)	1991		1998, 2003	2002			1938, 1990	1969, 1978, 2004 (since 1963 Biological Reserve)
	Core of NP								
	National Park (I)								
	National reserve (IV)					1927, 1975, 2011	1975		
	Natural Monument (III)								
	Landscape reserve								
	Natural Park (eq VI)								
	Nature Conservation Act			1981 1993, 2005	2010				
Regional	Regional NP (V)		1992			1970			
	Natural Park (VI)								1989
	Natural Reserved Area (V)								1989, 1991, 2000
NGO	NGO					1954			
Provincial	Provincial					2007	1990		
Municipal	Natural Monument								

	Short Name (ECOP)	Hardanger-vida	Bavarian Forest National Park	Kalkalpen	Swiss National Park	Gran Paradiso	Pieniny	Sierra Nevada	Samaria	Ohrid	Prespa
	Full official name	Hardanger-vida	Bavarian Forest National Park	Kalkalpen	Swiss National Park	Gran Paradiso National Park	Pieniny Slowakian part	Sierra Nevada Nature Area (Sierra Nevada National and Natural Parks)	Samaria National park or Cretan White Mountains National Park	Ohrid - Galacica NP	Prespa
	UNESCO Biosphere reserve (MAB program)				1979, 2010, 2016			1986, 2012	1981	2014	2014
	Unesco World Heritage Site			2017						1997	
International	Ramsar			2004				2006			1995
	IBA								2000		
	IUCN Green List							2014			
	International Landscape Park						1932				
	Natura 2000		1998	2004		2003	2004	2002, 2012	2006		
European	Tri Lateral Treaty										
	Europ Charter Sustainable tourism							2004, 2009, 2014			
	Strict Nature Reserve (Ia)										1996
	National Park (II)	1981	1970	1998		1922	1967, 1997	1999	1962	1958	
	Core of NP										
	National Park (I)				1914, (latest addition 2000)						
National	National reserve (IV)										
	Natural Monument (III)									1977	
	Landscape reserve								1973		
	Natural Park (eq VI)										2012
	Nature Conservation Act										
	Regional NP (V)										
Regional	Natural Park (VI)							1989			
	Natural Reserved Area (V)							1989			
NGO	NGO										
Provincial	Provincial										
Municipal	Natural Monument										

				Oceanic Islands		
Short Name (ECOP)	Peneda Geres	Montado	Appia Antica	La Palma	La Réunion	Negev
Full official name		Montado in Alentejo Natura 2000 network	Regional Park of Appia Antica (*Parco Regionale dell'Appia Antica*)	La Palma Biosphere Reserve	La Réunion	
UNESCO Biosphere reserve (MAB program)				1983, 1998, 2002, 2014		
Unesco World Heritage Site					2010	2005
Ramsar						
IBA						
IUCN Green List						
International Landscape Park						
Natura 2000	2009	1997, 1998, 1999				
Tri Lateral Treaty						
Europ Charter Sustainable tourism						
Strict Nature Reserve (Ia)						
National Park (II)				1954, 1981	2007 (core of PN), 2015 (Buffer zone)	1974
Core of NP					2007	
National Park (I)						
National reserve (IV)						1989
Natural Monument (III)						
Landscape reserve						
Natural Park (eq VI)	1984	1989 (Sao Mamede), 1995 (PN Guadiana)		2000		
Nature Conservation Act						
Regional NP (V)			1988			
Natural Park (VI)						
Natural Reserved Area (V)						
NGO						
Provincial						
Natural Monument	2007					

Table 9.2: Affiliation of pressures/drivers of change to main categories of drivers (cf. table 4.2)

Storyline	Driver of change/pressure (term in storyline)	Main driver (main category) or Risk cf Table 3.2
Negev Impact of residential settlements on the life supporting capacity of Har HaNegev arid environment	Settlements	Change of Land use
	Grazing	Change of Land use
	Agriculture (extent)	Change of Land use
	Agriculture (crop)	Change of Land use
	Climate change	Climate Change
Kruger NP Spatial-temporal dynamics of savanna ecosystems (tree-grass interactions, grass quality/quantity, biodiversity) as a life support system to wildlife and livestock production in and around Kruger National Park	Fire	Fire risk
	Grazing activities	Change of Land use
	Elephant pushover	
	Fuel wood collection	Change of Land use
	Bush encroachment	Change of Land use
	Land use – settlement and agriculture	Change of Land use
Alta Murgia NP Interaction between agro-ecosystems and natural grasslands: stone graining and loss of natural ecosystems	Pastures conversion	Change of Land use
	Wind farms and photovoltaic systems	Change of Land use
	Legal and illegal mining	Change of Land use
	Toxic mud dumping	Pollution - Nutrient over-enrichment
Alentejo Natura 2000 sites "Mediterranean wood-pasture for people and nature"	Drought and waterlogging events	Climate Change
	Grazing management	Change of Land use
	Soil management	Change of Land use
	Shrub management	Change of Land use
	Fire	Fire risk
Gran Paradiso NP "Dynamics of high-altitude environments as a life-support system to wild herbivores: carbon and moisture cycling, biodiversity and landscape modification"	Climate change	Climate Change
	Habitat modification/ Infrastructure	Change of Land use
	Abandonment of traditional practices	Change of Land use
	Tree encroachment	Change of Land use
	Human disturbance	Change of Land use
Northern Limestone National Park, Austria Managing mountain forests undergoing changing disease / disturbance dynamics	Climate	Climate Change
	Forest management	Change of Land use ??
	Disturbance areas	Change of Land use

Storyline	Driver of change/pressure (term in storyline)	Main driver (main category) or Risk cf Table 3.2
Bavarian Forest NP	Climate change	Climate Change
Interaction between climate change driven bark beetle outbreaks and forest decline and nitrogen deposition driven inertia in ecosystem succession in mountain ecosystems	Icreased N availability	Pollution - Nutrient over-enrichment
	Bark beetle outbreaks	Invasive species and/or Pest species
Gran Paradiso NP	Eutrophication	Pollution - Nutrient over-enrichment
Mountain Biodiversity as a sentinel of environmental change	Land use changes (overgrazing and land abandonment)	Change of Land use
	Mountain Biodiversity as a sentinel of environmental change	Climate Change
	Changes in the seasonal snow/ice/temperature cycle and in precipitation	Climate Change
Ohrid/Prespa, Gran Paradiso NP	Pollution	Pollution - Nutrient over-enrichment
Ecosystem services and biodiversity crisis across mountain lakes	Eutrophication	Pollution - Nutrient over-enrichment
	Land use changes	Change of Land use
	Changes in the seasonal snow/ice/temperature cycle and in precipitation	Climate Change
	Water exploitation	
	Loss of habitat and habitat diversity	Change of Land use
Swiss NP	Climate change	Climate Change
Comparing ecosystem services provided by protected areas with non-protected areas in mountainous areas of Europe using EO	Land use change	Change of Land use
	Tourism	Population growth / Tourism & Recreation
Peneda-Gerês (Portugal)	Land use dynamics	Change of Land use
Vegetation Dynamics as a Proxy of Socio-ecological Transitions and Future Societal Benefits in Mountain PAs	Fire dynamics	Fire risk
	Expansion of invasive plants	Invasive species and/or Pest species
	Climate change	Climate Change
Sierra Nevada NP	Annual and monthly precipitation	Climate Change
Ancient irrigation channels as management tools to buffer the impact of climate change in Sierra Nevada ecosystem services	Annual and monthly temperature	Climate Change
	Land use	Change of Land use
	Forest fires	Fire risk
	Forest pests	Invasive species and/or Pest species
	Mountain crops	Change of Land use

Storyline	Driver of change/pressure (term in storyline)	Main driver (main category) or Risk cf Table 3.2
Sierra Nevada NP Temporal evolution of ecosystem services in Sierra Nevada	Forest fires	Fire risk
	Deterioration of vegetation cover	Change of Land use
	Changes in market demand for raw materials and processed products	Change of Land use
	Forest felling	Change of Land use
	Pest	Invasive species and/or Pest species
	Drought	Climate Change
	Landslides / Soil loss / rain gullies	Climate Change
Waddenzee Improving coastal lagoon benefits under multiple pressures	Toxic substances (heavy metals, PCBs, PAHs, pesticides)	Pollution - Nutrient over-enrichment
	Nutrients	Pollution - Nutrient over-enrichment
	Oxygen	Pollution - Nutrient over-enrichment
	Algal blooms	Invasive species and/or Pest species
	Exotic species (macrobenthos and phytoplankton)	Invasive species and/or Pest species
	Climate change	Climate Change
	Fisheries and aquaculture	Change of Land use
	Tourism	Population growth / Tourism & Recreation
	Noise	Population growth / Tourism & Recreation
	Sand/silt dredging and dumping	Change of Land use
	Gas exploitation	Change of Land use
	Harbour extensions	Change of Land use
	Windfarms	Change of Land use
Camargue Conserving dynamic wetlands under combined global, regional and local stressors	Human-induced changes in marsh hydrology	Change of Land use
	Intensification of agriculture	Change of Land use
	Water pollution	Pollution - Nutrient over-enrichment[1)]
Doñana Conserving dynamic wetlands under combined global, regional and local stressors	Agriculture / water abstraction	Change of Land use
	Agriculture / nutrient and chemical pollution	Change of Land use[2)]
	Agriculture / erosion	Change of Land use
	Tourism / population growth	Population growth / Tourism & Recreation
	Tourism / water demand	Population growth / Tourism & Recreation
	Mining / pollution	Pollution - Nutrient over-enrichment
	Agriculture / overgrazing and bioturbation	Change of Land use

Storyline	Driver of change/pressure (term in storyline)	Main driver (main category) or Risk cf Table 3.2
Danube Delta The impact of aquatic ecosystems provisioning services on tourism	**Agriculture/ Nutrient pollution (from the catchment)**	Pollution - Nutrient over-enrichment
	Increase of crop production and livestock	Change of Land use
	Land reclamation	Change of Land use
	Agriculture/ erosion	Change of Land use
	Tourism/ population growth	Population growth / Tourism & Recreation
	Pollution	Pollution - Nutrient over-enrichment
La Palma Invasive species impacting the functioning and services of island protected areas through losses of endemic species.	**Grazing pressure by non-native herbivores**	Invasive species and/or Pest species
	Non-native plant species	Invasive species and/or Pest species
	Change in wildfire regime	Climate Change
	Anthropogenic infrastructures (e.g. settlements, roads)	Change of Land use
	Land Use Land Cover (LULC) Change	Change of Land use

Main Driver
Climate Change
Change of Land use
Pollution - Nutrient over-enrichment
Population growth / Tourism & Recreation
Main risk may be related to Driver
Invasive species and/or Pest species
Fire risk